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DISEASE PATHOLOGY

Predicting Rhizoctonia blight with 'risk models'

By Michael A. Fidanza, Ph.D.

Rhizoctonia blight (formerly called "brown patch") was one of the first turfgrass diseases to be identified, described, and investigated at the turn of this century (1,2,4). In cool-season turfgrasses, Rhizoctonia blight is associated with hot and humid weather common during the summer months (Fig. 1, 2,). Therefore, early investigations into Rhizoctonia blight focused on identifying the weather conditions associated with this disease.

In 1930, a University of Massachusetts researcher, L.S. Dickinson, was the first to observe the environmental conditions associated with Rhizoctonia blight (2). He noted that Rhizoctonia blight disease symptoms often appeared on creeping bentgrass when the afternoon air temperature ranged from 80- to-90°F. A researcher with the U.S. Department of Agriculture, A.S. Dahl, followed-up on Dickinson's work by examining air temperatures and Rhizoctonia blight development at the Arlington Turf Gardens (currently the site of the Pentagon building in Arlington, VA). Over five consecutive summers, Dahl observed that the disease occurred on 82% of those days from June through September when the daily minimum air temperature was >70°F (1). Unfortunately, Rhizoctonia blight disease or weather data were not included in his report.

Fig. 1. A circular ring of mycelium of Rhizoctonia solani infecting perennial ryegrass mowed at fairway height.

More than 60 years after Dickinson and Dahl published their observations, another researcher at the University of Massachusetts, Dr. Gail Schumann, launched an additional investigation into the environmental conditions associated with Rhizoctonia blight (5). As a result, a weather-based Rhizoctonia blight "risk model" was developed. (Note: the term "model" as defined by Webster's dictionary means "a hypothetical description, often based on analogy, used in analyzing something". With weather-based plant disease prediction methods, the term "model" is a name for a mathematical equation or set of rules which are used to describe the specific environmental con-

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ditions required for a disease to occur). In the recent work at the University of Massachusetts, the following environmental conditions were identified as being conducive to Rhizoctonia blight development on creeping bentgrass: relative humidity 95% for a duration of 10 hours; rainfall of 1 inch within 36 hours; minimum air temperature of 59° F; average air temperature of 68° F; minimum soil temperature of 64° F; and average soil temperature of 70°F.

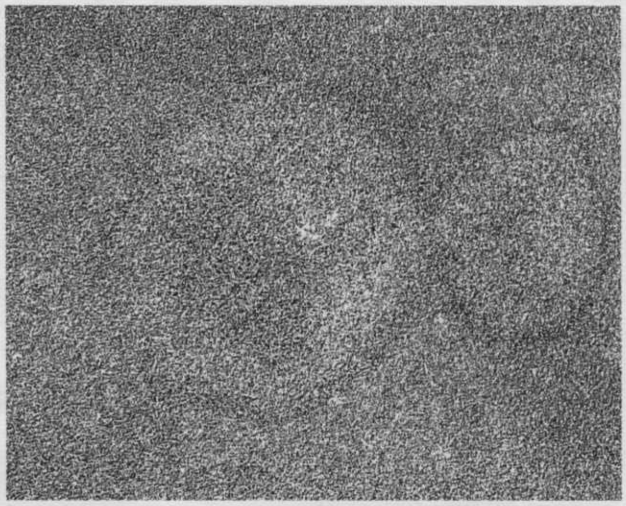

Fig. 2. Note the characteristic "smoke-ring" symptoms of Rhizoctonia blight, commonly observed on closely-mowed putting greens.

These environmental parameters are considered a "model" for predicting the "risk" of a Rhizoctonia blight occurrence. In other words, under those specific environmental conditions, the chance or risk of experiencing a Rhizoctonia blight problem is considered "favorable" or "very-high".

The "model", composed of the set of environmental "rules" listed previously, was evaluated by researchers in Massachusetts, New Jersey, and Georgia for its ability to predict Rhizoctonia blight (5). Disease development was based on increases in blight symptoms, and was predicted with an average of 81% accuracy for all three sites over two seasons. An important attribute was added to this model: a Rhizoctonia blight warning or risk alert was cancelled if air temperatures decreased below 59°F following a favorable disease forecast. As a result, these environmental conditions were incorporated into commercially available weather stations that included Rhizoctonia blight disease prediction programs. Next, researchers in Maryland developed a mathematical method to relate a combination of environmental conditions with Rhizoctonia blight (3).

