A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

Volume 7, Issue 6 • June 1999

PATHOLOGY

Gray Leaf Spot

An Emerging Disease of Perennial Ryegrass

Paul Vincelli, Ph.D
Department of Plant Pathology, University of Kentucky

Perennial ryegrass has increased in popularity for a variety of turfgrass uses. In Kentucky and most of the transition zone, this cool-season grass is widely used for fairways, tees, green surrounds, approaches and roughs. Many golfers find this grass to be their preferred choice for fairways. In locations further north, perennial rye is used alone or in combination with Kentucky bluegrass. In most southern locations, it is used for overseeding bermudagrass fairways and greens.

During the hot, very humid weather of the summer of 1995, perennial ryegrass swards in many areas of the transition zone suffered severe to catastrophic epidemics of wilting, blighting and turf loss. At that time, several plant pathologists suspected that a leaf-infecting fungus called *Pyricularia grisea* was the cause of these epidemics. However, conclusive proof that this fungus was indeed the cause was lacking. It is interesting to note that, as recently as four years ago, we knew so little about this disease of perennial ryegrass that turfgrass scientists were disagreeing as to what actually killed the turf.

Since 1995, epidemics of gray leaf spot on perennial ryegrass have been diagnosed throughout the transition zone from New Jersey to Virginia and as far west as Kansas. Significant outbreaks north of the transition zone have been observed in Connecticut, Rhode Island, southern Pennsylvania, southern Ohio, Iowa, southern Illinois and eastern Nebraska.

Much has been learned about gray leaf spot since the 1995 epidemic, including the fact that the fungus *Pyricularia grisea* is indeed the cause of widespread loss of perennial ryegrass in many regions.

The Pathogen

Pyricularia grisea is known to infect plants in over 20 genera of grasses. The first destructive outbreak of this pathogen on perennial ryegrass was observed as early as 1986 by Dr. Pete Dernoeden in Maryland. However, until the 1995 epidemic, gray leaf spot was not considered a significant disease threat over most of the area of perennial ryegrass adaptation. Among turfgrasses, *P. grisea* is also known to attack St. Augustinegrass and tall fescue. It is also possible to find leaf spots caused by *P. grisea* on certain weed grasses — notably large crabgrass and foxtails — as well as on German foxtail millet.

IN THIS ISSUE

www.landscapegroup.com

AN ADVANSTAR ★ PUBLICATION

TURFGRASS TRENDS

Executive Editor
Sue Gibson
440-891-2729; 440-891-2675 (fax)
sgibson@advanstar.com

Managing Editor
Bruce F. Shank, BioCOM
805-274-0321

Technical Editor
Nancy Stairs
440-891-2623

Senior Science Editor
Dr. Karl Danneberger

Consulting Editor
Chris Sann

Group Editor
Vern Henry

Production Manager
Karen Lenzen
218-723-9129; 218-723-9576 (fax)
klenzen@advanstar.com

Circulation Manager
Frank Christopherson
218-723-9271

Group Publisher
John D. Payne
440-891-2786; 440-891-2675 (fax)
jpayne@advanstar.com

Corporate & Editorial Office
7500 Old Oak Blvd.
Cleveland, OH 44130-3369

New Subscriptions
1-888-527-7008

Abstracts: 800-466-8443
Reprint: 440-891-2744
Permission: 440-891-2742
Single copy or back issues:
Subscription/Customer Service
1-888-527-7008; (fax) 218-723-9437
Website address:
www.landscapegroup.com

ADVANSTAR
COMMUNICATIONS

Chairman and Chief Executive Officer
Robert L. Krakoff

Vice Chairman
James M. Alic

VP-Finance, CFO & Secretary
David J. Montgomery

Executive Vice President, Business Development
Skip Farber

Executive Vice Presidents
William J. Cooke
Alexander S. DeBarr

Vice President & General Counsel
Eric I. Lisman

Treasurer and Controller
Adele D. Hartwick

This fungus infects the foliage, causing leaf spots and blighting. Under humid conditions, *P. grisea* produces microscopic spores on both upper and lower surfaces of infected leaves. These spores are produced on microscopic stalks so that the spores are held above the leaf surface, ready to be carried by air movement when dislodged.

Leaf wetness, high humidity and suitable temperatures are the three most important environmental factors that govern infection and by sporulation of *P. grisea*. Increasingly longer periods of leaf wetness allow for increasingly greater levels of infection. Studies indicate that temperatures in the high 70s to low 80s EF are ideal for infection of ryegrasses. On annual ryegrass, wetting periods with a temperature of 95EF had greatly reduced infection levels, so apparently high temperatures during wetting periods can inhibit infection activity by the fungus. While temperature can influence activity of *P. grisea,* it also may affect the susceptibility of perennial ryegrass to infection. One of our knowledge gaps is an understanding of how periods of high temperatures may predispose perennial ryegrass to infection — that is, increase its susceptibility.

Although tall fescue is also a host, it is generally regarded as less susceptible than perennial ryegrass. Epidemics of gray leaf spot on tall fescue have been reported in the southeastern-most portion of the range of this cool-season grass, namely in Georgia and in the Carolinas. Encouragingly, some varieties of tall fescue show substantial resistance to gray leaf spot and may even be a source of resistance genes for perennial ryegrass.

Recent studies of the molecular genetics of *P. grisea* by Dr. Mark Farman at the University of Kentucky have given us important insights into this fungus. His DNA fingerprinting studies, using neutral genetic markers, have shown that the strains of *P. grisea* that attack perennial ryegrass and tall fescue (hereafter referred to as prg/tf strains) are very nearly identical to one another and completely different from the strains which infect all other grasses. He also has found that prg/tf strains exhibit extremely little genetic diversity, even when collected from different regions of the U.S. These research findings have several important implications:

(1) Even though *P. grisea* infects many grass species, grasses other than tall fescue are not sources of inoculum for outbreaks of gray leaf spot on perennial rye.

