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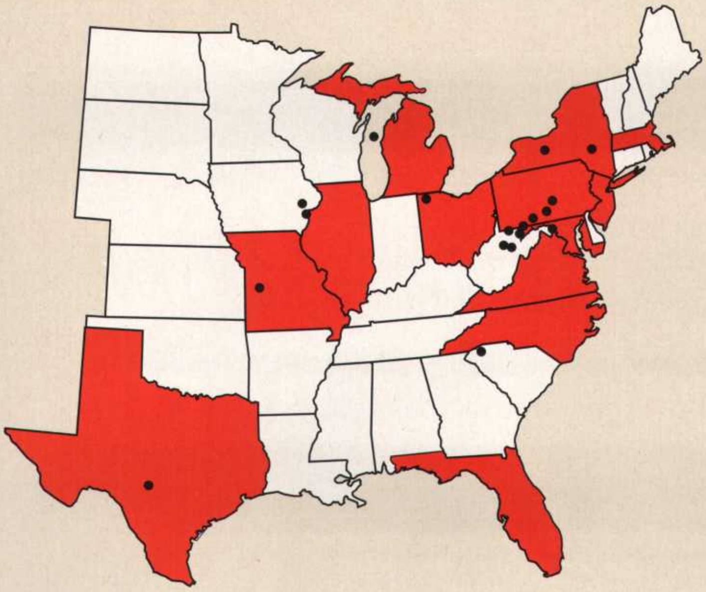
FIGURE 1

Locations of creeping bentgrass and bermudagrass confirmed to be infected by *Ophiosphaerella agrostis* between 1998 and 2003.



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O. agrostis ranged from 77 degrees Fahrenheit and 86 degrees Fahrenheit, and growth was suppressed at 95 degrees Fahrenheit.

A major obstacle of dead spot management is due to the rapid development of secondary inoculum. Unlike other *Ophiosphaerella* species associated with disease of turfgrass (i.e., *O. herpotricha*, *O. narmari*, and *O. korrae*), sexual fruiting bodies are commonly found embedded in necrotic tissue in the center of dead spots. Within each fruiting body, hundreds of spores are produced. When mature, ascospores are forcefully discharged and spread through wind currents or ooze out in the presence of water.

In growth-chamber studies, fruiting bodies developed on a tall-fescue seed/wheat bran mix at temperatures ranging from 55 degrees Fahrenheit to 82 degrees Fahrenheit. Under constant light, fruiting bodies development occurs rapidly, and viable spores may be present within one week.

At 77 degrees Fahrenheit, mature ascospores can germinate in as little as two hours. Germination during the first several hours of spore germination was enhanced by both light and the presence of bentgrass leaves or roots. During the early morning hours, naturally developing dew and guttation may create optimum conditions for spore germination and infection. Reducing leaf wetness through whipping or mowing may be important in reducing new infection.

Field studies on dead spot

Bentgrass cultivar susceptibility to *O. agrostis* was assessed on a USGA-specified research green between 2000 and 2002 at the University of Maryland Turfgrass Research Facility in College Park, Md., 20 *Agrostis spp.* (listed in Table 1 and Figure 2), including 17 cultivars and experimental selections of creeping bentgrass, two cultivars of velvet bentgrass and Bardot colonial bentgrass, were seeded in September 1999.

The area was maintained as a putting green and subjected to routine cultural practices (fertilization, vertical mowing, aeration and topdressing). To ensure dead spot infection, the area was inoculated with *O. agrostis* in 2000 and 2002.

In the first year of this cultivar study, disease symptoms were first observed in June, and the disease's severity increased throughout the summer. All common Agrostis species and cultivars grown on golf courses including creeping, colonial and velvet bentgrasses were susceptible to infection by *O. agrostis*.

Among the commercially available creeping bentgrass cultivars, dead spot generally was most severe in L-93, Penn A-1, A-4, G-1, G-6, Imperial and Providence. Creeping bentgrass cultivars Pennlinks, Penncross and Crenshaw as well as Bavaria velvet bentgrass generally were the least susceptible cultivars over the course of the study.

Disease incidence and severity varied between 2000 and 2002. In 2000, the total number of infection centers within each plot was greatest in early September. Recovery of bentgrass into infected patches began by mid-September and likely was enhanced by fertilizer applications in September and November.

