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This is because not all economically important cultivars have been tested using a single strain of each known causal agent species, let alone several strains within each of the important causal species. Fortunately, with a few exceptions, bermudagrass cultivars that are more winter-hardy generally have improved resistance to SDS disease where *O. herpotricha* is concerned. It is not known if this general trend holds where the other SDS pathogens are concerned.

Given that different species cause the disease, more than one species can be present within an area, and bermudagrass susceptibility varies depending upon the strain of fungus present (Iriarte et al. 2004).

A "one cultivar fits all" fix is not likely to be the solution for gaining control over SDS. Nevertheless, researchers must be allowed to systematically solve the SDS puzzle one piece at a time.

In the meantime, it is important for the practicing turf manager to use sound cultural management and be cognizant of the identity of the local species of importance so that an informed

decision is made about choosing a resistant cultivar and proper fungicide. To better make these informed decisions, one must get to know his or her local turfgrass pathologist for advisement on the SDS agent of importance as well as the local turfgrass specialist regarding whether bermudagrass cultivars that are more resistant can meet the aesthetic and functional features that are desired.

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Disclosure

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A Paclobutrazol Treatment Can Leave a Tree More Stress Tolerant

By William R. Chaney

Trees are an important part of the golf course landscape and frequently provide the distinct features that make a golfer's experience memorable and enjoyable. Well-groomed fairways and greens are expected and quite frankly don't vary too much from one course to the next. The trees, however, can really enhance the golfing experience through their beauty, appeal and often the challenges they present to golfers.

Preserving tree beauty and health should be a priority of good golf course management. To that end, paclobutrazol, a chemical growth retardant that provides more than just regulation of growth, could be of great benefit. The product has been used by utility foresters for several decades to manage trees growing under electric distribution wires and is now being adopted rapidly by arborists for care of amenity trees in urban landscapes.

Trees treated with this compound are 1.) more tolerant of drought conditions, 2.) resistant to several common fungal and bacterial diseases, 3.) less sensitive to air pollutants, and 4.) usually darker green in color. All of these effects would enhance the appearance and health of trees in golfscapes.

Paclobutrazol is applied as a water suspension approved by the EPA for soil injection or application as a basal drench. The dose rate, which is species-specific, is determined by measuring trunk diameter. The water

suspension of paclobutrazol can either be injected at about 150 psi into the soil to a depth of approximately 6 inches as close to the tree trunk as possible or simply poured into a shallow trench around the base of each tree.

The product label provides detailed information for proper application. Treatments can be made anytime the soil is not frozen or saturated with water.

Mode of action

Suppression of growth by paclobutrazol occurs because the compound blocks three separate steps in the terpenoid pathway for the production of gibberellins. One of the main roles of gibberellins in trees is the stimulation of cell elongation. When gibberellin production is inhibited, cell division still occurs, but the new cells do not elongate. The result is shoots with the same numbers of leaves and internodes compressed into a shorter length.

For many years this was considered to be the sole response of trees to treatment with paclobutrazol. However, research has demonstrated that blocking a portion of the terpenoid pathway causes shunting of the accumulated intermediary compounds above the blockage. The consequence is increased production of the hormone abscisic acid and the chlorophyll component phytol, both beneficial to tree growth and health.

The unique structure of paclobutrazol that allows it to bind to an iron atom in the enzymes essential for the production of gibberellins also has the capacity to bind to enzymes necessary for the production of steroids in fungi as well as those that promote destruction of abscisic acid. The result is that paclobutrazol-treated trees have greater tolerance to environmental stresses and resistance to fungal disease infections. Morphological modifications of leaves induced by treatment with paclobutrazol such as smaller stomatal pores, thicker leaves, and increased number and size of surface appendages on leaves may provide physical barriers to some fungal, bacterial and insect infections.