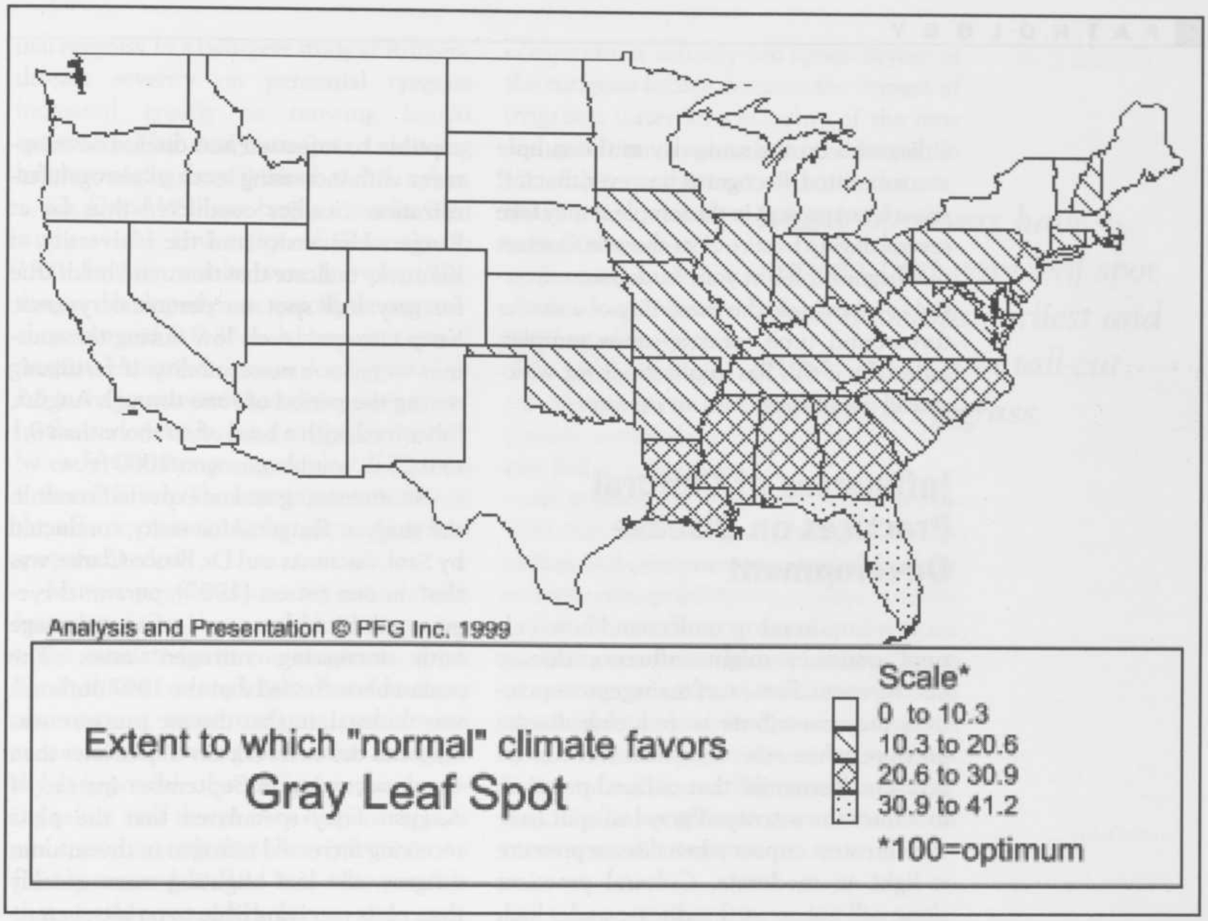
(2) The prg/tf strains of *P. grisea* that are wreaking so much havoc across much of the nation originated from some single, unidentified source.

(3) There appears to be no sexual recombination in prg/tf strains of *P. grisea* thus far. Consistent with this conclusion is the fact that the sexual stage of this fungus — which is known among plant pathologists by the name *Magnaporthe grisea* — has not yet been found in nature on perennial ryegrass. This is reassuring, because sexual reproduction would greatly increase genetic variability in the fungus. This, in turn, would also reduce the chances of long-term success through breeding for resistance and it would also increase the risk of fungicide resistance.

Symptoms

On established perennial ryegrass, the disease first appears as patches an inch or two in size and the leaf blades turn a reddish-brown color. These initial infections can enlarge to patches a foot or two in size within days. As the disease progresses, large, diffuse areas of turf can quickly become blighted. Affected turf often appears wilted despite adequate irrigation. In extremely severe outbreaks, most or all of the turf is killed.

Several types of symptoms can be found when individual leaves are inspected. Sometimes one can find brown, oval lesions which develop tan centers as they expand. These lesions can look very similar to "Helminthosporium" leaf spots. *P. grisea* may also produce leaf spots which are gray in color and which sometimes develop a yellow halo. These are often most common along the margin of leaf blades, a unique



feature of this disease. In yet other instances, infected leaves, especially the youngest leaves, may simply develop an olive-green, watersoaked appearance with no indication of a discrete lesion. When the youngest leaves of perennial ryegrass are infected and killed by *P. grisea*, they sometimes appear twisted and curled, a symptom referred to as a "fishhook" symptom.

Seedlings of perennial ryegrass are very susceptible to gray leaf spot. Plants less than 8 to 12 weeks old may rapidly blight. New seedings often fail when the disease is active during emergence and establishment.

P. grisea produces sporulation on diseased tissues under humid conditions. The fungus has a remarkable ability to produce very dense sporulation overnight on both upper and lower leaf surfaces. Dense sporulation looks like a grayish felt with a hand lense or even with the naked eye. No foliar mycelium is visible on diseased tissues. All of the fungal mycelium is within infected leaf blades and sheaths.

Scouting

Gray leaf spot commonly first appears in tall-cut perennial ryegrass, such as roughs, green surrounds or lawns. For scouting purposes, it is convenient that the disease is commonly first observed in roughs, since golfers are often more tolerant of disease damage in low-maintenance turf. The disease is commonly observed first in "heat-sink" areas: southern slopes and areas where the turf is exposed to long periods of summer sunshine. Some observers also note that it develops early in areas of cart traffic or other sites with compacted soil. Therefore, concentrate on these areas when scouting for early activity of gray leaf spot.