The recovery process was slow, however,

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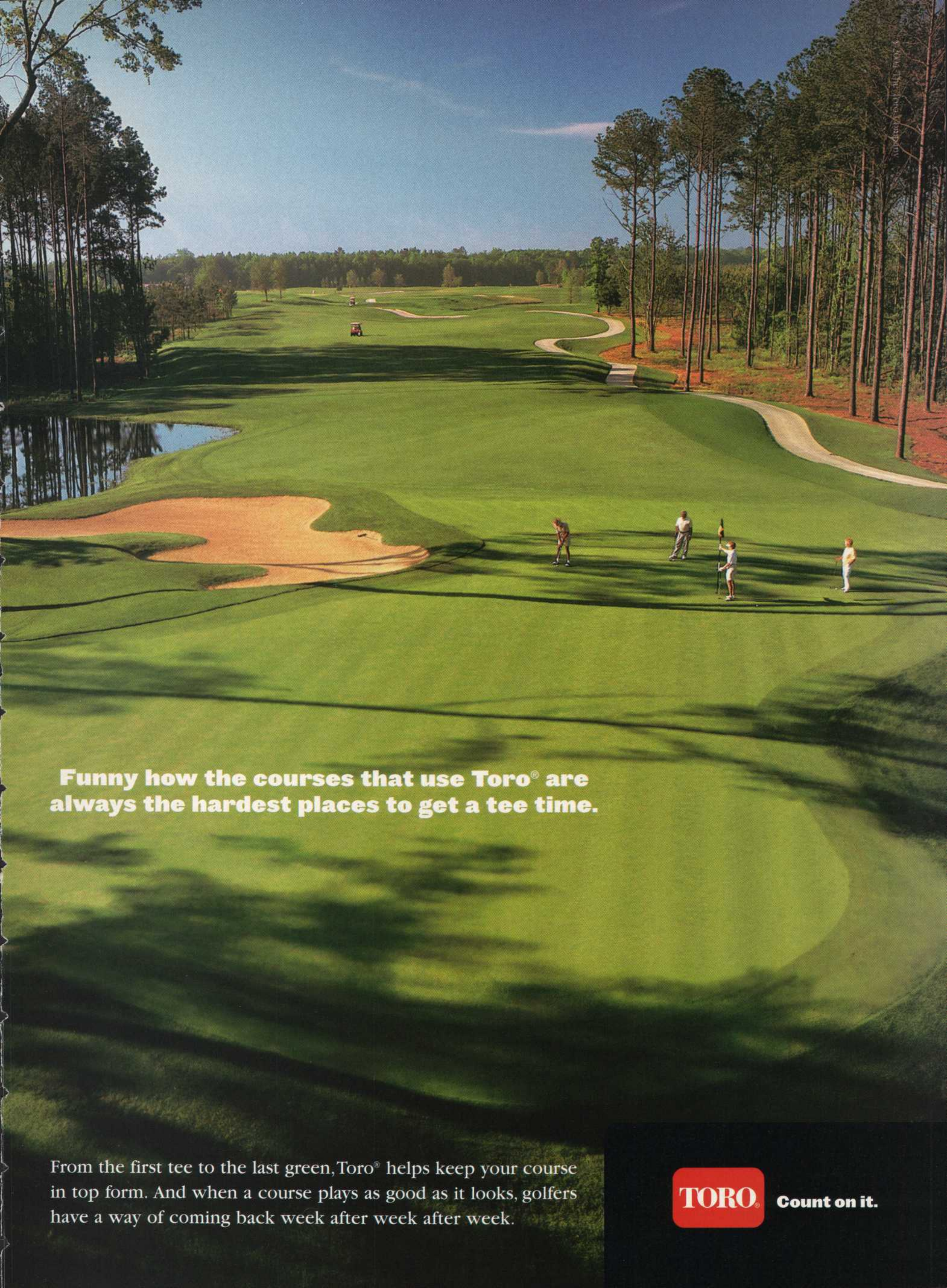
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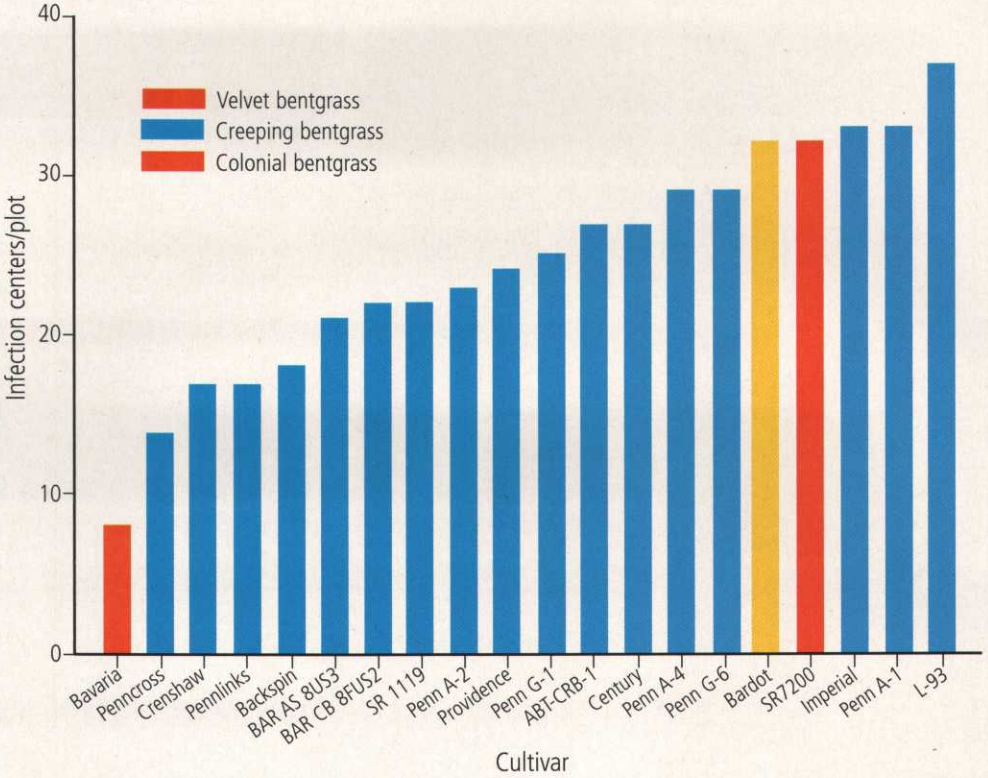
FIGURE 2

