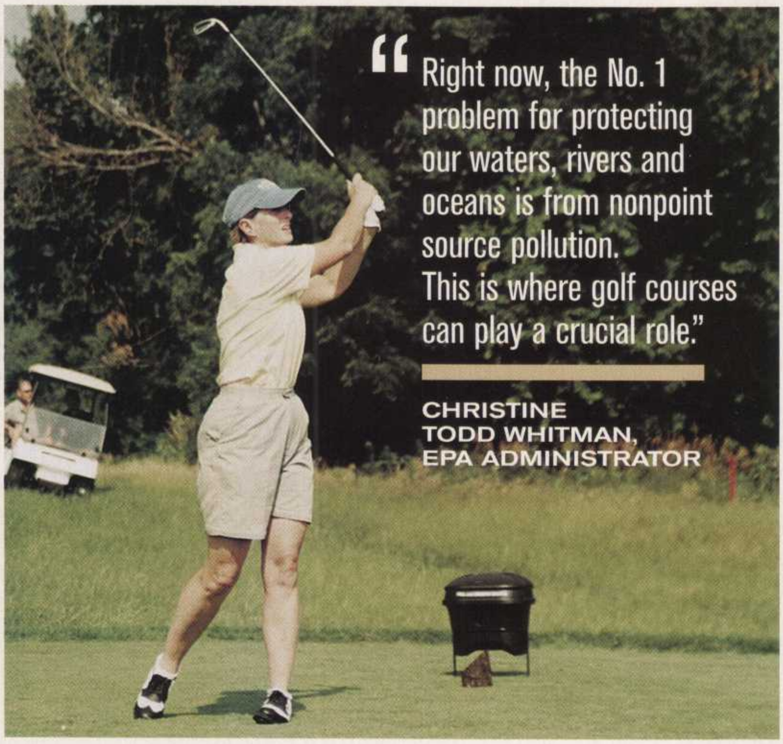

Continued from page 39
isn't interested in running stories on courses using more native grasses and using less pesticides for the sake of the environment.

"We've heard from the media that golfers aren't interested in the environment," Parker says. "They're interested in how to improve their swings and the latest drivers."

But if there was a big-name spokesperson to address the issue, maybe the golf media would change its tune. At the conference, one person's name kept coming up for the post.

"There's nobody better at educating golfers than Arnold Palmer," said Christine Todd Whitman, administrator of the Environmental Protection Agency, who was a keynote speaker at the conference.

"Golf and the environment has long needed a champion . . . a person and hero who can articulate how the game relates to community and respects the natural world," said Terry Minger, president of the Center for Resource Management, in hailing Palmer as "the beacon" for environmental education in golf.

"If you're going to focus on environmental education, you couldn't have a better spokesman than Arnold Palmer," Parker added.

How does "Arnie's Environmental Army" sound? We think it has a nice ring, but let's ask The King what he thinks.

"I'd be willing to do it," Palmer told *Golfdom.* "But I don't know that I have the time to do it full-time. I'll help in almost any way I can to protect the environment and enhance it."

Translation: It doesn't sound like Palmer wants to be the poster boy to help educate golfers about the environment, but he may be willing to do a few interviews for stories or PSAs.

"We'll have to figure out a way to capitalize on his willingness to help," Parker said.

Whitman's take

Palmer was also a keynote speaker at the conference and he officially opened ArborLinks by playing the course's front nine holes with Whitman (who, incidentally, has got game.)

Palmer, 73, grew up watching his father tend Latrobe (Pa.) CC as its superintendent. The golf course maintenance industry wasn't too concerned with environmental responsibility in those days.

"My father's dearest friends were arsenic and lead," Palmer said. "But things have changed."

Palmer said ArborLinks, designed by his company's Erik Larsen, is proof that an environmentally sensitive golf course can also be economically feasible (the course cost $5.5 million).

"We need to let people know that we're working in the best interest of the environment," Palmer said. "We're not just selfish, rich golfers whose only interest is playing the game."

Whitman was also impressed with ArborLinks and urged the industry to build similar courses. After her round of golf with Palmer, she stood outside the course's modest clubhouse and gave a course rating — based on environmental prowess, not degree of difficulty.

Whitman, the former governor of New Jersey, said she was impressed with how ArborLinks was designed in accordance with the natural contour of the land and used native grasses. She was glad to see the course was built as a refuge for wildlife.

"Golf is rapidly getting close to baseball as the national pastime," Whitman said. "With more courses being built, we need to understand that we all have a role in helping the environment. What's happening with this course and others being built like it will make a huge difference."

Whitman said controlling nonpoint source (NPS) pollution is vital. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. The runoff gathers pollutants and

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TURFGRASS TRENDS

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WEED CONTROL

Temperatures Affect Primo Applications

By Matt Fagerness

Bermudagrass is the most commonly grown warm-season turfgrass species in the southeastern United States. The aggressiveness of bermudagrass is attributable to a C-4 carbon assimilation pathway and to rhizomatous and stoloniferous growth habits (Beard, 1973). The ability of bermudagrass to grow rapidly vertically and horizontally has led to the extensive use of plant growth regulators (PGRs), which effectively control numerous species (Johnson, 1990).

Several PGRs are available for use on bermudagrass, but the most common of which is trinexapac-ethyl (Primo, Primo Maxx). Multiple applications of PGRs are usually required for effective long-term growth inhibition, as warm-season grasses have the potential for rapid growth over an extended period (Fagerness and Yelverton, 2000).

Preliminary field observations suggest that late season PGR applications might predispose bermudagrass to winter kill.

Although the main purposes for Primo applications to bermudagrass are to improve visual quality and slow growth during high temperatures, there are some indications that additional effects can occur. Recent research suggests summer applications of Primo may delay the onset of bermudagrass dormancy (Fagerness and Yelverton, 2000). Also, Primo applications near the end of the bermudagrass growing season can aid overseeding by assisting the transition to the cool-season species.

Preliminary field observations, however, suggest that these late-season PGR applications might also predispose bermudagrass to winter kill. The main objective of this study was to investigate growth of bermudagrass in response to Primo in different temperatures and during the transition into winter dormancy. We also examined whether Primo treatments altered the freezing tolerance of field-grown bermudagrass.

Materials and methods

To achieve our objectives, two different experiments were performed. Growth-chamber experiments were conducted to examine the connection between temperature and Primo on bermudagrass growth. Temperatures were approximately to 68 to 95 degrees Fahrenheit during the day, and 59 to 77 degrees at night. For growth chamber experiments that measured clipping biomass and lateral growth, turf was collected as 3.9-inch-diameter sod cores, all from a uniform field stand of bermudagrass. Samples were placed in pots and backfilled with soil from the collection site. Primo was applied to sod cores three weeks after their introduction to growth chambers at a rate of .01 pounds of active ingredient per acre. The bermudagrass was mowed to a height of .75 inches three times

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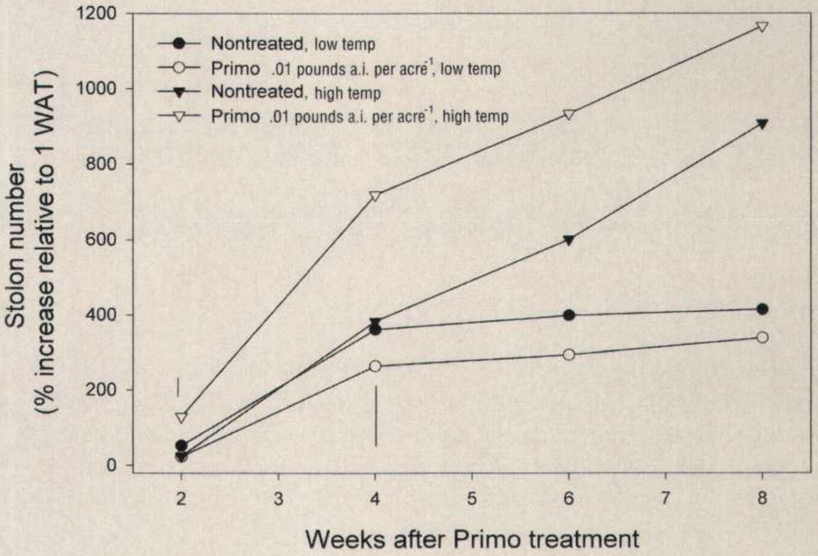
FIGURE 1

Effects of growth temperature and Primo on the number of stolons emerging from the central core of transplanted bermudagrass sod. Vertical lines above each time point represent Lowest Stastistical Difference values at a significance level of 5 percent.



per week for seven weeks. Clippings were dried in an oven at 158 degrees Fahrenheit for 72 hours and then weighed. Lateral growth was estimated by counting the number of stolons emerging from the central sod core.