Rhizoctonia blight warning model: materials and methods. The study site was located at the University of Maryland Turfgrass Research Facility in Silver Spring, MD. Environmental conditions and the occurrence of Rhizoctonia blight were evaluated in a mature stand of perennial ryegrass turf from June 1991 through August 1993. Perennial ryegrass was chosen because of their extensive use as fairways in Maryland and other transition-zone areas, and because perennial ryegrass is extremely susceptible to Rhizoctonia blight.

The environmental conditions were monitored, measured, and recorded with several sensors that were attached to a datalogger. The environmental conditions measured were summarized into 15 variables, and all variables were summarized in a 24-hour interval beginning and ending at 6:00 am. This interval was chosen because the mycelium of R. solani invariably develops in the turfgrass canopy at night (corresponding to hot and humid conditions, especially within the turfgrass canopy). The environmental variables measured were: mean relative humidity; hours of relative humidity >90% or >95%; hours of leaf wetness duration; total rainfall during the 24 or 48 hours prior to 6:00 am; minimum, mean, and average air temperature; minimum, mean, and average soil temperature; mean soil water potential; and mean and maximum solar radiation.

Rhizoctonia blight outbreaks were determined visually by noting the presence of *R. solani* mycelium infecting the turfgrass foliage. The study site was monitored daily between 7:00 and 8:00 am for the presence of foliar mycelium. Whenever mycelium was present, it was confirmed microscopically to ensure it was *R. solani* (Note: a discussion on detecting the R. *solani* pathogen in turfgrasses is included in this issue).

Environmental data and disease outbreak observations were subjected to intense statistical scrutiny (for example, correlation analysis, chi-square analysis, analysis of variance, and multiple regression techniques) to identify key environmental variables or conditions associated with disease development. As a result, it was determined that the best way to relate the many environmental conditions with disease development was through the creation of a "disease favorability index". Therefore, an "environmental favorability index" or "EFI" was developed to provide a warning of Rhizoctonia blight occurrence in turfgrasses.

Through multiple regression analysis of the data, mean relative humidity and minimum air temperature provided the best and simplest model for accurately predicting the EFI, and therefore for providing an accurate Rhizoctonia blight warning. An objective of this research was to develop a disease prediction method that was simple, accurate, and practical. For example, information regarding the length of leaf wetness duration, hours of continuous relative humidity >90%, and rainfall events were helpful to determine the EFI. However, leaf wetness sensors were difficult to calibrate and required a high level of maintenance, which was not considered practical for today's greenskeeper. In another example, the mean relative humidity over a 24-hour period was highly correlated with continuous hours of relative humidity >90% or >95%. Therefore, the mean relative humidity in a 24-hour period could be used to accurately account for those humidity variables measured in this research. Also, air temperature and relative humidity are easy and convenient to measure and record with today's technology in weather stations, or with weather satellite data downloaded to a computer terminal. Therefore, air temperature and relative humidity were the two environmental variables used to develop the EFI for predicting Rhizoctonia blight.

Fig. 3. Commercially-available weather station with built-in pest prediction models or pest alert programs.

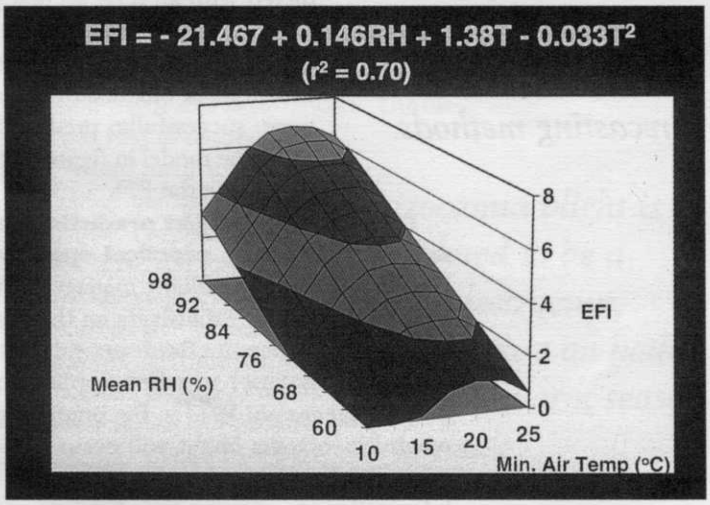

Fig. 4 A three-dimensional representation which depicts how relative humidity and minimum air temperature are related to the development of Rhizoctonia blight in turfgrasses. For example, conditions are favorable for disease development if the mean relative humidity and minimum air temperature combine to form an EFI (environmental favorability index) of >6.