Questionable samples should be examined microscopically for confirmation of the pathogen. In our Plant Diagnostic Laboratory at the University of Kentucky, such samples are treated as high priority. When a sample is infected, positive diagnosis is usually possible within 24 hours and it is not unusual for us to provide the superintendent with a diagnosis on the same day as the sample was submitted. Recognize, however, that if *P. grisea* is not present in the sample, it may take several days to be sure of its absence. Contact the diagnostic lab at your land-grant university to investigate the possibility of a similar turnaround time for suspicious samples, especially if this has implications for widespread use of fungicides on fairways.

Influences of Cultural Practices on Disease Development

It is important to understand how cultural practices might influence disease development. Some turf management practices may contribute to reducing disease pressure, while others may enhance disease pressure. Recognize that cultural practices to reduce the activity of gray leaf spot have their greatest impact when disease pressure is light to moderate. Cultural practices alone will not arrest this disease under high disease pressure and many superintendents will find it necessary to use fungicides preventively.

Variety Selection

There is rather strong evidence from several sources that, under severe disease pressure, all commercial perennial ryegrass varieties are susceptible to gray leaf spot and can suffer extensive turf loss. There is limited data (one site, one year) showing that some varieties are less susceptible than others under conditions of light to moderate pressure. These data are available through the National Turfgrass Evaluation Program. Superintendents may wish to consider these data when selecting varieties, but realize that all varieties of perennial ryegrass have the potential to be severely affected by the disease under high disease pressure.

Nitrogen Fertilization

Numerous studies on *P. grisea* have shown that grasses are typically more susceptible to infection and disease development with increasing levels of nitrogen fertilization. Studies conducted thus far at Rutgers University and the University of Kentucky indicate that this trend holds true for gray leaf spot on perennial ryegrass. Keep nitrogen levels low during the summer to reduce susceptibility. If fertilizing during the period of June through August, foliar-feed with a total of no more than 0.1 to 0.25 lb. soluble nitrogen/1000 ft^2.

An interesting and unexpected result in the study at Rutgers University, conducted by Saul Vaiciunas and Dr. Bruce Clarke, was that, in one season (1997), perennial ryegrass exhibited less gray leaf spot damage with increasing nitrogen rates. The researchers stressed that the 1997 outbreak was unusual, in that disease pressure was light and the outbreak developed later than usual, occurring in September instead of August. They speculated that the plots receiving increased nitrogen in the autumn outgrew the leaf blighting more quickly than plots receiving little to no nitrogen.

In 1998, a year of high disease pressure, increasing nitrogen rates were associated with increasing disease severity in the Rutgers study. Thus, the Rutgers research emphasizes the need to keep nitrogen levels low during the summer, so as to not enhance susceptibility of the grass should disease pressure become high. However, the Rutgers researchers suggest that their results in 1997 indicate that nitrogen fertilization in late summer and early fall may help the turf outgrow damage as long as disease severity is light to moderate.

Questions also arise regarding how the source of nitrogen might influence gray leaf spot development. Relatively little research addressing this issue has been conducted in turfgrass hosts of *P. grisea* as a whole. No such tests have been conducted in perennial ryegrass and are sorely needed.

Mowing

Mowing height: Many observers have noticed that gray leaf spot often develops earliest and most severely in tall-cut perennial ryegrass. In a two-year study at Rutgers, disease severity on perennial ryegrass increased greatly as mowing height increased. The study compared mowing heights ranging from 0.5 inch to 3.5 inches.

Dr. David Williams began a similar field study at the University of Kentucky in 1998, but the results were less clear. The disease developed more quickly in perennial rye mowed at 0.75 inch through most of August. However, disease development at 2.5 inches surpassed that of the shorter turf by the end of August and turfgrass recovery by early October was greater at 0.75 inch than at 2.5 inch. Thus, continuing studies on the effects of mowing height on gray leaf spot are needed.

Mower passes: Some superintendents have noted that the gray leaf spot is sometimes associated with mower passes, much like Pythium cottony blight. Based on these observations, some turfgrass pathologists recommend mowing when the foliage is dry. It is possible that early-morning mowing when turf is wet may disperse spores and create wounds that allow infection into freshly-mowed blades. It is also possible that freshly-wounded leaves are more aggressively colonized by *P. grisea* than unwounded leaves. This is another area where controlled research is needed.

Clipping removal: One study in St. Augustinegrass showed that removing clippings reduced gray leaf spot damage when disease pressure was low, but had no effect when disease pressure was high. A study at Rutgers showed a similar effect on some, but not all, entries of perennial ryegrass and tall fescue. Based on field observations, some turfgrass scientists have suggested that clipping removal on greens collars and approaches may reduce infection activity when disease pressure is light to moderate.

Other Practices

Foliar diseases caused by fungi are commonly enhanced when turf is irrigated at dusk as opposed to early morning. Irrigating at dusk allows long periods of leaf wetness that favor infection by foliar pathogens. In contrast, irrigation near sunrise can help reduce disease pressure. Even though early morning irrigation adds water to the turf ecosystem, it actually can speed drying of the turfgrass foliage, because the impact of irrigation water knocks many of the dew and guttation droplets from the leaves. So schedule irrigation near sunrise whenever possible.

Many observers have noticed that gray leaf spot often develops earliest and most severely in tall-cut perennial ryegrass.

A serious deficit exists in our understanding of the factors that predispose perennial ryegrass to explosive outbreaks of gray leaf spot. There is some speculation, based on field observations, that applications of plant growth regulators and postemergence herbicides may enhance susceptibility of perennial ryegrass to this disease. Testing the effects of such products have been limited, but in one year of testing, no disease enhancement was observed from Acclaim Extra on perennial ryegrass (University of Kentucky) nor from Primo on tall fescue (University of Georgia). This is an additional area that needs more research attention.