Field experiments were conducted in 1997 and 1998 near Pinehurst, N.C., on bermudagrass plots established in 1995 in a sandy soil. The turf was verticut each spring, received monthly fertilizer from May through September, and was irrigated as needed. Turf was mowed at a height of .75 inches.

Primo treatments simulated recommended application practices in North Carolina. Spray applications were all made at the recommended .01 pounds of active ingredient per acre rate. Initial applications were made in June or July, once the bermudagrass was actively growing. Sequential applications were made four and eight weeks later. Early fall applications of Primo were made to previously nontreated turf in September, with the intent of simulating Primo use as an overseeding aid.

Turfgrass quality was evaluated on five occasions. Visual quality ratings were a function of turfgrass color, texture and density, and were based on a 1 to 9 scale (1=dead or fully dormant turf, 9=ideal turf, and 5=minimally acceptable turf). Shoot density and root biomass were measured three times during the autumn at monthly intervals, beginning in late September when the early fall application of Primo was made.

Freezing tolerance was based on rhizome and stolon survival and subsequent regrowth. Samples were collected for each treatment in mid-October and again in mid-November to determine survivability at two different degrees of autumn dormancy. Eight segments of rhizomes and stolons, each with at least one node, were separately planted into potting soil. Sprigs were chilled at 37.4 degrees Fahrenheit for 21 days to allow sufficient development of cold hardiness (Beard, 1973).

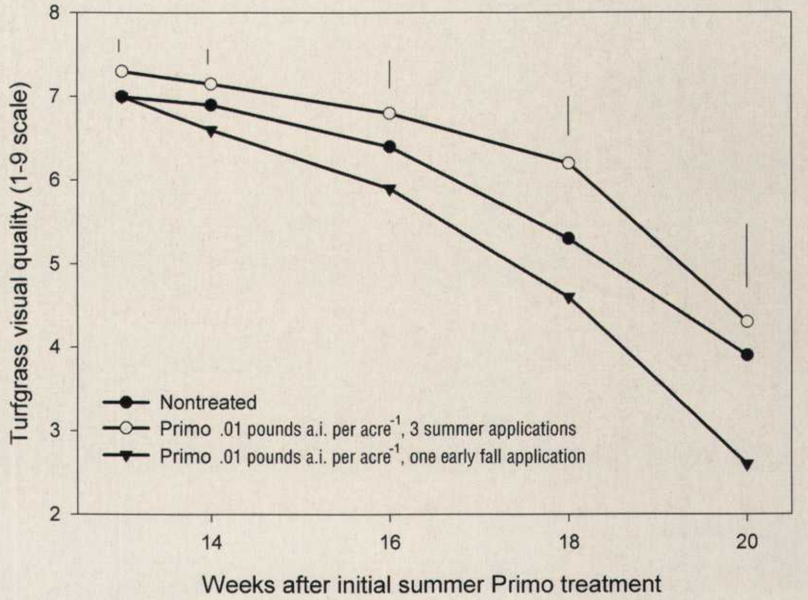
Selected sprigs were frozen to 23 degrees Fahrenheit, maintained at the target freezing temperatures for three hours and then thawed. Sprigs exposed to freezing temperatures were then replanted in potting soil. Samples were maintained at 77 degrees Fahrenheit and monitored for new leaf growth one and three weeks after freezing.

Results, discussion

One main objective of this study was to determine if Primo caused different responses when applied at different air temperatures. Before initiating the experiments, it

FIGURE 2

Effects of Primo on bermudagrass visual quality during the 1997 growing season. Quality was assessed using a 1 to 9 scale (1=dead or fully dormant turf, 9=ideal turf, and 5=minimally acceptable turf). Vertical lines above each time point represent Lowest Statistical Difference values at a significance level of 5 percent.



seemed reasonable to believe that Primo effects would be more pronounced at higher temperatures because of the greater potential for growth reduction when growth is more rapid. Our growth chamber studies, however, revealed that Primo suppresses growth at both high and low temperatures. These studies also showed that Primo increased stolon numbers, but only when turf was growing at higher temperatures (Fig. 1).

Field results showing greater fall shoot density following multiple Primo applications during the warm summer months (Table 1) also reflected these high-temperature stimulated increases in lateral shoot development.

It's not clear why Primo increased stolon growth only at higher temperatures. It's likely that higher bermudagrass growth rates at higher temperatures are associated with greater rates of nitrogen uptake and delivery to shoots. Thus, higher temperatures and more rapid nitrogen uptake likely stimulated growth of the stolons.

Following treatment with Primo, growth suppression would lead to increased allocation of resources (e.g., more nitrogen and carbohydrates would move to lateral meristems), further enhancing lateral stem development.

Our experiments have indicated that temperature also may play a role in how Primo affects bermudagrass dormancy. The process of dormancy, and the physiological basis for it, is still largely undefined. It was observed previously that three summer applications of Primo could delay the onset of bermudagrass dormancy (Fagerness and Yelverton, 2000). The pattern also was observed in the first year of this study (Fig. 2 and Table 1), when turf treated with three summer Primo applications consistently had higher fall quality and shoot density than untreated turf.

In contrast, the 1997 early fall Primo application led to decreases in shoot density (Table 1) and visual quality (Fig. 2), indicating a more rapid progression into dormancy.

Field studies have indicated that Primo can discolor bermudagrass when it is first applied in the summer months (Fagerness and Yelverton, 2000; Wiecko, 1997). Bermudagrass recovers quickly, however, under favorable temperature and growth conditions.

One explanation for the negative effects resulting from the early fall Primo application

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TABLE 1

Bermudagrass shoot density and root biomass as influenced by summer and early fall applications of Primo in 1997.

	WEEKS AFTER TREATMENT (WAT)		
Treatment	12	16	20
	SHOOT DENSITY (shoots m-2)		
Nontreated	118,000	110,000	111,250
Primo (3 summer apps.)	98,750	137,500	125,000
Primo (Fall)	117,750	97,500	87,500
LSD=.05	14,021	14,204	29,206

TABLE 2

Bermudagrass stolon freezing tolerance as influenced by harvest date and Primo in 1998.

	Tifway bermudagrass	
Treatment	Harvest	Stolons PERCENT SURVIVAL
Nontreated	October	22
Primo (3 summer apps.)	October	41
Primo (Fall)	October	56
Nontreated	November	81
Primo (3 summer apps.)	November	81
Primo (Fall)	November	69
LSD=.05		16

in 1997 (Fig. 2) is that the turfgrass was more sensitive to Primo. The early fall application occurred when mean daily temperatures were about 46.4 degrees Fahrenheit cooler than those in the July to August period. Bermudagrass was growing relatively slowly and beginning the transition into dormancy, which may have amplified the initial effects of Primo applied that late in the growing season.

The absence of Primo effects on fall visual quality and density in the second year (1998) was unexpected. It's conceivable this response was due in part to higher growth temperatures. Air temperature monitoring showed that seasonal temperatures were higher throughout 1998. Since air temperatures were higher at the time of the early fall application in 1998, growth regulating effects of Primo may have been offset by more rapid bermudagrass growth.

Variable growth temperatures between 1997 and 1998 corresponded to changes in sprig freezing tolerance between the two seasons. Cooler autumn temperatures in 1997 stimulated the natural development of cold hardiness (Beard, 1973), which may have accounted for the absence of any Primo effects on fall freezing tolerance.

Conversely, warmer fall temperatures in 1998 may have delayed the development of cold hardiness and thus predisposed stolons and rhizomes to winter kill. Accordingly, reduced growth in Primo treated stolons may have resulted in increased freezing tolerance in sprigs harvested in October 1998 (Table 2).

In summary, Primo treatments at different times during the year can lead to different growth responses that can be attributed in part to interactions with temperature.

From a turfgrass management perspective, Primo effects tended to be positive at higher temperatures, with slower growth accompanied by increased density and quality. At lower temperatures, Primo still slowed growth, but bermudagrass may have difficulty recovering from these suppressive effects.

Applications of Primo in the fall can result in decreased competitiveness because of slower growth and decreased density, allowing for this PGR's use during transition to an overseeded cool-season species.

Dr. Matt Fagerness is the extension turfgrass specialist at Kansas State University. His research interests focus on optimizing of turfgrass selection and management and turfgrass weed management for the northern transition zone.