Results of model development

The air temperature and mean relative humidity information were combined to form the EFI (Fig. 4). At first glance, the mathematical equation or model shown in figure 6 may look complicated or intimidating. The mathematical equation is also represented in figure 6 as a three-dimensional picture. Basically, the model is an academic way of showing a relationship between the hot and humid weather conditions that are favorable for Rhizoctonia blight development. The EFI is a simple was to determine a Rhizoctonia blight warning based on the complex relationship between air temperature and relative humidity. For example, an EFI of 6 indicated that the environmental conditions were highly favorable for a disease outbreak. As a result, Rhizoctonia blight outbreaks were predicted with an 85% accuracy over a three-year period. However, all major Rhizoctonia blight outbreaks were successfully predicted using the model in figure 6 to determine the EFI.

Advances in computer technology and the availability of weather information should lead to improved forecasting methods.

A Rhizoctonia blight prediction or warning method: practical applications: Rhizoctonia blight management has focused almost exclusively on the use of fungicides since the Bordeaux mixture ($CuSO4$ plus lime) was first applied to putting greens in 1917. By predicting when Rhizoctonia blight will occur, turfgrass managers may be able to use this information to proper time and target disease management strategies. Therefore, to determine the practicality of the EFI "model" for predicting Rhizoctonia blight, it was tested in a fungicide efficacy study conducted on both perennial ryegrass and colonial bentgrass (3).

In both turfgrass species, there were equal levels of Rhizoctonia blight control in turfgrass plots treated with a fungicide applied when an EFI warning was issued, and in turfgrass plots treated with a fungicide according to a 14-day calendar-based spray schedule. With the EFI-based spray schedule, however, there were five fungicide applications made during the summer months versus seven with the calendar-based spray schedule. In this one year field trial, using weather-based information to predict Rhizoctonia blight and guide fungicide spray decisions resulted in a reduction in the number of fungicide applications without compromising disease control. A weather-based disease prediction method may help reduce fungicide sprays during certain years, however, more fungicide sprays may be called for in high disease pressure years (Note: a list of fungicides commonly used for Rhizoctonia blight management is included in this issue).

For a Rhizoctonia blight outbreak to occur, there must be a continuous interaction between the turfgrass host and the environment, where the environmental conditions favor the *R. solani* pathogen's growth and development over that of the susceptible turfgrass host. For turfgrass disease management, knowledge of the pathogen, environment, and host are critical to implementing successful control strategies and programs. A key component with Rhizoctonia blight management in turfgasses is to utilize cultural practices that promote healthy and vigorous turf and thereby reduce disease severity. Also, proper timing and targeting of fungicide applications can be achieved through the use of weather-based disease prediction models and methods.

Advances in computer technology and the availability of weather information (for example, satellite imagery of regional and local weather patterns) should lead to improved disease forecasting methods. Satellite imagery also will be useful for enhancing the precise delivery of fungicides, biological agents, and other materials for enhancing turfgrass quality and managing turfgrass diseases. Future research will focus on both new technology and traditional approaches for improving turfgrass disease management programs.

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Rhizoctonia blight disease in turfgrasses, described

The soil-inhabiting fungus, *Rhizoctonia solani*, is responsible for causing numerous diseases of plants worldwide and under diverse environmental and ecological conditions. Historically, a French mycologist, De Candolle, first described the genus Rhizoctonia in 1815. However, a German mycologist, Kuhn, is credited with naming the fungus because of his early work on the ability of R. solani to cause disease on cultivated plants. Today, *R. solani* is pathogenic to over 200 grass species worldwide and is the causal agent for Rhizoctonia blight (formerly called "brown patch") in turfgrasses.

Fig. 1. Mycelium of Rhizoctonia solani, the causal agent of Rhizoctonia blight, infecting perennial ryegrass. This is referred to as a "sign" of the pathogen.