Although growth reduction is dose-sensitive

Soil injection and basal drench are methods of applying paclobutrazol.



and varies widely, evergreen and hardwood species (with few exceptions), and even palms grow less when treated with paclobutrazol. Treated trees have more compact crowns and somewhat smaller and darker green leaves but otherwise look normal. As a consequence of the reduced growth in height, there is a significant reduction in weight and size of branches removed when trees eventually require trimming.

Expansion of cells produced by the cambium, which is responsible for increases in girth of the trunk and roots, also is dependent on gibberellins. Hence, the trunks and basal roots of paclobutrazol-treated trees do not grow as much in diameter. Up to 30 percent of city trees cause sidewalk and curb damage because of expansion in girth of the trunk and roots, requiring significant portions of annual tree budgets for costly repairs.

At least some of the trees on golf courses will be near cart paths or other hardscape fixtures. Suppression of diameter growth of tree trunks and roots would at least forestall costly damage and the creation of hazards.

Root growth

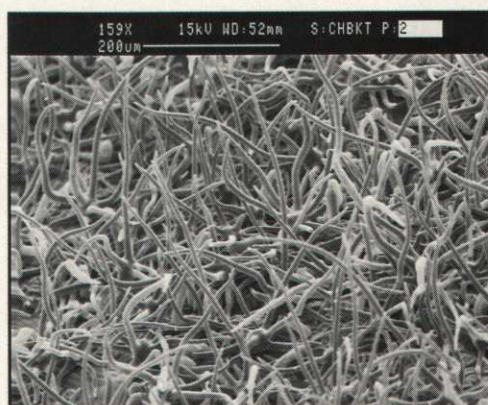
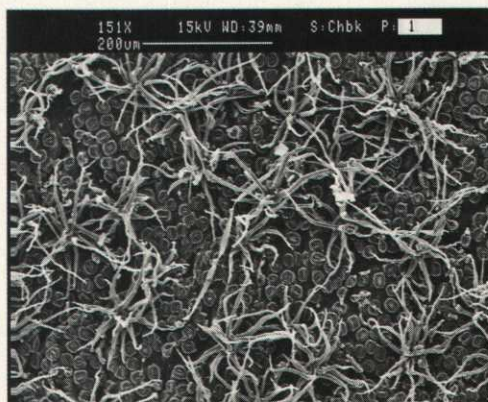
Effects of paclobutrazol on root growth vary from enhancement to inhibition and are far from being clearly defined and understood. In almost all cases, however, the response in paclobutrazol-treated trees is an increase in root-to-shoot ratio.

Gary Watson at the Morton Arboretum conducted one of the few studies on large mature trees exposed to paclobutrazol. Soil injection at the base of white and pin oaks caused fine root densities to be 60 percent or 80 percent higher, respectively, near the trunk base.

Fine root densities were 60 percent to 80 percent higher near the trunk base.

It is unclear whether the responses observed in roots of treated trees are a direct effect of paclobutrazol on root growth or an indirect effect resulting from shoot growth reduction and a shift in carbohydrate allocation to the roots. Root response to paclobutrazol is an important question because root growth and vigor influence not only water uptake but many other aspects of tree health.

Trees treated with paclobutrazol generally have leaves with a rich green color, suggesting high chlorophyll content.



Electron images of cherrybark oak leaf surfaces before paclobutrazol treatment (top) and after, illustrating thicker leaves and masses of hairs on treated surfaces.

There are two possible explanations for this response. One is that the leaves of both treated and untreated trees contain the same number of cells, but the chlorophyll is more concentrated in the reduced cell volume because the cells in leaves of treated trees are smaller. In addition, however, there is evidence that the amount of chlorophyll is actually increased too because phytyl, an essential part of the chlorophyll molecule, is produced via the same terpenoid pathway as gibberellins.

Paclobutrazol treatment, which blocks the production of gibberellins, results in a shunting of the intermediate compounds for gibberellin synthesis to the production of even more phytyl. An analogy might be an accident blocking the flow of traffic on a major highway causing drivers to divert to alternate routes.