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Breeding Improves Fine Fescue Varieties

By Leah A. Brilman

Improved fine fescues should be used more extensively in this country for fairways, homes and roadsides.

Through biotechnology and breeding on other species, we try to capture what we already have in improved fine fescues: low maintenance turfgrasses with reduced needs for fertilizer, nitrogen and irrigation. Yet, most consumers, whether homeowners, landscape contractors or superintendents, associate fine fescues only with turfgrass mixtures intended for shade sites.

Although the most appropriate use for older or common fine fescue varieties may have been for these shady sites, turfgrass breeders have made significant advances in new fine fescues, making them appropriate for many additional sites, both high and low maintenance.

Despite these dramatic differences in performance, the availability and cheap price of many of these older and common fine fescues have led to their continued use in turfgrass mixtures and have limited the commercialization of many of the improved fine fescue varieties. Increased use of the improved cultivars will increase breeding efforts of these valuable species.

Fine fescues are low-maintenance turfgrass species requiring less fertility, irrigation and mowing than many other turfgrass species. This has been demonstrated by their excellent performance on roadsides and as orchard cover in many areas. The newer cultivars can be used in full sun much further south than earlier varieties.

Endophyte presence

These expanded uses may be due to the presence of endophytes in the new cultivars, which provide protection against many surface feeding insects, increase dollar spot resistance and increase summer stress tolerance.

An additional characteristic of fine fescues, useful in many situations, is their tolerance to the herbicides sethoxydim and fluazifop, enabling the removal of certain weeds and grasses from these stands (labels should be followed for this use).

Fine fescues prefer lower nitrogen levels than many turfgrasses. In fact, high levels of nitrogen can cause excessive thatch development and decrease their heat tolerance.

Brief taxonomy

Fine fescues include many species of turfgrasses characterized by their fine leaf texture, generally (less than one-third of an inch) and are included in the *Festuca* subgenus of the *Festuca* genus. The species are divided into two major complexes: the red fescue complex and the hard/sheep fescue complex. Taxonomy within these complexes remains under debate, and you may find many scientific names for each species in the literature. The following are the most recently accepted names but may still change over time.

The red fescues include the traditional turfgrass species, which include Chewings fescue, strong creeping red fescue, and slender creeping red fescue.

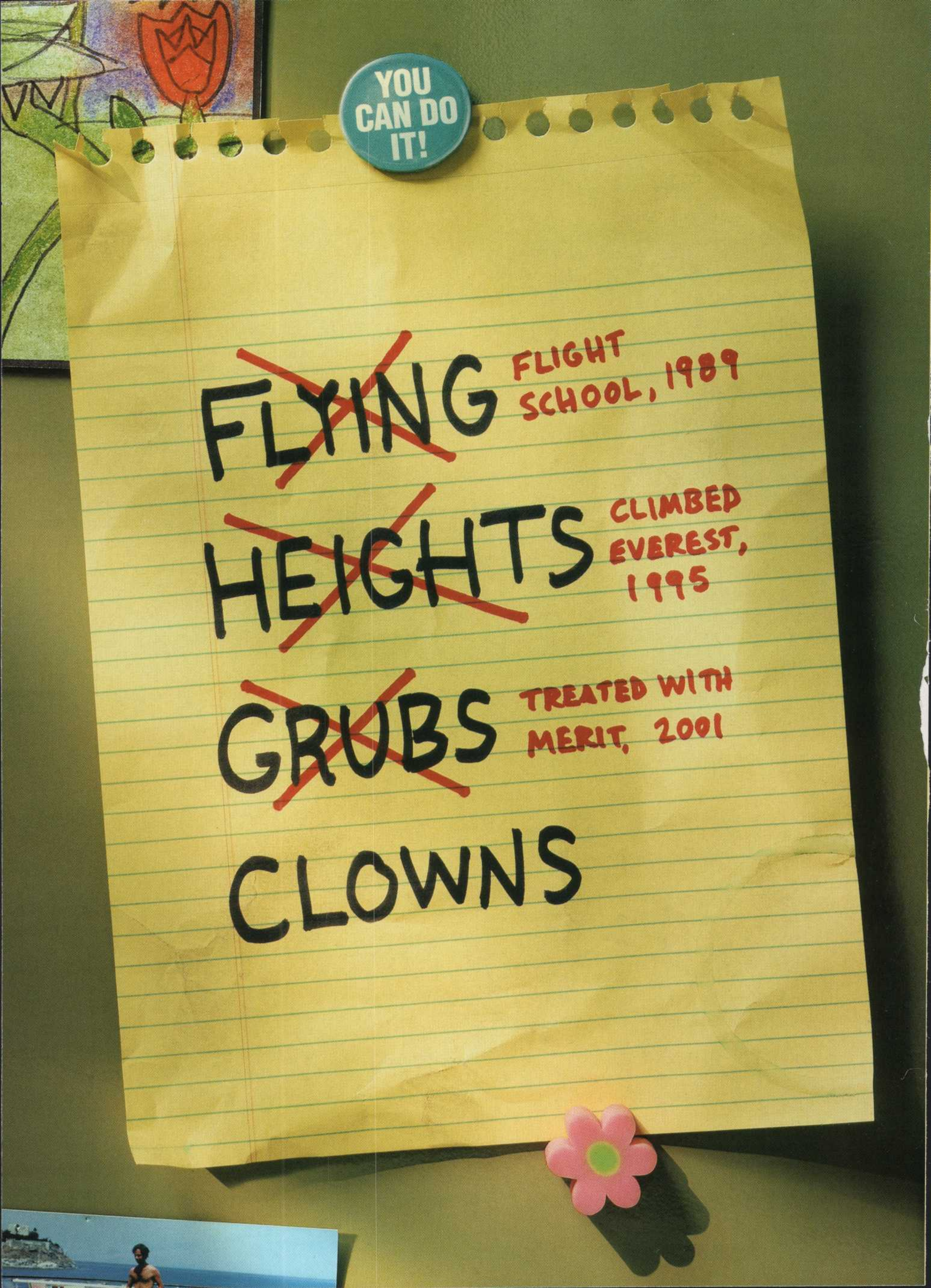
The members of the hard/sheep fescue complex that have been used for turf include hard fescue, sheep fescue, blue sheep fescue, fine-leaved sheeps fescue and Idaho fescue.

The two most important characteristics used to distinguish the two complexes based on Stace et al., 1992 are as follows:

Red rescue complex: Sheath of young tiller-leaves fused into a tube almost to top; some or all tillers extravaginal.

Hard fescue complex: Sheath of young tiller-leaves with at least the upper 40 percent with free, overlapping margins; all tillers intravaginal.

Additional characteristics, such as placement and number of sclerenchyma bundles in leaf cross-sections, width and folding of leaves, presence and absence of rhizomes and chro-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The left-hand plot has been endophyte-enhanced while the right-hand plot has not. Endophytes enhance turfgrass' ability to battle diseases such as dollar spot.

mosome numbers, further divide these complexes. The taxonomy of these species is difficult, and correct names and designations of subspecies are still being debated. Here are the different varieties within those species.

Chewings fescues

Chewings fescues derive their common name from George Chewings, who exported seed with his name from New Zealand to many areas of the world (Morgan, 1998). It's probably one of the most versatile of the fine fescues being used for greens, fairways and roughs of golf courses; home lawns in sun and shade; highway roadsides and orchard covers; and in overseeding of warm-season turfgrasses as well. It's a bunch-type grass that germinates and establishes quickly.

Chewings fescues have seen significant improvements in heat and drought tolerance, seed yield, dwarf growth form, dark green color and disease resistance primarily against red thread, brown patch and dollar spot.

Improved cultivars have shown good performance in Arkansas, North Carolina and other areas in the Southern transition zone in full sun. In a trial at low pH, with no irrigation and low mowing height at Georgia's Griffin Research Station, SR 5100 and Bridgeport maintained 50 percent cover over three years, which would have been considered impossible a few years ago (1993 Fineleaf Fescue NTEP study results).

In the 1998 NTEP results, Chewings fescues have done the best of the fine fescues when managed under high input as a fairway grass, both with and without traffic. They show good resistance to summer patch, which limits the use of some fine fescues in heavy wear or compacted areas. Overall, they show the most consistent performance under high to low management.

They blend well with other fine fescues, with colonial bentgrass, with Kentucky bluegrass and with perennial ryegrass, depending on the use. Improved cultivars of Chewings fescue include: Shadow II, Longfellow II, Ambassador, Longfellow II, Tiffany, Intrigue, Jamestown II, SR 5100, Magic, Banner III, Bridgeport, Silhouette, Columbra, Treazure (E), Sandpiper and Brittany. Other promising experimentals in the 1998 NTEP have not yet been brought to market.