Rhizoctonia blight is considered to be a highly destructive, foliar disease on both cool- and warm-season turfgrasses. The disease was first described from observations made in 1913 on a creeping bentgrass putting green near Philadelphia, PA. At that time, the disease was named "brown patch", however, turfgrass pathologists recently changed the name to Rhizoctonia blight. Further observations on Rhizoctonia blight were recorded from field work conducted by U.S.D.A. scientists in the 1920's and 1930's. These early investigations led to the development of the science of turfgrass pathology and turfgrass disease management.

Rhizoctonia blight is considered to be a highly destructive, foliar disease on both cool- and warm-season turfgrasses.

The biology and lifecycle of R. solani as a turfgrass pathogen is well documented. The fungus survives as thick-walled mycelial masses during periods when environmental conditions are unfavorable for fungal growth. These mycelial masses are called sclerotia or bulbils, and they

Fig. 2 With Rhizoctonia blight, leaf lesions are commonly observed on wide blade turfgrass such as tall fescue.

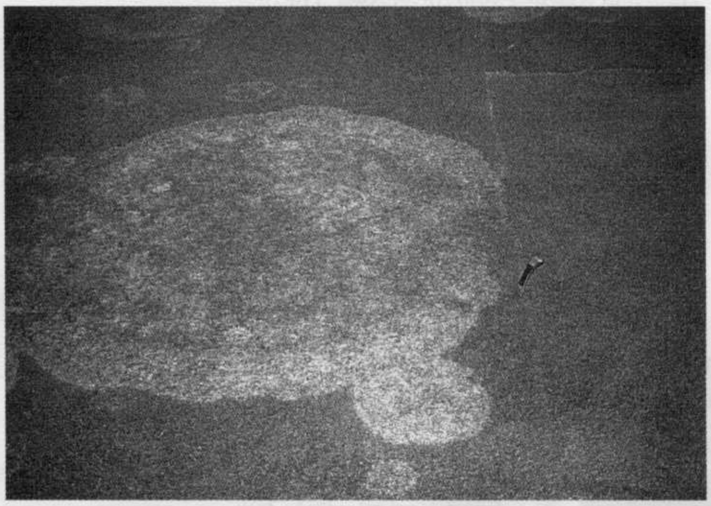

Fig. 3. A circular ring of blighted turfgrass, which is a characteristic symptom of Rhizoctonia blight on a bentgrass putting green.

reside in the upper layers of soil, thatch, and plant debris. The bulbils are very difficult to see with the naked eye. They may germinate over a temperature range of 45 to 105°F, with an optimum germination temperature of about 80oF.

The optimum temperature for infection and disease development varies among turfgrass species and Rhizoctonia biotypes (referred to as "anastamosis groups"). The fungus is capable of saprophytic growth in soil – meaning that the fungus can survive from dead, decaying organic matter. When the bulbils germinate, the fungus spreads radially in the upper soil surface or thatch to form a roughly circular colony.

During warm, moist and humid conditions, typically from late spring through late summer, the fungus can spread over the soil and up onto moist turfgrass sheaths and leaves. Gray- to white-colored fungal mycelium form an infection cushion, which penetrate the leaf tissue causing cell contents to ooze-out into intercellular spaces. Visual observations of the fungal mycelium infecting the turfgrass are referred to as a "sign" of the fungal pathogen (figure 1). Infected leaf tissue appears water-soaked and darkened. Turfgrass leaves then wilt and turn brown upon exposure to sunlight or a drying wind. When plant tissues decompose, bulbils can form again on or in dead tissues, and are released into the thatch and soil.

Rhizoctonia blight symptoms vary depending on turfgrass species and cultivar, level of turfgrass maintenance, soil and environmental conditions, and Rhizoctonia biotype. Infected turfgrass will display roughly circular patches of blighted and necrotic foliar tissue. Tan lesions with dark borders, where necrotic and green tissue meet, are sometimes evident on diseased leaves (Fig. 2).

In cool-season turfgrasses, Rhizoctonia blight is favored by periods of warm, humid, and moist environmental conditions. On closely mowed cool-season turfgrasses (for example, a bentgrass putting green or fairway height turfgrass), circular or irregular-shaped patches of blighted turfgrass are commonly observed (Fig. 3). A darkened, grayish-black border at the patch margin is called a "smoke-ring", and may be evident during the early morning hours. The "smoke-ring" is a sign that reveals the presence of mycelium actively infecting the leaf tissue, as indicated by water-soaking of leaves on closer, visual inspection (Fig4). On high-cut cool-season turfgrasses (for example, the fine fescues, Kentucky bluegrass, perennial ryegrass, and tall fescue), a light brown, circular patch of blighted leaf tissue is the primary symptom and patches often appear without a "smoke-ring" (Fig. 5). Leaf lesions are easily detected on wide leaf blades (for example, tall fescue), and often fungal mycelium can be observed covering wet leaves during the early morning hours.