Dead-spot infection centers for 20 *Agrostis spp.* grown on a USGA putting green located in College Park, Md. Ratings were made on Sept. 6, 2000 and represent peak dead-spot infection.



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and most infection centers remained visible throughout the winter. A majority of the dead-spot patches recovered during late spring and early summer of 2001. Similar to observations on golf courses, dead-spot activity in the second year declined to low levels, and all cultivars fully recovered by November 2001. In 2002, however, disease severity again increased to unacceptable levels. Dead-spot recurrence likely was influenced by an extended period of summer heat stress and reinoculation of the study site. The impact of fertilization and nitrogen (N) source on dead spot severity is unknown.

Preliminary work at the University of Maryland revealed that once symptoms appear, no N source was found to be superior in speeding turf recovery. Applying small amounts of a water-soluble N (.1 to .125 pounds of N per 1,000 square feet) with each fungicide application may help to reduce dead-spot severity and speed bentgrass recovery.

When applied preventively, however, ammonium sulfate may help to reduce the potential for disease recurrence, while urea and nitrate-based N-sources may enhance dead spot.

According to Wetzel (2000), weekly applications of urea in conjunction with an effective fungicide reduced dead-spot severity. On the other hand, when applied alone, urea did not significantly reduce dead-spot severity when compared to the untreated control (Wetzel, 2000).

Field fungicide evaluation trials reported by Wetzel (2000) and Towers et al. (2001) showed

Continued on page 66

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The Andersons produce granular fungicides on several different inert carriers such as cob, pulp, clay, or DG Pro (dispersible granule). Our DG Pro carrier is a proprietary water dispersible particle that represents a real breakthrough in granular carrier technology. DG Pro particles become invisible after 4-5 minutes of irrigation or contact with dew. This means that mower pickup is virtually eliminated. Distribution of the active ingredient is also improved with over 56,000 dispersed particles per granule. More particles per square inch help improve the efficacy of fungicide treatments. The following is our current offering of granular fungicides on inert carriers as well as Fertilizer plus Fungicide combination products.