Chewings fescues still need improvement in leaf-spot resistance. Newer cultivars are usually endophyte-enhanced, giving them resistance to many insects, dollar spot and summer stress. They also show improved establishment and excellent spring green-up.

Creeping reds

Though research into strong creeping red fescues have shown some of the most significant advancements, common creeping red fescue continues to be used extensively, which prevents the new varieties' advantages from being fully realized. This species is probably the most compatible with Kentucky bluegrasses and perennial ryegrasses in mixtures since they have similar color, leaf texture, density and extensive rhizomes.

Newer strong creeping red fescues are being released that are endophyte-enhanced to assist with insect resistance and summer stress tolerance.

The 1998 NTEP fine fescue tests in Oklahoma, which concluded in 2001, showed many promising varieties of the creeping reds. Several varieties showed an increased ability to maintain their ground coverage during the hot summer months. In particular, SRX 52961 (75 percent), Navigator (66.7 percent), Cindy Lou (63.3 percent) and Aberdeen (60 percent) showed great improvement.

A similar pattern was evident in Kentucky, where Jasper II (90 percent), SR 5210 (87.3 percent) Cindy Lou (85 percent) SRX 52691 (81.7 percent) and Navigator (80.3 percent) outshone their common creeping red cousins.

In private trials in Pomona and Fresno, Calif., with three companies cooperating, we've also seen this ability of the newest creeping red fescues to establish rapidly, perhaps due to their larger seed size and ability to maintain excellent turf cover under heat stress. Most of the same improved strong creeping red fescues above also showed excellent performance in fairway trials with traffic at Wisconsin. They show high summer patch, typhula blight and pink snow mold resistance, but need more work on red thread resistance in low-nitrogen sites.

Their drought resistance needs improvement, but creeping reds recover quickly from any damage due to their extensive rhizomes. Superior strong creeping red fescues should be included in turf mixtures for many areas of the country, for both sun and shade.

Slender creeping reds

Slender creeping red fescues have probably received the least breeding work in this country, yet show excellent attributes that make them ideal for many sites.

The slender creeping red fescues have slender short rhizomes and spread more slowly than the strong creepers. They've also been found to tolerate high salt levels and heavy metals more effectively.

Plants of this species can be found growing in tidal areas. The salt tolerance probably contributes to their resistance in initial trials against rapid blight, caused by chytridiomycete, in overseeding situations where saline or effluent water is used. They tolerate low mowing heights and have superior winter-active growth. The salt tolerance also makes it ideal for any area where salts are used for ice control.

TABLE 1

Mean turfgrass quality ratings of fine leaf fescue cultivars grown at the NTEP Madison (Fairway Traffic), Wisc., trials. Top statistical group + common shown:

2001 DATA

Variety	Species	Mean
BRIDGEPORT	CHEWINGS	5.5
LONGFELLOW II	CHEWINGS	5.5
TREAZURE (E)	CHEWINGS	5.4
SRX 52961	STRONG CREEPING	5.4
JASPER II	STRONG CREEPING	5.3
ACF 083	CHEWINGS	5.1
CINDY LOU (CIS FRR 7)	STRONG CREEPING	5.1
PATHFINDER	STRONG CREEPING	5.1
TIFFANY	CHEWINGS	5.1
ABERDEEN (PST-EFL)	STRONG CREEPING	5.1
AMBASSADOR	CHEWINGS	5.1
SRX 3961	HARD	5.1
SILHOUETTE (PICK FRC 4-92)	CHEWINGS	5.0
SR 5100	CHEWINGS	5.0
BAR SCF 8 FUS3	SLENDER CREEPING	5.0
SHADOW II	CHEWINGS	5.0
ASR 049	SLENDER CREEPING	4.9
NTRIGUE	CHEWINGS	4.9
MB-63	CHEWINGS	4.9
SHADEMASTER II	STRONG CREEPING	4.9
DGSC 94	STRONG CREEPINGS	4.9
FLORENTINE	STRONG CREEPING	4.9
ABT-CHW-1	CHEWINGS	4.9
ABT-CR-2	STRONG CREEPING	4.9
BANNER III	CHEWINGS	4.9
CULOMBRA	CHEWINGS	4.8
NAVIGATOR (CIS FRR 5)	STRONG CREEPING	4.8
PST-4FR	STRONG CREEPING	4.8
BRITTANY	CHEWINGS	4.8
SANDPIPER	CHEWINGS	4.8
WRIGLEY (ACF 092)	CHEWINGS	4.8
JAMESTOWN II	CHEWINGS	4.7
SALSA	STRONG CREEPING	4.7
BAR CHF 8 FUS2	CHEWINGS	4.7
INVERNESS (PST-47TCR)	STRONG CREEPING	4.7
SHADEMARK	STRONG CREEPING	4.7
ABT-HF-4	HARD	4.6
BARGENA III (BAR CF 8 FUS1)	CHEWINGS	4.6
DAWSON E+	SLENDER CREEPING	4.6
SEABREEZE	SLENDER CREEPING	4.6
BERKSHIRE (4001)	HARD	4.6
ABT-CR-3	STRONG CREEPING	4.6
COMMON CREEPING RED	STRONG CREEPING	4.3

LSD=.8

Initial problems being solved by breeders have been reduced seed yields compared to other fine fescues, especially in the highest quality, dense types and less heat tolerance than other fine fescues.

The lack of heat tolerance may have been due to a lack of endophytes in this species, but recently the variety Dawson has had an endophyte introduced into it to form Dawson (E). New germplasm have been identified with endophytes in them. In the 1998 NTEP tests, the slender creeping red fescues showed excellent performance in the high maintenance trials, and new experimentals have shown high performance in Fresno and Pomona, Calif., with heat stress. This species is used extensively in Europe for home lawns and golf courses. As new markets open up in the United States, more breeding will be done.

Hard fescues

The hard fescues are the low maintenance workhorses of the fine fescues.

Found extensively in low maintenance turf sites in the United States from the transition zone northward, they thrive on neglect. Low nitrogen, low water-use turfgrasses that require little mowing sound like the couch potato's dream grass. With too much nitrogen or water, however, they develop extensive thatch and will deteriorate.

They are ideal for shade, but do not like to be wet. They are also typically the slowest of the fine fescue to germinate and establish, although improvements have been made as was evident by increased establishment rates in new material in the 1998 NTEP trials.

Seed production problems include susceptibility to new disease and short lifespan of seed fields, producing a partial crop the first year, a full crop in year two and a lighter crop the third year.

Recently, breeders have been crossing this species with the blue fescues, which some taxonomists think may be just another form of the same species, to obtain varieties without the seed production disease problems and a longer seed field lifespan. These crosses have been selected both for those types that more closely resemble the blue fescues, one of the lowest maintenance turf species, and those types that resemble hard fescues.

Typically, hard fescues are less tolerant of low mowing heights and traffic, due to low summer patch resistance. But one experimental, SRX 3961, did well in the fairway trial with traffic in Wisconsin.

Hard fescues are typically more resistant to leaf spot, brown patch and red thread than other fine fescues. They can be blended with other fine fescues and Kentucky bluegrass, but higher percentages of hard fescues must be used to obtain the benefits.

The blue fescues are ideal for the lowest maintenance turf sites, such as roadsides. They also add an attractive addition to blends with wildflowers, if seeded at a reduced rate. The individual plants remain smaller than the other fine fescues, so they leave room for the flowers. The seedheads are ornamental, and the blue color adds to the landscape.

The sheep fescues can also be used in similar areas as the blue fescues. Although additional varieties are sold as sheep fescues due to their appearance and low maintenance growth, only the variety Quatro is a true sheep fescue. The other varieties are other species.

Further exploration needs to be done on using other fine fescues for low maintenance turf. Native species such as Idaho fescue, native to the Pacific Northwest and California, have been looked at for their reclamation potential but need to be explored for potential turf usage, especially in the western United States.

Breeders are exploring other characteristics of fine fescues. Many of them can tolerate low rates of glyphosate naturally. Screening for improved salt tolerance is also being done by a number of programs, as well as screening for improved heat tolerance.

Higher disease resistance, in both turf and seed production, is always major emphasis of breeding programs. Perhaps as more people realize the true low maintenance potential of these species and the important breakthroughs that have already occurred, the increased use will enable more rapid improvements in these important species of turfgrass.

Leah A. Brilman is research director for Seed Research of Oregon.