On warm-season turfgrasses (for example, bermudagrass, centipedegrass, St. Augustinegrass, and zoysiagrass), blighted patches commonly are observed in the spring when these grasses break dormancy, or in the fall as they approach dormancy. Leaf sheath and basal rots are associated with Rhizoctonia blight in warm-season grasses.

Fig. 4. Notice the Rhizoctonia solani mycelium active on the patch margins in this fairway height perennial ryegrass.

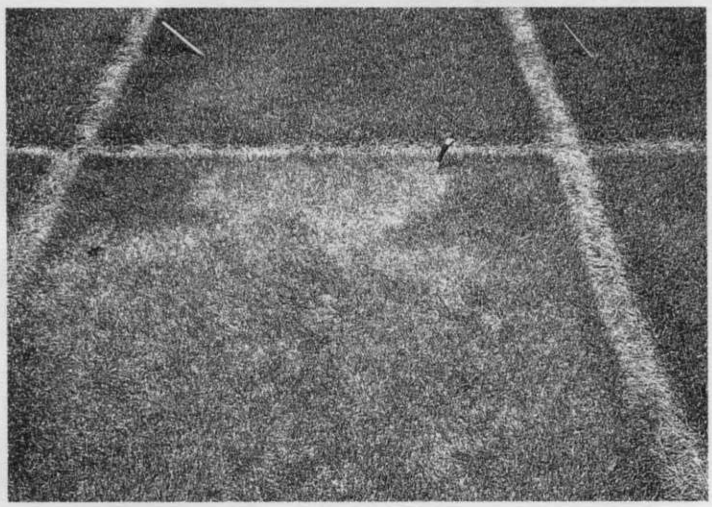

Fig. 5. Rhizoctonia blight symptoms observed on Kentucky bluegrass.

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TurfGrass TRENDS website ready soon

TurfGrass TRENDS will soon have a presence on the world-wide-web, at *www.landscapegroup.com*. The TGT website will contain abstracts of TurfGrass TRENDS articles, with links to other key Green Industry websites and information libraries.

The site, whichis currently under construction, will also contain articles and information originally published in LANDSCAPE MANAGEMENT and *Athletic Turf Maintenance & Technology*, which, along with TurfGrass TRENDS, make up the Advanstar Communications, Inc. Landscape Group of publications.

Detecting Rhizoctonia solani pathogen in turfgrass

Traditional plant disease diagnosis often depends on visual symptoms of necrotic plant tissue, visual signs or evidence of the fungal pathogen and the environmental conditions observed during disease development. This method relies on the principles represented by the "plant disease triangle" in figure 1.

In order for a plant disease to occur, the pathogen must be present and have a viable host to infect and colonize, and the environmental conditions must favor the growth and development of the pathogen over the host. The plant pathologist must rely on "detective-like" skills to piece the pathogen-host environment information together and properly diagnose the plant disease.

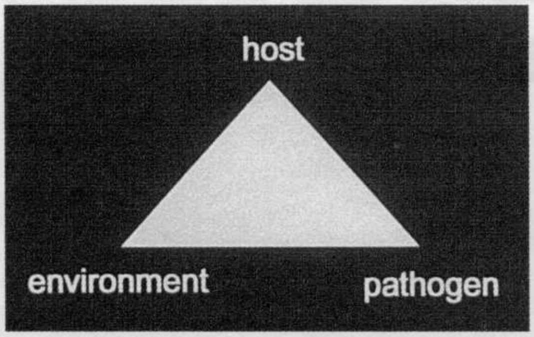

Fig.1 Plant disease triangle represents the plant host/pathogen/environment relationship and its importance in disease development.

Fig.2 Rhizoctonica solani, the causal agent for Rhizoctonia blight, shown under 400x magnification. Notice the "right angle" branching useful in distinguishing this pathogen from others that cause diseases among turfgrasses.