Granular Fungicides

PRODUCT	CARRIER	ACTIVE INGREDIENT	COMMENTS
Fungicide VII	DG Pro	Triadimefon	Prevents/controls brown patch; dollar spot, anthracnose and rust
Fungicide V	Cob	Chloroneb	Prevents/Controls Pythium blight and gray snow mold
5% Daconil Fungicide	Cob	Chlorthalonil	Controls brown patch;dollar spot; copper spot; stem rust in bluegrasses
Fungicide IX	Cob	Chloroneb and Thiophanate-Methyl	Prevents/Controls gray snow mold; Pythium blight; dollar spot; brown patch, copper spot and pink snow mold
Fungicide X	Pulp	Iprodione	Prevents/Controls brown patch; red leaf spot; pink and gray snow mold
Systemic Fungicide	DGPro	Thiophanate-Methyl	Prevents/Controls brown patch; dollar spot and copper spot
Golden Eagle	DGPro	Myclobutanil	Prevents/Controls brown patch; dollar spot; anthracnose and other diseases. Prevents summer patch and necrotic ring spot
Pythium Control	Clay	Mefenoxam	Prevents/Controls Pythium blight and damping off

Fungicides with Fertilizers

PRODUCT	ACTIVE INGREDIENT	COMMENTS
24-0-18 Fertilizer + Fungicide VII	Triadimefon	Prevents/controls brown patch; dollar spot, anthracnose and rust
11-0-22 High K Fertilizer + Fungicide VIII NEW !	Iprodione and Thiophanate Methyl	Prevents/controls dollar spot, red thread, brown patch, dollar spot, leaf spot, melting out and pink snow mold.
23-3-5 Fertilizer + Fungicide VIII	Iprodione and Thiophanate Methyl	Prevents/controls dollar spot, red thread, brown patch, dollar spot, leaf spot, melting out and pink snow mold.
21-3-20 Fertilizer + Golden Eagle	Myclobutanil	Prevents/Controls brown patch; dollar spot; anthracnose and other diseases. Prevents summer patch and necrotic ring spot
10-0-14 Fertilizer + 15% PCNB	PCNB	Prevents pink and gray snow molds and other diseases.
FFII 14-3-3	PCNB	Prevents pink and gray snow molds and other diseases.

New Granular Fungicides

Andersons continues to be the leader in granular fungicide technology. Introduced this spring, 11-0-22 High K Fertilizer plus Fungicide VIII is a new high potassium formulation with broad spectrum disease control. In addition, Andersons is in the process of developing new granular fungicides based on the latest technology with expected availability soon.

The advantages of using Andersons granular fungicides are:

- **Ease of use**. You can spread with a broadcast spreader with fewer equipment hassles. This provides better worker safety.
- **Perfect for specialty uses**. Low impact on wet turf. Excellent for use on new construction where heavy equipment can cause damage or ruts. Great for spot treatment of isolated outbreaks. Excellent for hard to reach areas such has bunker faces and small, elevated tees.

Look to The Andersons Advantage when using granular fungicides. Better carriers; expert formulations and years of experience all add up to dependable products you expect from The Andersons.

Article contributed by Rich Christ, Andersons Territory Manager

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Figure 3: *Active dead-spot infections exhibit reddish-brown tissue along the periphery of infected spots and tan, dead tissue in the center.*

Figure 4: *Pseudothecia (sexually produced fruiting bodies) can often be found embedded in necrotic leaves, sheaths and stolons. Spores (arrow) contained within each fruiting body are a source of secondary inoculum.*

Continued from page 64

that propiconazole, chlorothalonil, thiophanate methyl, fludioxonil, iprodione and pyraclostrobin effectively controlled dead spot.

Future work

Dead spot continues to be a problem on newly constructed or methyl bromide-renovated putting greens throughout the eastern United States.

Preventive measures using both cultural and chemical strategies appear to be the best management strategy against the disease. During the first few years of bentgrass putting-green establishment, applying ammonium sulfate may help to prevent dead-spot occurrence.

Soil pH should be routinely monitored when ammonium sulfate is used as the sole nitrogen source because of the potential to reduce turfgrass quality. Preventive applications of the aforementioned chemicals will aid in reducing disease incidence. After disease symptoms appear, however, chemical control is more difficult and fungicides must be applied on a shortened interval (7 days to 10 days).

Curative management of dead spot often requires increased labor and expenses and generally is less effective. Studies currently are being conducted to elucidate environmental conditions that predispose plants to infection. Results from these studies likely will play a major role in the timing and implementation of preventive and curative control strategies aimed at managing dead spot.