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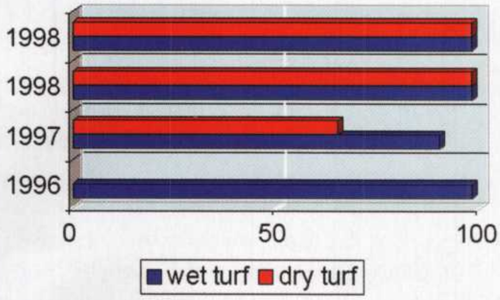
Granular Postemergent Broadleaf Herbicides

The photo above demonstrates the difference in white clover population between a section treated with the Andersons fertilizer with Millennium Ultra in the foreground and an untreated section in the rear.

Advances in formulation expertise and the introduction of more root-absorbed chemistries in recent years can make granular postemergent broadleaf herbicides a useful and practical alternative to spraying. Granular postemergent products are excellent for areas that are hard to spray, windy and or wet locations, for spot treatments, or when spraying is environmentally risky.

The introduction of clopyralid in the 1980's helped to usher in a new era in broadleaf weed control. Clopyralid is a low-toxicity chemical that poses little hazard to people, animals and most vegetation. Since it is root absorbed clopyralid will provide effective control of some broadleaf weeds such as white clover even when applied to dry foliage, or washed from the leaf surface immediately following application either from irrigation or rainfall. Generally speaking however, granular postemergent products are the most effective when applied to wet unmowed foliage and allowed to remain on the leaf surface for twenty-four hours before being watered in.

Clopyralid is often incorporated with 2,4-D and dicamba to broaden its spectrum of control over a wider variety of shallow and deep-rooted broadleaf weeds. Formulations containing clopyralid, 2,4-D, and dicamba are marketed under the trade Millennium Ultra™.



The graph above demonstrates the ability of Millennium Ultra to control white clover even when applied to dry turf.

Particle size and formulation expertise are critical variables affecting the ability of granular postemergent products to provide effective control. Particle coverage on the weed surface is critical in order to obtain efficacy especially with products containing foliage absorbed chemicals like 2,4-D and MCPP.

The Andersons ability to formulate small particle (150 SGN) products that deliver up to four times the number of particles per square inch compared to larger particle size formulations (SGN 240) with the same percentage of active ingredient, provide better efficacy and a wider spectrum of weed control. The Andersons manufacture a range of granular postemergent Fertilizer with Millennium Ultra and Fertilizer with Trimec® products designed to meet the needs of the golf and lawn care markets. Fertilizer with postemergent combination products allows turf managers to more efficiently utilize key labor resources by taking care of turf nutrition and weed pests in one operation. For control of annual and perennial weeds such as dandelion, English daisy, plantain, white clover, bur clover, black medic, oxalis, spotted spurge and others, 18-5-9 and 16-4-8 with Poly Ns-52 and Millennium Ultra have proven extremely effective. To eliminate shallow rooted weeds such as dandelions, 20-4-10 with Poly-NS-52 and Trimec is an excellent option.

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Copper Is Essential Bridge For Many Plant Functions

By Richard J. Hull

Copper (Cu) is present in turfgrasses at low concentrations (5 to 20 parts per million [ppm]) and or cycles through its functions quickly. Cu serves a number of essential roles based upon its easy ability to capture and surrender electrons, especially in reactions with free oxygen (O_2).

There is a strong tendency for Cu^{2+} ion to capture an electron and function as an oxidizing agent. The resulting Cu^{+} ion, which is unstable, readily gives an electron and acts as a reducing agent, particularly to oxygen. This endows Cu with properties exploited for plant and animal metabolism. The uniqueness of Cu to function as a strong oxidizing and reducing agent enables it to serve in ways that no other element can. What follows is a discussion of how these properties of Cu are utilized in plant metabolism.

Photosynthesis and respiration

Photosynthesis involves the reduction of carbon dioxide (CO_2) to carbohydrates (a gain of 4 electrons per carbon atom), while respiration is the oxidation of carbohydrates back to CO_2. Consequently both processes depend on the transfer of electrons.

In photosynthesis, electrons are taken from the oxygen of water, while in respiration they are returned to oxygen to make water.

Even mild Cu deficiency causes a sharp decrease in lignin synthesis resulting in leaf and stem distortions and greater lodging susceptibility.

We have already discussed the central role played by iron (Fe) in this electron transport pathway (Hull, 1999), but Cu also is an essential participant.

In both photosynthesis and respiration, electron transport is a separate process from carbon metabolism. In photosynthesis, electron transport is involved in producing a strong reducing agent (NADPH) needed to reduce CO_2 to sugars. In respiration, sugars are oxidized to CO_2 with the electrons going to form a similar strong reducing agent (NADH) that channels its electrons down a transport chain that ultimately reduces O_2 to water. In both processes, the electron-transport pathway is coupled to the synthesis of adenosie triphosphate (ATP), which is required to power many biochemical and physiological events. The biosynthesis of cell walls, proteins and lipids all require ATP, as does nutrient ion transport and the opening of water channels across cell membranes.

It's in these electron transport chains that Cu is required. In photosynthetic electron transport, two photosystems use light energy to drive electrons from water to NADPH. They are connected in series by a Cu-containing protein called plastocyanin.

Here, a single Cu atom oscillates between its Cu^{2+} and Cu^{+} forms transferring electrons from photosystem II to photosystem I, thereby connecting the two major components of the photosynthetic electron transport chain. More than 50 percent of the Cu in chloroplasts is part of plastocyanin. When Cu becomes deficient, the plastocyanin content of leaves drops sharply, as does the photosynthetic electron transport rate while chlorophyll levels are unchanged.

In respiratory electron transport, electrons flow from NADH (derived from the oxidation of sugars) to O_2, the final step of which requires the binding of Cu^{+} to O_2 and the transfer of four electrons to O_2, producing two water molecules (H_2O). Here, Cu is part of the enzyme cytochrome oxidase that catalyzes the transfer of electrons to O_2 again through the oscillation of Cu between its Cu^{+} and Cu^{2+} forms.

Toxins such as cyanide and azide bind Cu and block its capacity to transport electrons to O_2. Thus, these chemicals are lethal to both plants and animals. Iron and manganese are also capable of transporting electrons, but they cannot substitute for Cu because their affinity for O_2 is not as great.

Detoxification of oxygen radicals

In a closely related function, Cu is also involved in the detoxification of superoxide radicals in chloroplasts, mitochondria and cytosol of leaf cells (Marschner, 1995). Cu acts as a component of the specific enzyme superoxide dismutase (SOD) that catalyzes the reaction between two superoxide radicals, forming a hydrogen peroxide (H_2O_2) and one free oxygen.

In this SOD, Cu functions in cooperation with a zinc (Zn) atom (CuZnSOD) as we discussed in our article on Zn function in turf (Hull, 2001a). In this case, it's Cu that binds with O_2^- and allows an electron to flow from one O_2^- to another O_2^-, reducing one to H_2O_2 and oxidizing the other to O_2. When Cu is withheld from plants, the CuZnSOD activity declines dramatically.

The H_2O_2 is also potentially dangerous, but it's detoxified by the enzymes peroxidases or catalase to harmless H_2O and O_2. In this way, plants are able to protect themselves from toxic O_2 radicals that are inevitable when biochemical oxidation-reduction reactions occur in the presence of free O_2. There are circumstances when the production of H_2O_2 is useful, and Cu can play an essential role there as we shall see in the next section.

Lignin formation in cell walls

Before plants could successfully invade dry land and achieve any real height, they needed to evolve a means for making their cell walls stiff. Cellulose walls tend to be flexible, like a cotton fiber. The internal accumulation of water causes turgor pressure can generate considerable force within cells that but not much strength.

Also, the water conducting cells (xylem vessels and tracheids) must resist collapsing when subjected to substantial tensions. This need for greater stiffness was achieved through the synthesis of lignin, a cell-wall encrusting substance composed of many six-sided unsaturated rings each containing at least one –OH group (phenols) that become polymerized through the fusion reactions of phenol-free radicals.

The enzyme polyphenol oxidase catalyzes the oxidation of phenol rings, thereby making additional –OH groups (polyphenols). Phenol free radicals are produced when a ring –OH group is oxidized by H_2O_2 that is the product of cell-wall diamine oxidases. Both polyphenol oxidase and diamine oxidase are Cu-containing enzymes that produce the substrates needed for peroxidative polymerization of phenol-free radicals to form lignin within plant cell walls.