Reduced water stress

In addition to interfering with gibberellin production, paclobutrazol is known to increase the production of the hormone abscisic acid, which also is made through the same pathway as gibberellins. When gibberellin synthesis is inhibited, more precursors in the ter-

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Sugar maple leaves from trees untreated (top) and treated with paclobutrazol. The treated leaves show higher chlorophyll content.



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penoid pathway accumulate and are shunted to the production of abscisic acid.

In addition, paclobutrazol interferes with the normal breakdown of abscisic acid by complexing with the enzyme involved in that process. The combined effect on both the production and breakdown processes results in more abscisic acid in leaves.

One of the functions of abscisic acid is to cause stomates to close, reducing water loss from leaves through transpiration. Horticulturists applying paclobutrazol to ornamental perennials and annual bedding plants have reported a similar enhanced tolerance to drought stress. Reduction of transpirational water use could become a valuable tool for superintendents to improve water-use efficiency in the face of persistent droughts and water shortages.

Improved water relations in trees could arise from a combination of increased abscisic acid contents that physiologically reduce stomatal opening, reduced shoot growth resulting in less leaf and stem surface area, more fine roots to absorb water, and structural changes in leaves that provide physical barriers to moisture loss.

Yadong Qi at Southern University in Baton Rouge has dramatic scanning electron images showing thicker leaves and masses of hairs on leaf surfaces of cherrybark oaks in response to treatment with paclobutrazol.

There are numerous observations of

reduced incidence of common fungal diseases such as anthracnose and apple scab following treatment with paclobutrazol.

Karel Jacobs at the Morton Arboretum has shown paclobutrazol to significantly reduce the growth of eight fungal pathogens in laboratory cultures. More and more data from field trials is being published to substantiate the fungistatic benefit of using paclobutrazol. Bruce Fraedrich with Bartlett Tree Expert Co. has recently demonstrated that even bacterial leaf scorch is markedly reduced in red oaks following a soil drench application of paclobutrazol.

The fungistatic ability of paclobutrazol is due to the inhibition of steroid production in fungi, also via the terpenoid pathway. This is the same mode of action that accounts for the fungistatic property of the class of fungicides known as steroid biosynthesis inhibitors (SBIs). Steroids are essential constituents of fungal membranes.

The increased resistance of paclobutrazol-treated trees to bacteria is not thought to be a direct effect on the pathogen, but rather due to alteration in leaf surface structure or even the size of stomatal pores that make infection more difficult.

Conclusions

The many benefits of paclobutrazol can be explained based on an understanding of its ability to combine with iron containing enzymes and to inhibit, as well as foster production via the terpenoid pathway of several important compounds for tree growth and development.

Because of its many positive effects on trees, paclobutrazol has evolved from use solely on trees under electric distribution lines to an important tool for commercial landscape and arboricultural care where both growth suppression and improved tree health are desired. These same benefits could also easily yield more aesthetically pleasing and healthier trees on golf courses too.

William R. Chaney is a professor of tree physiology at Purdue University in the department of forestry and natural resources, with responsibilities in teaching and research. He received a bachelor's degree in plant and soil science from Texas A&M University and a Ph.D. in botany and forestry from the University of Wisconsin. He has authored more than 160 scientific articles and book chapters that have contributed to the basic understanding of the growth of trees and their physiology.



QUICK TIP

Achieving early recovery and density at the end of winter or overseed can lay the foundation for a season of strong turf. Carbon Power N-P-K plus Per "4" Max and Renaissance can jump start spring turf without nitrogen overload.

Is It Going to Be a White Bedding?