Kaminski is a graduate student and Dernoeden is a professor in the Department of Natural Resource Sciences and Landscape Architecture at the University of Maryland in College Park.

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Primo Changes Plant Hormone Levels That Prompt Beneficial Side Effects For Healthy Turf

By Erik H. Ervin and Xunzhong Zhang

Primo (trinexapac-ethyl) is probably the most commonly used plant growth regulator (PGR) on fine turf surfaces throughout the world. Most of us are quite familiar with the fact that, when used at label rates and timings, Primo reduces leaf elongation at four to seven days after initial application and will usually provide a 50 percent reduction in clippings.

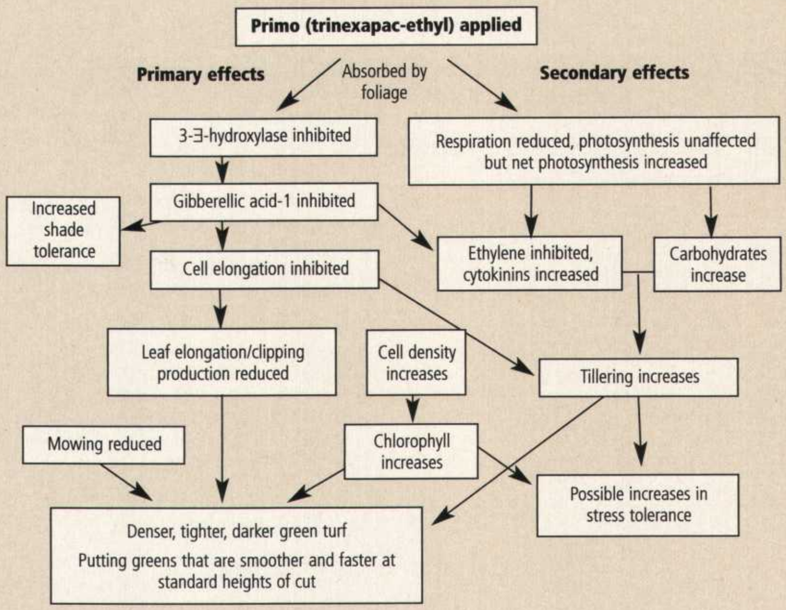
However, for many turf managers, reduced mowing frequency is often not the primary reason for continued Primo use. What they come to value most are many of the side- or secondary-effects that Primo has on turfgrass growth and development.

A recent hypothesis that we were able to test is that increased tillering and prolonged green color of Primo-treated leaves may be correlated with increased levels of cytokinins, a group of hormones responsible for cell division, new tiller initiation and delayed senescence.

However, before discussing these results, we need to spend some time trying to understand the data and observations on secondary effects that led to this hypothesis. To guide and visualize this discussion, a "Primo roadmap" has been developed presenting primary and secondary effects (Figure 1).

FIGURE 1

Proposed Roadmap of Primo (trinexapac-ethyl) Effects



Primary effects

The current formulation of trinexapac-ethyl, Primo Maxx, is absorbed by foliage one hour after application (Shepard, 2002). A radioactive tracing study reported that 24 hours after application more than 50 percent of absorbed trinexapac-ethyl remained in the foliage, while 33 percent was translocated into the crown and less than 5 percent into roots and rhizomes of Kentucky bluegrass (Fagerness and Penner, 1998).

This information indicates that the primary sites of gibberellic acid and subsequent cell elongation inhibition are shoot growing points (shoot basal and intercalary meristems).

Such inhibitions lead not only to reduced mowing requirements, but also to increased shade tolerance (Qian et al., 1998; Ervin et al., 2002; Stienke and Stier, 2003), and to smaller darker leaves with densely packed, chlorophyll-rich cells (Ervin and Koski, 2001a; Heckman et al., 2001a).

Secondary effects

The presence of dwarfed, darker green shoots has led many researchers to ask: Is photosynthetic energy conserved under regulation? If so, is conserved photosynthate being moved to

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other growing points (crown) and what is its fate? There is published evidence to support answering "yes" to all of the above.

To tell this story, we must first start with the processes of energy production and use: photosynthesis and respiration. It has been reported that Primo does not reduce photosynthesis in either cool-season (Kentucky bluegrass; Stier et al., 1997) or warm-season (zoysiagrass; Qian et al., 1998) turfgrasses and that it may even increase overall photochemical activity in creeping bentgrass (Zhang and Schmidt, 2000).