Fungicidal Management

There is a widespread consensus that, in areas with a substantial risk, most superintendents are faced with need to use fungicides preventively on perennial ryegrass. When the logarithmic phase (the period of rapid disease increase) kicks in, this disease is rapid and extremely destructive. Those who have direct experience with this disease know that fungicidal protection is needed against this disease before it "explodes" into a full-scale epidemic.

This is not to suggest that all perennial ryegrass should be treated aggressively for gray leaf spot. It has not been reported in all areas where perennial rye is grown. Furthermore, some growing seasons are not conducive for epidemics of gray leaf spot. However, it is a dynamic and emerging problem. Some areas, such as southern Connecticut, Rhode Island, Iowa and eastern Nebraska, developed the disease for the first time last year.

We understand very little about the conditions that lead to the logarithmic phase in natural turfgrass swards. Given our current state of knowledge, no one can positively identify those locations nor forecast those seasons when superintendents can safely withhold all preventive sprays.

Learn as much as you can about disease development in your area, and be informed about what turfgrass scientists know about the disease for your region. Also, scout for the disease, so as to get optimal protection from the fungicides used.

Timing and Efficacy

Research-based comments regarding the timing and efficacy of labeled fungicides are obviously important for readers. This article provides comments based on a careful study of available research, much of which can be found in recent and forthcoming volumes of the journal *Fungicide and Nematicide Tests*, published by APS Press. The comments provided are consistent with the labels of products mentioned. However, fungicide labels do change, and the only valid guides regarding legal rates and timing of fungicides are the product labels themselves.

Seedings made in mid- to late-summer might need preventive fungicide protection from emergence until near the first frost.

On established perennial ryegrass, preventive fungicide protection is needed prior to the logarithmic phase of the disease. The first lesions of gray leaf spot may appear six weeks or more prior to this phase, but the logarithmic phase is the time when protection is critical. In many areas, this phase commonly occurs sometime during the first three weeks of August.

However, in some locations, such as eastern and central Maryland, the logarithmic phase can occur as early as mid-July. In other locations, especially at the more northern range of occurrence, this phase may not develop until around, or after, Labor Day. Again, this reinforces the value of scouting your own course.

Seedlings are more susceptible to gray leaf spot than is established turf. Seedings made in mid- to late-summer may need preventive fungicide protection from emergence until near the first frost.

Azoxystrobin (Heritage) and thiophanate-methyl (Cleary's 3336) are the only labeled fungicides shown to be effective against gray leaf spot under high disease pressure (Table 1).

Heritage 50WG at 0.4 oz. can be expected to provide a minimum of three weeks of protection under high disease pressure. Heritage 50WG at 0.2 oz. at 2 to 3 week intervals also has worked very well in several tests, although some loss in disease control has been observed in some studies.

Cleary's 3336 F at 6 fl. oz. at a two-week spray interval has provided excellent control in almost all studies, although control slipped slightly at the end of the two-week interval in one study at the University of Maryland. The 8 fl. oz. rate of Cleary's 3336 F applied at a maximum of two-week intervals may be necessary for assuring excellent disease control in all circumstances. Given the research to date, stretching the spray interval for Cleary's 3336 F beyond two weeks not only exceeds the instructions on the label, but also is unwise in the event that disease pressure becomes intense.

Studies to date suggest that several labeled fungicides would fall into the "second tier" for gray leaf spot control. These are products that, in my opinion, can be expected to provide adequate disease control under low to moderate pressure, but inadequate disease control under high disease pressure. Products which fall into this category include: those containing chlorothalonil (Daconil and related products), propiconazole (Banner) and cyproconazole (Sentinel). In fairness, it is important to note that Daconil products have only been tested at two-week spray intervals, whereas the labeled spray interval for gray leaf spot is actually 7-10 days. Thus, studies are needed to evaluate chlorothalonil at a shorter spray interval. However, until such studies are conducted, I opt for the conservative approach and consider it a Tier II product based on the best data available to date.

It is noteworthy that iprodione (Chipco 26GT) and flutolanil (Prostar) — fungicides commonly used for brown patch control on perennial ryegrass — are ineffective against gray leaf spot.

Fungicide Resistance

Azoxystrobin and thiophanate-methyl are clearly key players for gray leaf spot control. However, superintendents are advised not to rely exclusively on these products for gray leaf spot control. Azoxystrobin and thiophanate-methyl are systemic fungicides with a significant potential for resistance development.Both chemicals are toxic to fungi by different biochemical modes of action and strains of *P. grisea* resistant to one fungicide would not be expected to be resistant to the other. Yet, *P. grisea* is remarkably adaptable to new control strategies, so I have great concern that repeated, widespread use of these fungicides could lead to a buildup *P. grisea* strains resistant to both fungicides in a short time. Therefore, superintendents across the nation would be well-advised to practice appropriate resistance management strategies. Such strategies would include using all reasonable cultural practices to reduce disease pressure and avoiding exclusive use of fungicides with a similar mode of action.

Based on my assessment to date, it seems that the most sensible use of azoxystrobin and thiophanate-methyl is to apply them during the period of greatest risk — the period when logarithmic disease increase is likely — and to use Tier II products when the risk of disease is low to moderate. This balances the need for excellent disease control with concerns about fungicide resistance as well as cost of the Tier I products (Table 2).

In 1999, we will conduct studies at Griffin Gate Golf Club in Lexington to evaluate the efficacy of fungicide programs designed for resistance management. For example, in central Kentucky logarithmic disease increase in established perennial ryegrass usually occurs sometime during the first two weeks of August. However, substantial disease activity can occur through the end of September and possibly later for seedlings. Thus, one of the treatment programs we'll be testing is Daconil applied in mid-July, followed with Heritage sometime during the first week of August and then Banner or Daconil in mid-September.