As a consequence, even a mild Cu deficiency causes a sharp decrease in lignin synthesis, resulting in leaf and stem distortions and greater lodging susceptibility of grasses. Because lignin, being composed of many phenol units, is an effective deterrent to the attack of most pathogenic fungi, a lack of lignin due to insufficient Cu can make plants more susceptible to disease. Since lignin synthesis is among the biochemical processes most sensitive to a Cu deficiency, increased disease incidence is an early symptom of low Cu that likely will occur before other Cu deficiency symptoms.

Carbohydrate and lipid metabolism

Since Cu is required for the photosynthetic generation of reducing power necessary for CO_2 fixation, it's not surprising that an inadequate Cu supply will reduce carbohydrate levels and vegetative growth rates. This carbohydrate limitation is most pronounced when plants are well supplied with nitrogen because it stimulates vegetative growth and increases the demand for photosynthetic products.

However, following anthesis (pollen release and fertilization), carbohydrate levels often increase. Because Cu is critical for pollen production, effective pollination and fertilization, few seed are set and a major need for photosynthetic products does not develop. The failure of seed set also delays leaf senescence, so photosynthesis continues but plant demand is low and carbohydrates accumulate. Thus, the impact of insufficient Cu on carbohydrate supply will be a function of a plant's developmental stage. This is unlikely to be noted in turf where frequent mowing maintains plants in a vegetative state.

Another less obvious effect of Cu deficiency in plants is a reduction in the degree of desaturation in membrane lipids (Ayala *et al.*, 1992). When Cu becomes deficient, membrane lipids in chloroplasts (and probably elsewhere) become more saturated (contain fewer double bonds). This is attributed to reduced activity of a Cu-containing desaturase enzyme that is responsible for inserting double bonds in the long chain lipid fatty acids.

A loss of lipid double bonds can have profound effects on plant function. In chloroplasts, the ability to tolerate high light levels without damaging the photosynthetic machinery depends on double bonds in carotenoids and other membrane lipids. The capacity for low temperature tolerance is also dependent on a high level of desaturation in membrane lipids. Thus, low Cu levels can drastically restrict the ability of plants to respond favorably to several environmental stresses.

Copper deficiency and toxicity

A Cu deficiency is rarely observed in turfgrass. Most soils provide sufficient Cu to meet turfgrass needs, and Cu may be inadvertently applied to turf in fungicides or soil amendments. However, turf growing on sand-based greens or in high pH organic soils when clippings are removed may experience Cu levels below that needed to supply plant needs. Deficiency symptoms on turf are not well defined and, as is often the case with micronutrient deficiencies, more than a single element might be lacking. Because Cu is essential for chloroplast functions, deficiency normally promotes chlorosis in young growth.

If apical growing points are injured, tillering will be stimulated. This could cause an increase in turf density but a healthy green color will not occur. Nitrogen fertilization can aggravate a Cu deficiency by increasing plant demand and by binding cell Cu with amino acids and proteins. Wilting, even when water is abundant, can be observed if a lack of Cu has prevented lignification of vascular cells and they have collapsed or are less efficient in transporting water to the leaves.

Reduced lignification can also make turf more susceptible to foliage diseases and more attractive to leaf-feeding insects. All of these symptoms will be subtle, and a Cu deficiency is not likely to be the first cause that will come to mind when diagnosing the problem.

Of greater concern to turf managers is the probability of Cu toxicity. The problem of metal toxicity in turf management will be considered in an upcoming issue of this journal and will not be treated in detail here. However, it should be noted that potentially toxic levels of Cu have been reported on golf courses where Cu fungicides have been used over an extended period or Cu-containing sludge-based composts have been used for topdressing.

An excellent study conducted at Iowa State University by Faust and Christians (2000) found that elevated soil Cu is most injurious to roots. In creeping bentgrass, for example, it accumulates to more than 4,000 ppm while Cu concentrations in shoots never exceeded 20 ppm. This means that leaf tissue analysis is not a good indicator of potential Cu injury to turfgrasses and root growth may be severely impaired before any leaf symptoms are noted.

Even though Cu is not likely to be a problem for the turf manager, it's essential for photosynthesis, respiration, secondary cell wall synthesis and stress tolerance. It is reasonable, therefore, that Cu should be recognized for the important jobs it does in supporting turfgrass growth and health.

Richard Hull, a professor of plant sciences at the University of Rhode Island in Kingston, R.I., specializes in plant nutrition.

TURFGRASS TRENDS

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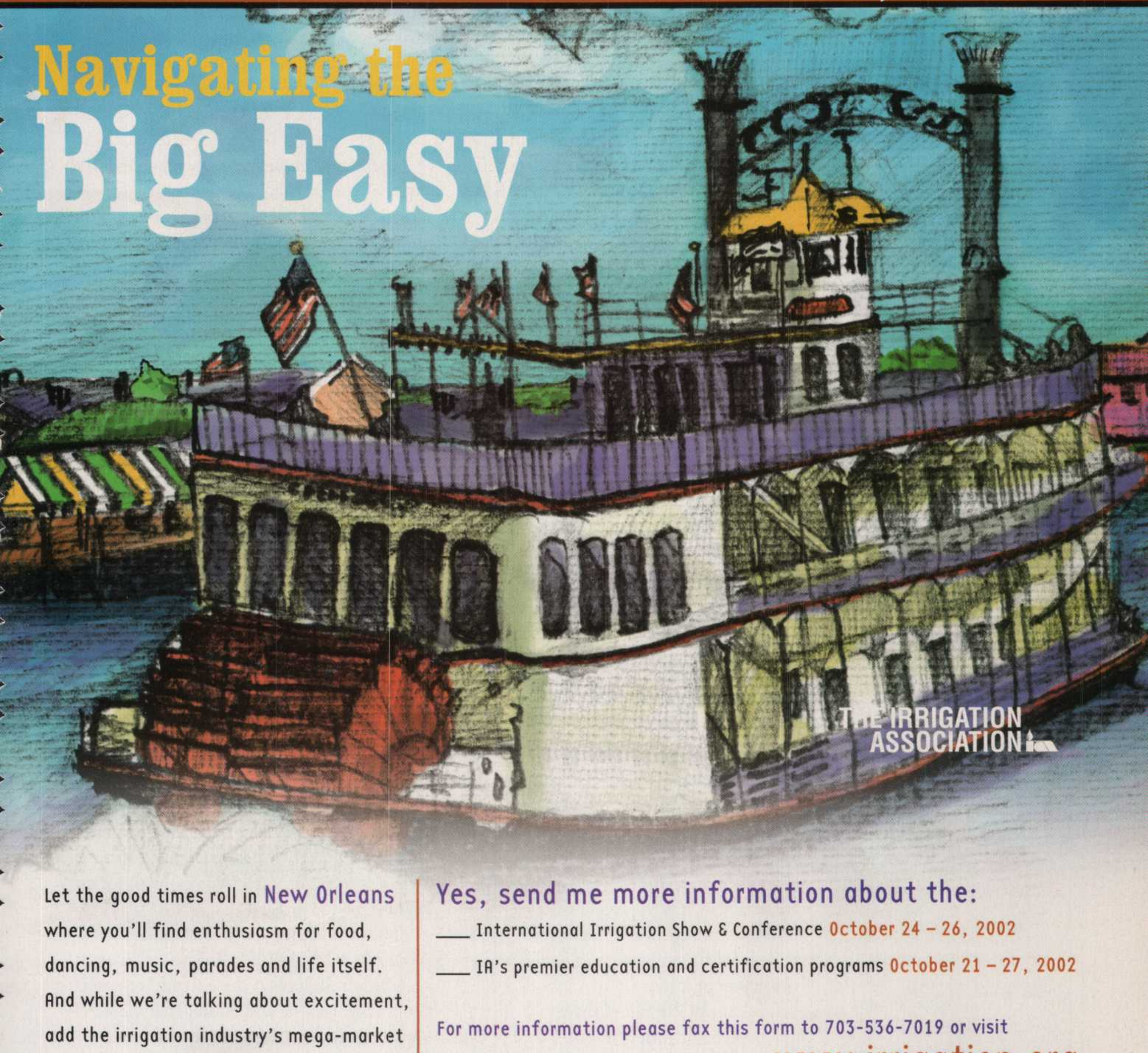

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Continued from page 42

deposits them into lakes, rivers, wetlands, oceans and drinking water sources. These pollutants include fertilizers and pesticides from agricultural lands, residential areas and golf courses.

"Right now, the No. 1 problem for protecting our waters, rivers and oceans is from nonpoint source pollution," Whitman said. "This is where golf courses can play a crucial role."