Couple this with a reported Primo-induced decrease in maintenance respiration (Heckman et al., 2001b), and it can be concluded that increased net photosynthesis may occur on Primo-treated turf.

To state it more plainly, Primo-regulated turf should contain increased free (or nonstructural) carbohydrates. This conclusion is supported by Han et al. (1998), who reported that Primo significantly increased the total nonstructural carbohydrate content of creeping bentgrass verdure (crowns + tillers) at two weeks after application, with enhancement diminishing at four weeks as inhibition subsided.

These results are also consistent with the postinhibition shoot growth flush that is often noted on PGR-treated turf that does not receive sequential applications (Bingaman and Christians, 1997).

For sequentially treated turf, the question of how these conserved carbohydrates are used remains. They could be used to increase rooting, lateral growth or tillering. Recall the general rule that shoots generally take precedence over roots for carbohydrate use during periods of optimum growing temperatures.

In fact, overapplication of nitrogen during periods of vigorous cool-season shoot growth (mid-spring through early summer), have been shown to favor shoot growth at the expense of root growth.

Such facts allow us to reason that increased carbohydrates caused by Primo may not be immediately used by the plant for root growth.

Additionally, since the process of leaf elongation is not functioning as a normal energy sink in Primo-regulated shoots, the next energy sink in line would appear to be the crown.

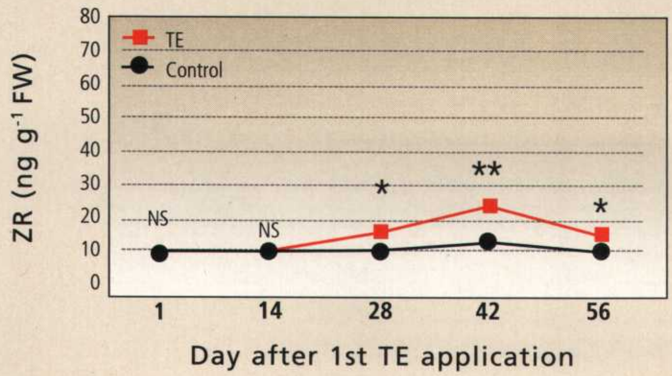
If greater carbohydrates are partitioned to the crown, more energy may be available for intravaginal and extravaginal branching. While greater tiller density of turf that has been sequentially treated with Primo has often been reported (Ervin and Koski, 1998, 2001b; Fagerness et al., 2001), no effects (positive or negative) on lateral growth (Stienke and Stier, 2003; Richardson, 2002; Fagerness and Yelverton, 2001) or gross root mass (Ervin and Koski, 1998, 2001b; Fagerness and Yelverton, 2001) have been noted

In summary, greater available energy to the crown appears to result in greater tillering, but not rooting or lateral spread of Primo-regulated turf.

Is this the whole story? No — plant devel-

FIGURE 2

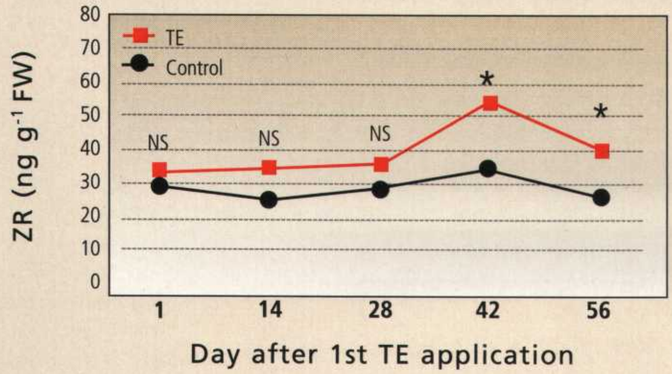
Leaf zeatin riboside (ZR) content as influenced by trinexapac ethyl in creeping bentgrass



'*' '**', significant cultivar differences on LSD=.05 and LSD=.01, respectively; NS, not significant

FIGURE 3

Leaf zeatin riboside (ZR) content as influenced by trinexapac ethyl in Kentucky bentgrass



'*' '**', significant cultivar differences on LSD=.05, LSD=.01, respectively; NS, not significant opment is not merely controlled by how much energy is available and where; changes in the developmental pattern of growth are usually determined by certain chemical signals, that is, changes in hormone concentrations and ratios.