TABLE 1. EFFICACY OF FUNGICIDES FOR GRAY LEAF SPOT

Product	Active ingredient	Fungicide Group[2]
Tier I[1]		
Heritage	azoxystrobin	Strobilurin
Cleary's 3336	thiophanate-methyl	Benzimidazole
Tier II[1]		
Daconil Ultrex	chlorothalonil	Multisite contact
Banner	propiconazole	DMI
Sentinel	cyproconazole	DMI
No meaningful efficacy		
Chipco 26019	iprodione	Dicarboximide
Prostar	flutolanil	Benzamide

1. Tier I fungicides are those that, in studies to date, have generally provided good to excellent disease control under severe disease pressure. Tier II fungicides are those that, to date, provide good to excellent control under low to moderate pressure but unacceptable disease control under high disease pressure.
2. Fungicides in the same fungicide group have a similar biochemical mode of action. Superintendents are advised to rotate among (or tank-mix) systemics and contacts or among systemics in different fungicide groups.

Why Is Gray Leaf Spot an Emerging Disease?

Although there are still many unanswered questions, I believe a reasonable explanation for the emergence of gray leaf spot in recent years is analogous to a predator/prey relationship: a steady increase in the use of perennial ryegrass has allowed the buildup of prg/tf strains of *P. grisea*.

A steady increase in the geographic range of P. grisea on perennial ryegrass has been reported each year since 1995.

In the late 1960s, varieties of perennial ryegrass suitable for use on golf courses became commonly available. In the 1980s and early 1990s, acreage of golf turfs sown to perennial ryegrass grew steadily, because of the many agronomic advantages of this grass. The first report of serious damage came as early as 1986, on a golf course in Maryland.

In 1991, as the fungus spread, more frequent reports occurred from several areas in the transition zone, including Pennsylvania, Maryland, and Kansas. Prg/tf strains of *P. grisea* had spread throughout much of the transition zone by 1995 and, with the hot, humid summer that year, an epidemic developed in many areas across the transition zone. A steady increase in the geographic range of *P. grisea* on perennial ryegrass has been reported each year since then. The molecular genetics studies of Dr. Farman's support this explanation: the lack of significant genetic diversity of the prg/tf strains from across the U.S. suggests that these strains originated and spread from some single, unidentified source.

No matter where *P. grisea* originated from, it is clear that the disease is well-established in the transition zone and may constitute an endemic threat to areas further north. Learn what you can about the disease, watch for new research developments and consider the possibility of changing to other suitable species of turfgrasses if the opportunity arises.

Acknowledgments: I thank Pete Dernoeden of the University of Maryland, A. J. Powell of the University of Kentucky, and Dr. Bruce Clarke of Rutgers University for reviewing part or all of a previous draft of the manuscript.

Paul Vincelli is associate extension professor in the Department of Plant Pathology, College of Agriculture, University of Kentucky, Lexington. He can be reached at 606-257-7427 or fax 606-323-1961.

TABLE 2. FUNGICIDE COSTS FOR GRAY LEAF SPOT

Product	Rate	No. Appl.	Cost ($) Per appl.	Cost ($) per season
Heritage 50 WG	0.4 oz	2	11,108	22,215
Cleary's 333650WP	6 oz	4	9,287	37,146
Daconil Ultrex	3.7 oz	6	2,691	16,145
Banner MAXX	2 fl oz	4	5,084	20,337

Assume: preventive treatment for 8 wk (26 Jul - 20 Sep)
30 acres of fairway\par
Prevailing prices in Lexington in March 1999

Humic Substances
and Their Potential for Improving Turfgrass Growth

Richard J. Cooper, Ph.D.
Department of Crop Science,
North Carolina State University

One aspect of turfgrass management which seems constant from year to year is the introduction of new products which aim to allow turfgrass managers to grow better quality turfgrass. Many of these products are designed primarily for high use, intensively managed areas such as putting greens, athletic fields and other closely-mown areas growing on sand-based rootzones. Indeed, these types of areas often require the most management input and are subject to great environmental and use stresses. It is not easy to maintain them at peak quality, especially during the summer stress period.

During recent years, many commercial products containing humic substances have been promoted for use on turfgrasses. While the effects of humic substances on cereal grasses and numerous other plants have been studied for some time they are a relatively new addition to the management arsenal of the turfgrass manager. The following material is meant to provide a thorough introduction to humic substances and their potential use on turfgrass.

Introduction

It has been recognized for centuries that soils containing ample organic matter are usually more fertile and productive than sandy soils. Organic matter has been shown to improve soil water holding capacity, cation exchange capacity (CEC), nutrient retention, soil microbial activity and other properties (Tate, 1987). Although it often composes only 1 to 4% of the dry weight of a soil, it has been estimated that organic matter is responsible for about one-half of a soil's CEC and water-holding capacity.

In recent years, scientists have begun to study specific components of soil organic matter to determine their influence on plant growth. In particular, much research has focused on evaluating the humic substances present in soil.

Interest in humic substances is not a recent phenomenon. In 1786, Achard extracted a substance from peat that we now know as humic acid. Achard's procedure is still the basis for common methods of extracting humic substances from soil today. In the 1800s, plant scientists believed that plants obtained the carbon they needed for growth from carbon present in soil organic matter, including humus. This theory was known as the humus theory of plant nutrition. Of course, we now know that plants obtain the carbon they need through the process of photosynthesis, not from fertilizers or the soil. Even so, soil organic matter remains very important for plant nutrition.

Humic substances can be generally described as "naturally occurring, highly decomposed organic substances with very complex structures." They are derived from plant and animal residues and are usually dark in color. Humic substances can be divided into humic acids (HA), fulvic acids (FA) and humins based upon their solubility in acidic and basic solutions. Aiken et al. (1985) have characterized the fractions as:

Humic acid – The fraction of humic substances that is not soluble in water at a pH less than two, but is soluble at higher pH values.

Fulvic acid – The fraction of humic substances that is soluble in water at any pH.

Humin – The fraction of humic substances not soluble in water at any pH.

Humic substances are essentially a component of organic matter and can be found almost anywhere: streams, lakes and virtually any soil which contains organic matter, animal or plant residues. Some common sources of HAs and humates are coal, Leonardite (a coal-like material) and peat.