We asked Whitman if she thought the golf industry uses too many pesticides and chemicals, but she sidestepped the question. She did say the golf industry is becoming more important on EPA's priority list, but ranks "way below" the agricultural industry.

Golfers' takes

So what do golfers think of the environment? Jon Last, executive director of corporate marketing and research for The Golf Digest Cos., presented an eye-opening study to attendees entitled, *Trends in Golfer Perceptions & Attitudes on the Game and Its Relationship With the Environment.* Last conducted a similar study in 1994 and presented it to attendees of the first conference. Both studies featured interviews with about 300 *Golf Digest* subscribers, who were mostly male, about 50 years old and avid golfers (yeah, we know there are other golfer demographics).

The most recent study, conducted in May, revealed that golfers are less likely to participate in conservation activities than they were in 1994. Golfers also expressed contradictory opinions regarding course maintenance in the 2002 study — 75 percent said they would be willing to play on brown grass during periods of low rainfall, but 74 percent said golf courses should be uniformly maintained throughout the year for the enjoyment of golfers and enhancement of scenery.

Last's study also found that:

- 57 percent of golfers in 2002 believe that health dangers of pesticides are sensationalized by the media, compared to 44 percent in 1994.
- 46 percent of golfers in 2002 said the amount of water used on courses should only be enough to keep the grass alive, not make it green and lush, compared to 41 percent in 1994.
- 77 percent of golfers in 2002 said a golf course that integrates natural habitat would increase golfers' enjoyment of the game, compared to 80 percent in 1994.
- 47 percent of golfers in 2002 said they would pay higher green fees to minimize the use of pesticides on courses, compared to 51 percent in 1994.

Interestingly (or not), the study indicated that golfers in the Northeast are more environmentally aware than golfers from other regions. The study also revealed that golfers who play primarily municipal/daily fee courses are more environmentally sensitive.

Last says complacency may be setting in with golfers because they "believe that courses have mitigated many environmental concerns." He also surmised that "golfers are less likely to be willing to make significant personal sacrifices to their golf experience toward an environmental end," and that "integrating environmental education into the golf experience may be a tough sell."

Those are three things the conference's steering committee probably didn't want to hear.

What's next?

It's time to take the environmental message to the streets — or the golf courses, in this case. Parker said the conference's steering committee will meet to discuss the points and opinions raised at the meeting and use them to form an organized strategy to educate golfers. The committee will also assign specific roles to certain groups, such as the GCSAA, to assist in the process.

Conference attendee and speaker Tim Hiers, certified superintendent of the Old Collier GC in Naples, Fla., says the golf industry must be subtle in its approach to make golf courses more environmentally viable. "Don't go in and make wholesale changes," warns Hiers, who advocates a five-year plan for an environmental project.

The conference itself is at a crossroads, Parker said. "We're at a point where we want to take a fresh look at the golf and environment initiative," he said, adding that the steering committee will discuss several issues related to its function, including implementing a more formal structure and staging conferences on a more regular basis (before Nebraska City, the last conference was held in 1998.)

Here's betting another conference is held sooner than later. The environment will always be near the top of the golf industry's priority list. ■

Aylward, the author of this story, can be reached at laylward@advanstar.com.

Mona: Give Back an Acre to Mother Nature

Steve Mona, GCSAA's CEO, introduced the association's new environmental program at the fourth National Golf & The Environment Summit – the ArborLink National Golf Course Habitat Project. The philosophy behind the program is for all of the nation's courses to try and give an acre of land back to nature in the next five years.

"We want to try and measure the amount of wildlife habitat that currently exists on golf courses, and we want to expand that number by 16,000 acres in the next five years," Mona said. "That translates into each golf course returning an acre to its natural state."

INSIDE

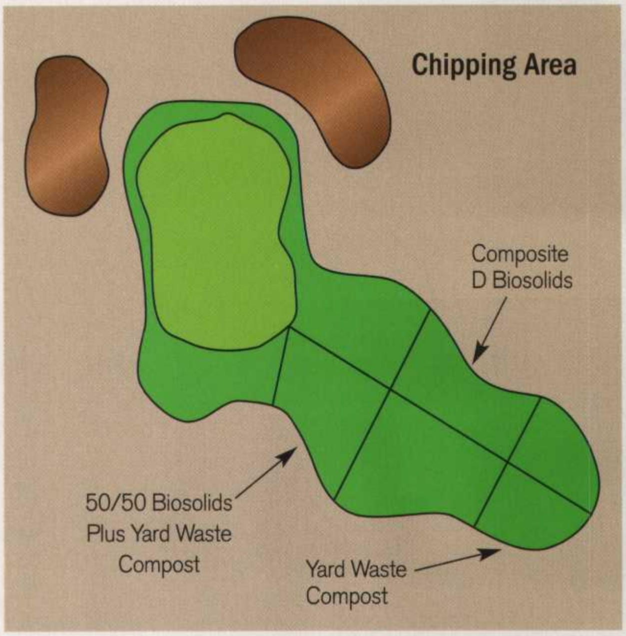
The Fringe

SPECIAL SECTION: THE PUTTING SURFACE

In this issue, *Golfdom* reports on matters affecting greens, from amendments to turf covers.

The First Amendment, But...

Though sphagnum peat moss still reigns as the leading greensmix additive, other choices are gaining ground in industry trials



The chipping green at North Shore CC in Glenview, Ill., became a testing ground for a variety of amendments under the care of certified superintendent Dan Dinelli.

By Frank H. Andorka Jr.
Managing Editor

Sand-based greens possess wonderful drainage qualities, but they don't do a good job of retaining water and nutrients. That's why the USGA, in its green construction guidelines, recommends amending the greensmix with materials to improve the growing medium for golf turf.

"I'm a great proponent of using amendments when constructing greens," says Steve Merkel, director of agronomy for Lincoln, Neb.-based Landscapes Unlimited, a golf course construction firm. "I know there are green construction meth-

PHOTO: JASON NABB/SNITILY CARR

Landscape Unlimited's Steve Merkel is a great advocate of amending greensmixes.

ods that don't call for them, but I think amendments are important."

Sphagnum peat moss has long been the industry's standard additive because of its stability and ease of use. But ongoing studies, sponsored by the National Turfgrass Evaluation Program (NTEP) and the USGA, indicate peat may soon face stiff competition from composts and inorganic amendments.

Conventional wisdom

For the last nine years, the USGA maintained consistent standards about the composition of greensmixes. Superintendents are urged to use a mixture of sand (at least 60 percent of which should be coarse- or medium-grained) and an organic amendment. The most common amendment is sphagnum peat moss, which the USGA says should contain a minimum of 85 percent organic matter by weight. (The percentages are determined by a burn test, where the peat is weighed, burned and weighed again. The leftover material is considered inert and of no use to the turf.)

"Peat is currently the most cost-effective amendment," says Jim Moore, director of construction for the USGA. "There's not much variability from batch to batch of peat because the manufacturers have refined its production to ensure good consistency."

Joe Traficano, certified superintendent at Renegade GC at Desert Mountain in Scottsdale, Ariz., says he used peats in his greensmix because they're easy to use.

"Superintendents all have experience with peats, so they have a proven track record," Traficano says. "I'm not saying other amendments aren't good, but there hasn't been as much university research into the others."

Studies show competition

Though peat is the safest choice in amendments, that doesn't mean it always produces the best results. Two studies, conducted independently by the USGA and the NTEP, indicate composted amendments may be a better investment because of the additional nutrients they offer.

Dan Dinelli, certified superintendent at North Shore CC in Glenview, Ill., agreed to participate in an NTEP-sponsored study that tested different turf varieties. He furthered the study by adding different rootzone amendments on another section of the research green. Dinelli combined with different amendments. When he constructed his facility's practice green, he divided it into 20 different zones, each with a different combination of sand and amendments.

"We tested them all — peat, composted materials and inorganic amendments," Dinelli says. "We didn't treat it any differently than we did the other greens on the course. We wanted to see how the amendments would react under real-world maintenance practices."

After five years of observation, Dinelli says he believes the compost helped the plots mature at least twice as fast as the others.

"The compost-amended plots were consistently denser and greener," Dinelli says. "We also observed slightly less disease pressure."

Dinelli says more research is needed into the long-term stability of those products, and Jim Murphy, a professor of turfgrass science at the Center for Turfgrass Science at Rutgers University in New Brunswick, N.J., may be the man to do such studies. Murphy started his study of amendments in 1997 and plans to continue for the foreseeable future.

"The nutrient-holding capacity of the composts has been good so far," Murphy says. "But we've got a way to go before we can determine their long-term success."