Ammonium or urea-based nitrogen fertilizer increases the odds of producing L-glutamine, which encourages the production of 'snow white' fungal isolates such as *Helminthosporium*

By Michael J. Healy, Ph.D

I had run into a brick wall, so to speak. My doctoral dissertation dealt with the pathogenicity of fungal isolates obtained from creeping bentgrass and annual bluegrass putting green turf. I had numerous isolates of *Helminthosporium* (since renamed *Bipolaris*), obtained from putting green turf at 26 golf courses.

At the time, no turfgrass scientist thought of *Helminthosporium* as anything other than a true and potentially serious turf pathogen. I had also made numerous isolations of *Curvularia* and *Fusarium* species from the same samples of putting green turf. The status of *Curvularia* as even a weak pathogen was almost universally in doubt; and for *Fusarium* (as a summer disease), only slightly less so.

The L-glutamine had been exuded in guttation fluid and prevailing low relative humidity allowed the L-glutamine to accumulate on leaf blades and tips as white deposits.

I didn't wish to get involved in any controversial research — just focus my research on *Helminthosporium*, obtain my Ph.D. and exit the University of Illinois. But I was having problems getting my isolates of *Helminthosporium* to infect greenhouse- and growth chamber-grown creeping bentgrass and annual bluegrass turf. Getting infection in the greenhouse or growth chamber should have been a breeze; attempting successful inoculation and infection in the field far more uncertain.

Summer snow

At the time I was doing the research, the predecessor of our modern Internet — the Arapanet — was still several years away from its startup. So a trek down to the main agricultural library



was the primary route to increasing one's knowledge base. I recall that it was late one evening when I came across an article written by a researcher at the Connecticut Agricultural Research Station in the early 1940s. The researcher had been called out to observe a Kentucky bluegrass lawn that had turned snow white seemingly overnight.

This event had taken place not in the winter but in the summer. What the researcher determined was that a heavy application of an ammonium fertilizer had preceded the "snow white" event and that the plants had

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Top: White deposits form on Tifdwarf turf maintained as approaches in Naples, Fla., area, in fall 2002. **Bottom:** Deposit found on ryegrass overseed on a fairway of a course in Gulf Shores, Ala. Preceding both events was an application of ammonium or urea-based nitrogen fertilizer.

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taken up ammonium ions and converted one amino acid, glutamic acid, to a second amino acid, L-glutamine.

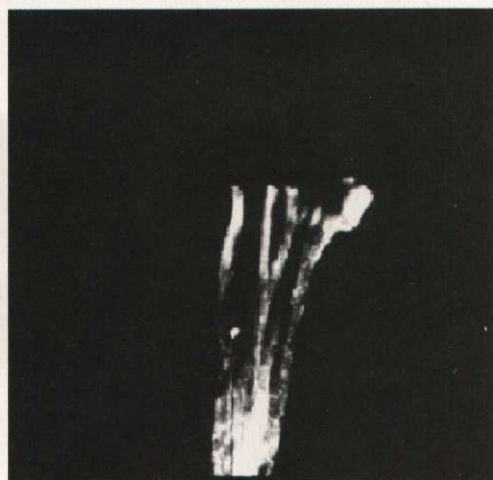
The L-glutamine had been exuded in guttation fluid and prevailing low relative humidity had allowed the L-glutamine to accumulate on leaf blades and tips as white deposits.

So the thought occurred to me: What would happen if I inoculated my target turfgrass plants with fungal spores immersed in various concentrations of L-glutamine?

Fungal free-for-all

What I found almost immediately was that bathing my *Helminthosporium* spores in a dilute L-glutamine solution made them easily able to infect and cause visual symptoms in both creeping bentgrass and annual bluegrass leaf tissue. And the same end result was also true for inoculations of *Curvularia* and *Fusarium*.

Using thin layer chromatography, I was able to prove that both creeping bentgrass and annual bluegrass produce L-glutamine in response to an application of either an ammo-



Accumulation of L-glutamine on an annual bluegrass leaf tip

Let us now fast-forward to the early 21st century. *Helminthosporium* (Bipolaris) is still considered an important turfgrass pathogen while the status of *Curvularia* is still being debated. So what can be said for sure regarding production of L-glutamine by turfgrass species and the possibility of a "smoking gun" — i.e. L-glutamine — being responsible for fungal disease severity on golf course turf?