Table 1 lists several commonly used soil organic amendments, their humic and fulvic acid content and their CEC. Reed-sedge peat is often used in high sand content rootzones because of its higher CEC and humic content compared to the other sources.

Extracting and producing humic and fulvic acids from various naturally occurring materials often results in a material too acidic for use on many turfgrass areas. To produce a more usable commercial product, HA can be treated with a basic compound to produce a soluble salt with a near neutral pH referred to as humate. It is also possible to mine soil deposits which contain a high percentage of HA or humate. Humic acids and humates are the most commonly marketed types of humic substances currently available for use on turfgrass.

The Composition of Humic Substances

Because humic substances are highly complex organic molecules, their structure varies widely from source to source and no characteristic structure can be described. Even though it is not possible to accurately detail the structure of a typical humic substance, it is known that the major functional groups in humic substances include carboxyl, alcohol, carbonyl and phenolic hydroxyl groups. Also, the general nutrient composition of many soil humic substances has been evaluated. Table 2 lists the average nutrient content for some typical humic substances.

Although several of the possible benefits of humic substances are associated with improved nutrition, it is important to recognize that humic substances themselves are not fertilizers and do not supply appreciable amounts of the major nutrients needed by turfgrasses. It is interesting to note that while research has shown that humic substances can affect a range of plant growth responses, they do not elicit a response because of their fertilizer value. Indeed, carbon, hydrogen, oxygen and sulfur often account for almost all of their composition with only slight and variable amounts of the macroelements N, P and K. Since humic substances are organic in origin, it is not surprising that carbon and oxygen generally make up over 80% of their mineral composition. Generally, humic acids have a greater carbon content and a smaller oxygen content than fulvic acids. (MacCarthy, et al., 1990).

TABLE 1: HUMIC & FULVIC ACID CONTENT OR AMENDMENTS

Humic and fulvic acid content and cation exchange capacity of four commonly used soil organic amendments (adapted from Dixon, 1990).

Amendment	Humic acid (%)	Fulvic acid (%)	CEC (meq /100g)
Reed-sedge peat	21.1	12.0	118.0
Sphagnum peat	8.3	8.6	74.8
Rice hull compost	5.8	6.9	16.5
Fir bark	3.1	5.8	18.3

How Humic Substances Influence Plant Growth

It has been well documented that humic substances may have both indirect and direct effects on plant growth. Indirect effects generally involve a change in soil properties such as: increasing the nutrient holding capacity (CEC) or water holding capacity of the soil; enhancing the population of desirable soil microbes in the soil; improving soil aggregation, aeration, or permeability; and improving micronutrient availability and transport into roots. In addition to these indirect soil-related effects, it is thought that humic substances might also have the ability to directly impact plant growth. Direct effects are those which require uptake of humic substances into the plant tissue resulting in various biochemical effects.

There are several hypotheses as to how humic substances may function in plants to produce positive changes in growth. Some possible mechanisms indicated by past research include: enhanced absorption of mineral nutrients; reduction in soil levels of toxic elements; enhancement of soil microbial populations; increased photosynthesis and protein synthesis; increased plant hormone activity; and alteration of cell membranes resulting in improved transport of nutrients from the soil.

Several researchers have noted an increase in the transport of nutrients (P, K, calcium, magnesium, iron and manganese) from roots to shoots following HA application to various crops (Fortum and Lopez-Fando, 1986). Application of HA has also been shown to reduce aluminum toxicity to plants by chelating available aluminum and rendering it unable to compete with P uptake, thus increasing P availability in acidic soils (Tan and Binger, 1986). Kreij and Basar (1995) reported that humic substances lowered the uptake of manganese, zinc and copper for several herbs with the response being more pronounced at low pH. Reduced uptake at low pH may be due to increased complexation by humic substances and lower availability in complexed form.

Increased iron uptake in response to HA application has also been reported (DeCock, 1955) and it has been suggested that the increase in iron uptake might be due to increased cell membrane permeability. Chen and Aviad (1990) have also speculated that humic substances may interact with the phospholipids in cell membranes to facilitate nutrient transport.

Humic substances may also influence plant growth as a result of their effect of various aspects of plant metabolism (Vaughan and Malcolm, 1985). HA has been reported to increase both photosynthesis and respiration in a wide range of plants (Chen and Aviad, 1990), as well as leaf chlorophyll content (Sladky, 1959 a,b). Increases in these processes might be expected to result in increased plant growth. Miroslava (1960) reported that HA increased root respiration with increased respiration linked to greater growth.

TABLE 2: CHEMICAL COMPOSITION OF HUMIC SUBSTANCES

Average chemical composition of selected humic substances. (From Steelink,1985).

Element	Humic Acid	Fulvic acid
	%	
Carbon	54 - 59	41 - 51
Hydrogen	3 - 6	4 - 7
Oxygen	33 - 38	40 - 50
Nitrogen	1 - 4	1 - 3
Sulfur	0 - 2	0 - 4

Plant Growth in Response to Humic Substances

While scientists have not conclusively determined the exact mechanism(s) responsible for influencing plant growth, the positive effect of humic substances on the growth of numerous plants in the Gramineae family has been well documented (Chen and Aviad, 1990). Dixit and Kishore (1967) reported enhanced germination in corn, barley and wheat treated with humic or fulvic acids.

Many studies have associated improved rooting with the application of humic substances. Kononova and Pankova (1950) compared the root development of corn growing in solution culture with or without added humic acid and found that root length and number doubled in response to humate added at 4 to 5 mg/litre. Lee and Bartlett (1976), also working with corn grown in solution culture, found that rooting was enhanced significantly at a humate concentration of 8 mg/litre. Tattini et al. (1990) reported that HA improved the root:shoot ratio and increased the production of lateral roots in olive (*Olea europaea* L.). They also observed increased partitioning of carbohydrates to the roots and an increase in whole plant dry weight.