Plant growth and development is controlled by five classes of major plant hormones and can be broken into the "growth" hormones — cytokinins, auxins, and gibberellins — and the "stress" hormones abscisic acid and ethylene. Changes in the relative ratios of these hormones will signal certain processes to occur.

For example, a higher ratio of auxins to cytokinins will promote adventitious rooting, while a higher ratio of cytokinins to auxins will promote tiller initiation and development. Further, higher levels of ethylene relative to cytokinins will allow chlorophyll degradation and leaf senescence, while the opposite ratio will protect chlorophyll function and retard senescence.

During the early commercial development of trinexapac-ethyl and compounds with closely related chemical structures, it was shown that such compounds reduced ethylene production in addition to gibberellic acid inhibition (Grossman, 1991).

Cytokinins not only promote tillering, they also function as antioxidants, thereby helping to preserve chlorophyll integrity.

This data, along with observations of enhanced green color retention, lent credence to the hypothesis that cytokinin levels may also be enhanced in Primo-treated shoots.

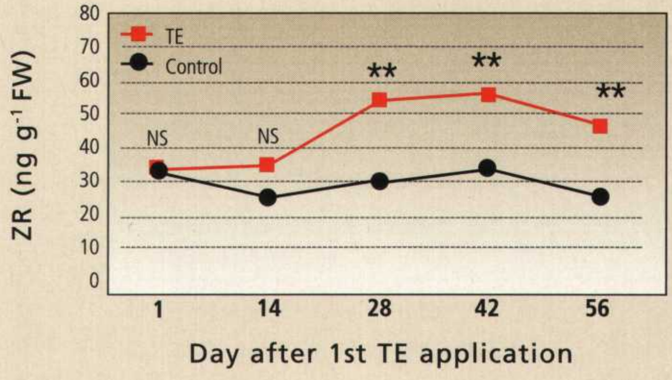
Further support for this hypothesis occurred when numerous reports of increases in tiller density because of repeated Primo applications were published because a higher ratio of cytokinins are needed to promote tillering.

Last year, our lab tested this hypothesis for the first time in L-93 creeping bentgrass, Midnight Kentucky bluegrass and Tifway hybrid bermudagrass (Ervin and Zhang, 2003).

Primo was applied every 14 days at labeled rates (3 ounces per acre (oz./A) for bentgrass, 6 oz./A for bermuda and 13 oz./A for bluegrass), and leaf tissue samples were taken every 14 days for determination of zeatin riboside levels. Zeatin riboside is one of the most prevalent and bioactive of the cytokinins present in turfgrasses.

FIGURE 4

Leaf zeatin riboside (ZR) content as influenced by trinexapac ethyl in bermudagrass



'*' '**', significant cultivar differences on LSD=.05 and LSD=.01, respectively; NS, not significant

A total of four Primo applications were made, and zeatin riboside levels were determined at five sample dates and compared to untreated controls. It was found that zeatin riboside levels increased following the second application and remained higher than the untreated control through the fourth application (Figures 2, 3, 4).

At 14 days following the last application (day 56), it appeared that zeatin riboside levels were returning to untreated levels as the inhibitory effects of trinexapac-ethyl subsided.

What are the possible implications of this new secondary-effect finding of Primo? Recently, turfgrass researchers have reported increased creeping bentgrass drought (Zhang and Ervin, 2004) and heat tolerance (Liu and Huang, 2002) because of artificially induced increases in tissue cytokinin levels.

Cytokinins not only serve to promote tillering. They also function as antioxidants to help preserve chlorophyll integrity and photosynthetic function during stress.

These results serve to support periodic research (Jiang and Fry, 1998; Zhang and Schmidt, 2000; Heckman et al., 2001c) and anecdotal (Shepard, 2002) reports indicating that.

Primo may precondition turf for improved stress resistance. As with any product, Primo

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and PGRs with similar modes of action should never be regarded as substitutes for adherence to sound cultural management programs.

However, research and practical experience continue to reveal various products that informed turfgrass managers might employ to modify plant hormone levels to encourage optimized turfgrass performance.

Ervin is assistant professor of turfgrass physiology and Zhang is a research scientist in the Crop and Soil Environmental Sciences Department at Virginia Polytechnic Institute and State University.

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It's not too late to start a seasonal program for control of summer stress. Begin applying Chipco® Signature® fungicide when conditions first favor disease development, and repeat the treatment at 14-day intervals. Turf quality will improve along with your turf's ability to withstand disease pressure.