It seems clear from research (both old and new) that many monocots (grasses) produce L-glutamine as a response to the uptake of nitrogen in its ammonium form. The production of white deposits of nearly pure L-glutamine on leaf blades and tips is an unusual event and based on unusual atmospheric conditions. Such a condition allows this amino acid to accumulate and dry on leaf material before being washed or mowed off.

It is extremely likely that L-glutamine is produced often as a response to the application of an ammonium or urea fertilizer but goes unnoticed as it remains dissolved in either guttation fluid and/or dew.

Beginning attempts to increase fungal disease severity on putting green turf by application of a dilute solution of L-glutamine have not proven successful. Nor is there a clear understanding as to conditions that maximize (or minimize) the production of L-glutamine as a consequence of nitrogen fertilization.

In no case do we recommend the avoidance of ammonium or urea forms of nitrogen, as they are the basis of many successful turfgrass fertilization programs.



Bayer Environmental Science

QUICK TIP

As winter draws to an end, it's a good time to plan your spring cleanup for snow mold and other diseases lingering in the soil. An early-season fungicide application will set the stage for reduced disease pressure throughout the year. Bayer fungicides Compass, Bayleton and 26GT control a broad spectrum of turf diseases, including gray snow mold, pink snow mold, dollar spot, anthracnose and more.

Spores bathed in a dilute L-glutamine solution produced multibranched hyphae along with numerous infection structures called appressoria.

nium or urea-based nitrogen fertilizer. And the same end-result occurred on real putting green turf in the field.

I could apply urea or ammonium nitrate at 1 pound actual nitrogen per 1,000 square feet as a solution at 4 p.m. and identify L-glutamine as being in the guttation fluid collected at 6 a.m. the next day.

So what did L-glutamine do to increase the pathogenicity of a known pathogen (*Helminthosporium*) along with debatably nonpathogenic isolates of *Curvularia* and *Fusarium*? The answer seemed to be in the fungus spore germination and infection process. Spores bathed in a dilute L-glutamine solution produced multi-branched hyphae along with numerous infection structures called appressoria.

Researchers Turn to Turfgrass Instead of Chemicals to Deter Pests

By Kris Braman

Each turfgrass species and cultivar has particular optimal growth requirements. Water, fertility and mowing height differ. Similarly, insect pest management needs vary with grass type.

As chemical pest management tools become less available, researchers at the University of Georgia are seeking alternative methods in the management of common turfgrass pests. Their foundation management strategy, they stress, should always be to deploy pest-resistant plants. Why spend time and money fighting a pest problem when it can be simply avoided with plants that are less susceptible?

It is important to keep in mind, however, that sustainable systems always use multiple tactics for pest suppression. In other words, we don't want to simply replace chemical control with highly pest-resistant plants. That approach simply increases selection pressure for pests to overcome the pest resistance provided by the plant material and become "resistant to the resistance."

Research at the University of Georgia is seeking to develop strategies that complement or better yet synergize one another, believing that this approach makes more economic (and environmental) sense.

Cultivar effects

Interactions between host plant resistance and biological control (control by natural enemies) may be advantageous or disadvantageous for pest management. Numerous beneficial insects and their relatives inhabit turfgrass (Braman and Pendley 1993, Terry et al. 1993, Heng-Moss et al. 1998).

Turfgrass cultivars have rarely been tested for extrinsic resistance characteristics, such as occurrence and performance of beneficial arthropods on plants with resistance to known turf pests. Among the six turfgrass cultivars tested at the university, predaceous big-eyed bug (*Geocoris uliginosus*) nymphs varied in ability to reduce numbers of fall armyworm (*Spodoptera frugiperda*) larvae. The six grasses tested — Sea



Pests feeding on resistant grasses rather than susceptible grasses remained for a longer period in a size range susceptible to predation.