Vaughan and Malcolm (1985) compared root and shoot growth of wheat grown in water alone, in a complete (Hoagland's) nutrient solution and in each solution supplemented with 50 mg/litre humic acid. The results showed a 58% increase in root growth when humic acid was added to water alone. This was less than the increase in growth when plants were grown in a solution with adequate mineral nutrition but no humic acid. The greatest response, however, occurred with the addition of humic acid to plants growing in nutrient solution. These plants increased root growth approximately 25% compared to plants which were growing in nutrient solution alone. While the use of humic substances cannot substitute for proper nutrition, they do seem to improve nutrient uptake and utilization.

In a review of research evaluating humic substances, Chen and Aviad (1990) cite many studies demonstrating the influence of humic materials on nutrient uptake by plants. Dormaar (1975) reported an increase in N uptake by rough fescue (*Festuca scabrella* Torr.) in response to application of humic substances extracted from three soils while P, K, calcium, magnesium and sodium were unaffected. Guar (1964) found increased N, P, and K uptake in perennial ryegrass (*Lolium perenne* L.) grown in sand amended with humic acid extracted from compost. Varshovi (1991) found no increase in N uptake by bermudagrass (*Cynodon dactylon* L.) following application of a commercial humate material at 0, 268 and 803 kg/ha. Dorer and Peacock (1997) reported no increase in leaf tissue concentration of N, P or K following applicartion of liquid or granular humate to a creeping bentgrass putting green. Whether nutrient uptake increases, decreases or remains constant in response to humic substances appears to depend in large part on the plant species and humic materials used.

It is important to keep in mind that humic substances are classified primarily according to their solubility, not upon chemical structure. In fact, it is sometimes said that if you can identify a the structure of a particular compound, it is not a humic substance. It is difficult to make comparisons among different humic materials.

Two products may contain identical amounts of humic or fulvic acid, but they may have come from completely different sources and produce very different results when applied to a turf area. Therefore, it is important to gain as much information about a specific product as you can before using it yourself. Good sources of information include: independent research results from unbiased labs, university research, impressions from superintendents who have used a particular product and small test plots on your own golf course. While the positive effects of humic substances on cereal grasses and other plants have been documented, the growth response of turfgrass has not been studied extensively.

In an upcoming issue, we will summarize current research results dealing specifically with the effects of humic substances on turfgrasses.

Richard J. Cooper, Department of Crop Science, North Carolina State University, Raleigh. He can be reached at (919) 515-7959 or e-mail at rich_cooper@ncsu.edu.

REFERENCES

Aiken, G.R., D.M. McKnight, R.L. Wershaw and P. MacCarthy. 1985. Introduction to humic substances in soil, sediment and water. Pp. 1-9 *In* Aiken,G.R. *et al.*, ed. Humic substances in soil, sediment and water: geochemistry, isolation and characterization. Wiley-Interscience, New York, NY.

Chen, Y. and T. Aviad. 1990. Effects of humic substances on plant growth. Pp. 161-186 *In* MacCarthy, P. *et al.*, ed. Humic substances in soil and crop science: selected readings. SSSA and ASA, Madison, WI.

DeCock, P.C. 1955. Influence of humic acids on plant growth. Science. 121:473-474.

Dixit, V.K. and N. Kishore. 1967. Effect of humic acid and fulvic acid fraction of soil organic matter on seed germination. Indian J. Sci. Ind. 1:202-206.

Dixon, C.R. 1990. Evaluating organic amendments for sand-based turf systems. Golf & Sports Turf. Sept. p. 23-25.

Dorer, S.P. and C.H. Peacock. 1997. The effects of humate and organic fertilizer on establishment and nutrition of creeping bent putting greens. J. Int. Turf. Res. Soc. 8:437-443.

Dormaar, J.F. 1975. Effects of humic substances from Chernozemic Ah horizons on nutrient uptake by *Phaseolus vulgaris* and *Festuca scabrella*. Can. J. Soil Sci. 55:111-118.

Fortum, C. and C. Lopez-Fando. 1986. Action of peat compost humic acids on growth and mineral content of ryegrass. Agrochemica. 30(1):83-92.

Guar, A.C. 1964. Influence of humic acid on growth and mineral nutrition in plants. Bull. Assoc. Fr. Itude Sol. 35:207-219.

Kononova, M.M. and N.A. Pankova. 1950. Action of humic substances on growth and development of plants. Doklady Akad. Nauk. SSSR. 73:1069-1071.

Kreij, C. and H. Basar. 1995. Effect of humic substances in nutrient culture on nutrient uptake. J. Plant Nutrition. 18:793-802.

Lee, Y.S. and R.J. Bartlett. 1976. Stimulation of plant growth by humic substances. Soil Sci. Soc. Am. J. 40:876-879.

MacCarthy, P., R.L. Malcolm, C.E. Clapp and P.R. Bloom. 1990. An introduction to soil humic substances. Pp. 1-12 *In* MacCarthy, P. *et al.*, ed. Humic substances in soil and crop sciene: selected readings. SSSA and ASA, Madison, WI.

Miroslava, J.L. 1960. Influence of humic acid on respiration of plant roots. Biol. Plant. 2:152-164.

Sladky, Z. 1959a. Effect of extracted humus substances on tomato growth. Biol. Plant. 1:142-150.

Sladky, Z. 1959b. The application of extracted humus substances to overground parts of plants. Biol. Plant. 1:199-204.

Steelink, C.A. 1985. Implications of elemental characteristics of humic substances. Pp. 457-476 *In* Aiken, G.R. *et al.*, ed. Humic substances in soil, sediment, and water: geochemistry, isolation and characterization. Wiley-Interscience, New York, NY.

Tan, K.H. and A. Binger. 1986. Effect of humic acid on aluminum toxicity in corn. Soil Sci. 141(1).

Tate III, R.L. 1987. Soil organic matter. John Wiley and Sons, Inc. New York, NY.

Tattini, M.A., A. Chiarini, R. Tafani and M. Castagneto. 1990. Effects of humic acids on growth and nitrogen uptake of container grown olive. Acta Horticulture. 286:125-128.