Composts can be inconsistent because the composition of materials can vary from company to company, Murphy says. Before using a composted material, superintendents should test it by a laboratory to see exactly what's in it.

"There are plenty of horror stories out there from superintendents who've used composts with disastrous results," Murphy says. "You need to make sure you know what you're getting. When you find one that works well, stick with it."

Dinelli says the turf industry should institute testing procedures to ensure consistency.

Don't discount inorganics

In the field of amendments, companies that produce inorganic materials must feel like the whole industry is against them. The USGA green-construction guidelines recommend against them in rootzone mixes, and superintendents often complain about their cost. That doesn't mean, however, that they aren't useful, and the USGA may soon change its recommendations. This could overcome the reluctance of some superintendents to use amendments the USGA hadn't approved.

"We're looking to change our recommendations soon to include the possible use of inorganic amendments," Moore says. "It's not that they're bad, but they do tend to be costlier than organics."

Murphy says the longer he studies the inorganics, the more he is starting to recognize subtle differences in the effects they have on the turf. He says he wants to study the data from his project longer before he offers a recommendation on them.

Dinelli says the inorganics he used on his practice green performed well, and the differences between the composted plots and the inorganic plots have finally lessened five years after his study began.

"I'd hesitate to say anything one way or the other about the inorganic amendments," Dinelli says. "It's hard to make sweeping judgments based on tests at one location. In certain soils and under certain conditions, inorganic amendments may be the perfect solution."

Traficano says the debate over amendments will only be settled when more field tests are done in different regions of the country.

"Amendments are often tested under laboratory conditions instead of the real world," Traficano says. "It makes it difficult for superintendents to evaluate them independently. That often leaves superintendents at the mercy of salespeople who are trying to get you to buy their products."

Examining alternatives

Dinelli says the industry should also establish a protocol for organic products in particular to ensure consistency from batch to batch.

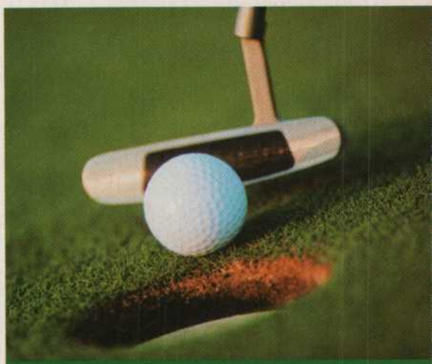
"We need standards so superintendents know what they're getting when they choose an organic alternative to peat," Dinelli says. "It would help alleviate the fears some superintendents have."

Merkel says the industry may also be missing the boat by not allowing native soil to be used as an amendment.

"Soil is another option that doesn't get a lot of attention, but there may be solid reasons to add it in lieu of another organic," Merkel says. "It's something I'd like to see studied."

Traficano says he doesn't know what the perfect amendment looks like, but superintendents must examine their own needs before making a decision.

"You may discover that there are 150 different microclimates on your course, which may require different amendments for different greens," Traficano says. "That's the hardest part of making the decision, but it's what we get paid to do." ■



Five Great Things About Modern Greens

By Geoff Shackelford

USGA Greens – They're manageable, they breed healthier turf and nothing better has come along.

Elimination of grain – Except in Johnny Miller's eyes.

They're faster and more consistent – Slick greens are fun and give people something to talk about. Of course, some of the talk says the greens are too slow or inconsistent.

They hold shots – And reward precise, well-struck iron shots.

They're getting larger – Which creates more hole locations for better golf and improved conditioning.

Five Lousy Things About Modern Greens

USGA Greens – They're expensive, difficult to construct and not as reliable as billed.

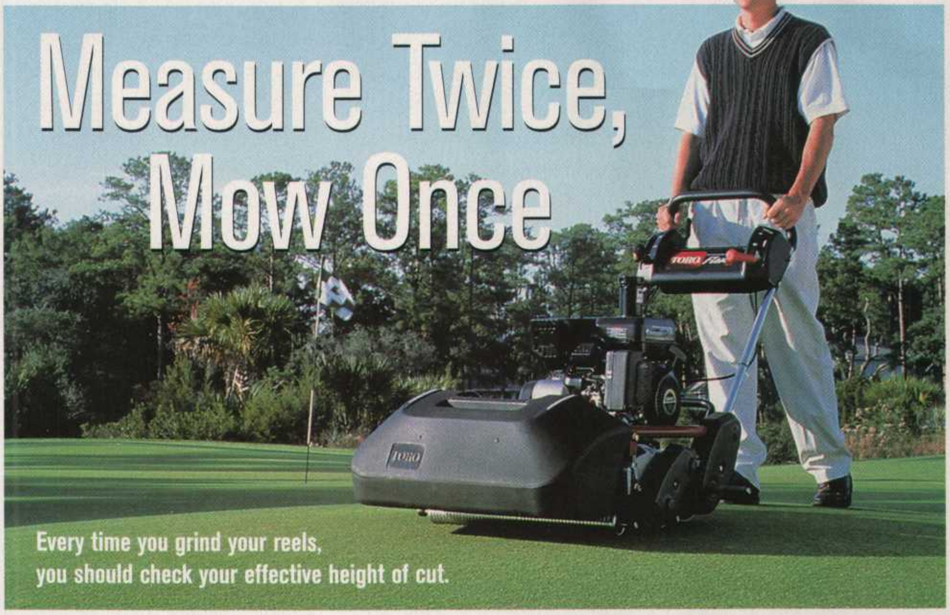
Elimination of grain – Pete Dye says that negotiating grain used to be one of the most interesting aspects of the game.

They're faster and more consistent – Slick greens slow down play, and more speed means less contour can be constructed.

They hold shots – Which can shift the game to a one-dimensional approach.

They're getting larger – If we could just get architects to build large greens that don't feel so huge and clumsy, like the old architects did.

Measure Twice, Mow Once



Every time you grind your reels, you should check your effective height of cut.

THE TORO CO.

Effective management of your height of cut requires diligence and focus to get it right

By Frank H. Andorka Jr.
Managing Editor

Superintendents' jobs often hang on the quality of their greens. Golfers can forgive a little brown turf in the rough and even occasionally on the fairway. But when they get to the pin, they expect perfection.

That's why superintendents must closely monitor their greensmowers' height of cut to ensure they're actually cutting at the heights their patrons expect. Here are some tips from the experts about how to get it done:

■ **Know the difference between your bench height of cut and your effective height of cut.** There's often confusion about the difference between a greensmower's bench height of cut and its effective height of cut, says Tracy Lanier, John Deere's administrative manager of golf and turf market development. Some superintendents assume that once you've set the bench height of cut, that's all you have to do.

"It's not a situation where all you have to do is set it and forget it," Lanier says. "The way the mower is transported to the green, the condition of the turf, the type of green — all these factors can change the height of cut after the mower leaves your building."

The cut quality will give you hints about whether it's out-of-whack or not, says Gary Kuhl, product training manager for Textron's Golf, Turf and Specialty Products division.

"If you expect your greens to look like a pool table and you notice the turf looks like shag carpeting, you have a problem," Kuhl says. "You have to rely on your own instincts, but you will notice a difference if the machine is out of alignment."

Always remember that the bench cut is merely a guide, Kuhl says. You'll have to get out on the green and measure the effective height of cut to see if you're cutting at the height you planned, he adds.

■ **Do the regularly scheduled maintenance on the machine.** Don Schnotala, senior program manager in commercial engineering for The Toro Co., says superintendents must perform the scheduled maintenance on their mowers so all parts work as intended.

"The reels will wear down over time as you mow," Schnotala says. "That wear will eventually affect your height-of-cut, requiring you to readjust your height of cut setting."

The same applies to grinding the reels, Schnotala says. Every time you sharpen the reels, you have to check your height of cut. At today's low mowing heights, thousandths of an inch matter.

■ **Check the alignment of the machine to make sure the bedknives are wearing evenly.** Your mechanic should align the reels with the front rollers, Kuhl says. If those two components aren't square, the cutting unit should be adjusted until they are.

"The roller should be flat and the reel should parallel it," Lanier says. "You should check those every 30 days."

■ **Understand the effect different attachments have on height of cut.** The type of roller you attach to the mowers will affect the effective height of cut, Schnotala says. Solid rollers give the overall mower more support, which in turn lessens the pressure on the turf because they disperse the weight over a wider area. Grooved rollers, on the other hand, cause the mower to sink lower into the turf, thereby cutting lower.

"That's something you have to factor into your cal-

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Using a prism gauge allows superintendents to measure their effective height of cut against their bench height of cut.