Isle 1 and 561-79 seashore paspalum; TifSport and TifEagle bermudagrass; and Cavalier and Palisades zoysiagrass — represented a range in resistance to the armyworm (Braman et al. 200b, 2002; Reinert et al. 1997).

In general, zoysiagrass is more resistant than bermudagrass or paspalum, but cultivars vary widely in their resistance status.

Resistance to other common turf pests has also been evaluated on these grasses (Braman et al. 1994, 2000a, Reinert 1993, Shortman et al. 2002). In the laboratory, the greatest reduction in fall armyworm larvae by a low density of big-eyed bugs occurred on the resistant Cavalier zoysiagrass.

A seven-fold difference in the weight of 10-day-old larvae between those feeding on susceptible vs. resistant grasses suggested that larvae, on the resistant grass, remained for a longer period in a size range susceptible to predation. Results of laboratory studies were not directly translated to the field, where a diverse predatory arthropod community varied in composition depending on turfgrass cultivar.

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In the field, the greatest reduction in *S. frugiperda* larvae by a low density of big-eyed bugs occurred on Sea Isle 1 and 561-79 seashore paspalum. In the field, vacuum samples indicated that predaceous Heteroptera (including big-eyed bugs) were most abundant in paspalum grasses and bermudagrasses, while ground beetles, rove beetles and spiders were more common in zoysiagrasses.



Predation was never significantly decreased on resistant turfgrass cultivars in any of the study experiments.

By contrast, pitfall traps indicated that other species of ground beetles were more common in bermudagrasses; spiders and rove beetles were similar among grass taxa; and tiger beetles were most common in paspalumgrasses and bermudagrasses. Predation was never significantly decreased on resistant turfgrass cultivars in any of the experiments, indicating no negative effect of resistant grasses on natural control by predators.

Based on our findings, it is important to recognize the benefit of these naturally occurring beneficial insects in the turfgrass system and to conserve them where possible. It could easily

be assumed, for example, that tiger beetle larvae that often make their pits in the ground in thinning turf are responsible for the turf damage. Remember fishing doodlebugs out of their pits in the ground with a long grass stem? Those ferocious jaws that grabbed onto the stem when you pulled them out of the soil are used to capture other insects, including grubs or large armyworms that probably caused the turf to thin out in the first place.

By simply learning to recognize the beneficials, one can avoid unnecessary and counterproductive pesticide applications. Color pictures and descriptions of the common beneficials and turfgrass pests can be viewed by visiting the insect sections on the UGA Turf Web site at www.Georgiaturf.com.

When the same six turfgrass genotypes were tested for their influence on parasitism of fall armyworm, the percentage of parasitism by a small braconid wasp (*Aleiodes laphygmae*) was greatest during July. A total of 20,400 first instar larvae were placed in the field; 2,368 were recovered; 468 parasitoids were subsequently reared; 92.2 percent were *A. laphygmae*.

The consistent numerical dominance of *A. laphygmae* in the turfgrass environment is a departure from the minor role observed for this species in agricultural crops such as corn and sorghum where fall armyworm is also an economic pest. In turf the greatest percentage reduction in fall armyworm larvae by *A. laphygmae* occurred on the armyworm-susceptible seashore paspalums (51.9 percent on Sea Isle-1 in July), followed by bermudagrass and then zoysiagrass. No parasitoids were reared from larvae collected from resistant Cavalier zoysiagrass. Percent parasitism of *S. frugiperda* in this field study decreased with increasing resistance levels to the host insect. However, substantial parasitism on TifSport, a cultivar of bermudagrass demonstrating low levels of resistance to fall armyworm, suggests a promising potential synergy between modest levels of

FIGURE 1