Varshovi, A.A. 1991. Humate: properties and influence on the growth and nitrogen uptake of bermudagrass. M.S. Thesis. Univ. of FL, Gainesville.

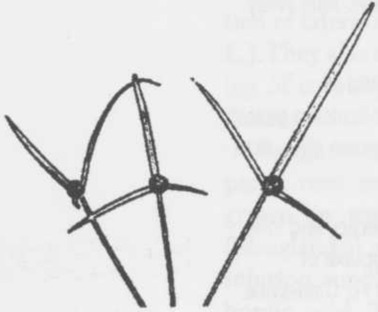
Vaughan, D. and R.E. Malcolm. 1985. Influence of humic substances on growth and physiological processes. Pp. 37-75 *In* Vaughan, D. and R.E. Malcolm, eds. Soil organic matter and biological activity. Martinus Nijhoff/Dr. W. Junk Publ., Dordrecht.

Green Kyllinga
Sedge Weed of Turf and Ornamentals

By David W. Cudney, Clyde L. Elmore, David A. Shaw and Cheryl Wilen

Green kyllinga (*Kyllinga brevifolia*) is a weedy sedge that is becoming a major problem in turf and ornamental plantings in California. The genus, *Kyllinga*, consists of about 40 species, which are distributed worldwide in subtropical and warm temperature regions. Green kyllinga has been reported as a weedy problem from Florida across the southeastern U.S. into Arizona, California and Hawaii. In California, it has been reported from San Diego to the Sacramento Valley.

Green kyllinga is thought to have originated in Asia and was reported as a weed in California more than 50 years ago. But, it has only been in the last few years that green kyllinga has developed into a major problem for turf and ornamental managers.



It is often confused with yellow or purple nutsedge due to its similarity in size and growth pattern. However, the flower and absence of underground tubers make it easily distinguishable from these species.

Life Cycle

Green kyllinga is a perennial that grows best in moist areas with full sun. However, it can withstand shade and drying once established. It grows well during the warm weather from April through October. When left unmowed, it can reach a height of 15 inches. It is a prostrate plant producing a network of underground stems and rhizomes. It roots and sends out leaves at each stem node. If green kyllinga rhizomes are removed and chopped into pieces, new plants can be produced from each node or stem section.

Leaves are long and narrow, ranging from one to more than five inches in length. The flowering stalks terminate in a globular inflorescence that is subtended by a group of three leaves immediately below.

Impact

In turf, green kyllinga forms a weak sod that gives poor footing for athletic fields and golf courses. Although primarily a problem in bermudagrass swards, it has been found in cool-season turf as well. Because it grows faster than most turf cultivars, it gives infested turf an undulating surface in as little as two days after mowing. Green kyllinga forms a dense mat that can expand at a rate of one inch per day. These mats can crowd out desirable species and reduce the vigor of those plants that survive.

Management

Hand pulling is usually futile because of the weed's extensive rhizome system. Prevention is the primary method of control. Mowers and cultivation equipment should be thoroughly cleaned before moving from an infested area to other areas. Individual plants should be spot sprayed with a nonselective herbicide, such as glyphosate. Open areas should be seeded shortly after treatment. Preemergence herbicides (pendimethalin, prodiamine, bensulide and benefin) have been successful in limiting germination in late spring and early summer.

Postemergence herbicides can limit growth of green kyllinga. Best control has been obtained when halosulfuron has been applied in two applications, spaced about two weeks apart. Multiple applications of MSMA will reduce infestations (at least three applications at 7- to 10-day intervals). Bentazon has reduced green kyllinga growth when two applications were made about two weeks apart.

Control of green kyllinga in ornamentals by hand hoeing is not effective in the long run. Spot spray solitary plants. Preemergence herbicides such as oryzalin and pendimethalin can be used to limit seedling germination. Application should be made in April prior to soil temperatures reaching 65°F. Few postemergence herbicides are registered for use in established ornamental plantings. Spot treatment with glyphosate can reduce green kyllinga growth but be careful to not spray or drift glyphosate onto desireable plants as injury will result.

Mulching with landscape fabrics can be effective if it is overlapped and no light is allowed to penetrate the soil. Use polypropylene or polyester fabric or black polypropylene tarp to block all plant growth. Organic mulches might not be effective since green kyllinga will probably grow through the mulch.

David W. Cudney, Department of Botany and Plant Science, University of California, Riverside. Clyde L. Elmore, Department of Vegetable Crops, Weed Science Program, University of California, Davis. David A. Shaw, University of California Cooperative Extension, San Diego. Cheryl A. Wilen, University of California Cooperative Extension, Southern Region, State IPM Project, San Diego, CA.

In Future Issues

- Nematode Life Cycle
- Annual Bluegrass Weevil
- Take-All Patch
- Black Turfgrass Ataenius
- Irrigation With Reclaimed Water

TURFGRASS TRENDS

TurfGrass Trends is published monthly. ISSN 1076-7207.

Subscription rates: One year, $180 (US); $210 (all other countries.)

ADVANSTAR
COMMUNICATIONS

Postmaster: Send address changes to TurfGrass TRENDS, 131 West First St., Duluth, MN 55802-2065.

TURFGRASS TRENDS

131 West First Street
Duluth, MN 55802-2065

QUICK REFERENCE NUMBERS

Editorial: *440-891-2729*
Subscription: *888-527-7008*
Permission: *440-891-2740*
Reprints: *440-891-2744*
Single copy or back issues: *218-723-9477*
Website: *www.landscapegroup.com*

USE OF TGT ARTICLES

PERMISSION MAY BE GRANTED ON REQUEST FOR TGT ARTICLES AS COURSE MATERIAL AND FOR REPRINTS IN PUBLICATIONS.

For course material: We can group articles by subject for you.

Please send request to:
TurfGrass Trends
Advanstar, Attn: Permissions
7500 Old Oak Blvd.
Cleveland, OH 44130
800-225-4569, ext. 742

Index and abstracts are available electronically through: www.landscapegroup.com and Michigan State University, TGIF 800-466-8443