Ideally, the best way to identify Rhizoctonia solani, the causal agent of Rhizoctonia blight (formerly called "brown patch") in turfgrasses, is with the aid of a microscope. Through a microscope lens, R. solani is differentiated from other turfgrass fungal pathogens by many traits, including characteristic "right angle" branching of the hyphae (Fig. 2). In this decade, advances in molecular biology have led to the identification and development of antibodies that are useful for detecting specific proteins or nucleic acids of plant pathogens. As a result, enzyme-linked immunosorbent assay (ELISA) methods were developed for plant pathogen detection and plant disease diagnosis (1,3,4). Currently, ELISA-based turfgrass disease detection kits are commercially available for identifying Rhizoctonia solani, Sclerotinia homoecarpa (causal agent for dollar spot) and Pythium spp. (causal agent for Pythium blight). In turfgrasses, diseased or necrotic tissue is sampled and processed in only a few minutes with an ELISA test-kit, then confirmation of the pathogen can be quickly determined. This procedure is fast and easy, and can be conducted on the back of a golf cart, or diseased samples can be taken back to the greenkeeper's office for an ELISA test.

A recent field study conducted in Massachusetts on Rhizoctonia blight showed that the number of fungicide applications could be reduced and acceptable disease control achieved by combining weather - based disease forecasts with ELISA-based confirmation of the pathogen. (5)

In a Maryland study, perennial ryegrass was assayed specifically for *R. solani* (2). In that study, the pathogen detection was influenced by the sampling time-of-day and mowing height. The *R. solani* populations assayed from the leaf tissues were detected

LIST OF FUNGICIDES COMMONLY USED FOR RHIZOCTONIA BLIGHT (FORMERLY CALLED "BROWN PATCH") MANAGEMENT IN TURFGRASSES1,2

Chemical Class	Contact[3] / Penetrant[4]	Common Name	Trade Name
Benzamide (also referred to as Carboximide)	penetrant[4a]	flutalonil	ProStar
Benzimidazole	penetrant[4a]	thiophanate-ethyl thiophanate-methyl	Cleary's 3336 Fungo 50
Dicarboximide	penetrant[4b]	iprodione vinclozolin	Chipco 26019 Curalan, Touche
Ergosterol Inhibitors (also referred to as	penetrant[4c]	propiconazole cyproconazole	Banner Sentinel
'DMI' or demethylation inhibitors)	mycobutanil	Eagle	
Ethylenebis-dithiocarbamate	contact	mancozeb	Fore, Dithane M-45
Strobilurin (also referred to as Beta-methoxyacrylates)	penetrant[4a]	azoxystrobin	Heritage
Substituted Aromatic Hydrocarbon	contact	chlorothalonil quintozene	Daconil, Thalonil PCNB, Terraclor

[1]No endorsement of named products is intended, nor is criticism for products that are not mentioned.

[2]List compiled from the following sources:

- Couch, H.B. 1995. Diseases of turfgrasses, Kreiger Publishing Company, Malabar, FL.
- Vargas, J.M. 1994. Management of turfgrass diseases. CRC Press, Boca Raton, FL
- Watschke, T.L., P.H. Dernoeden, and D.J. Shetlar. 1995. Managing turfgrass pests. CRC Press, Boca Raton, FL.

[3]Contact: fungicide active on leaf and sheath surfaces.

[4]Penetrant: fungicide is absorbed and can provide activity both on the outside and inside of plant tissues.

(4a – movement in plants is primarily upward)

(4b – limited movement in plants, considered a local penetrant)

(4c – movement in plants is primarily upward, with limited downward movement)

at greater intensity when sampled in the early morning compared to the late afternoon. Also, higher *R. solani* populations assayed from the leaf tissues were detected at greater intensity when sampled in the early morning compared to the late afternoon. Finally, higher *R. solani* population levels were detected from turfgrass mowed at a height of 2.0 inches compared to 0.66 inches.

The ELISA method is a helpful tool that turfgrass managers can use for determining if infected leaf tissue is colonized by the fungal pathogens *R. solani*, *Pythium spp.* or *Sclerotinia homoeocarpa* (2,6). This is particularly helpful in the hot and humid summer months, when diseased turfgrass can exhibit similar symptoms between Rhizoctonia blight (Fig. 3) and Pythium blight, and even dollar spot.

Fig.3 Symptoms of Rhizoctonia blight: necrotic and blighted tall fescue leaf tissue.

Proper diagnosis is critical to turfgrass disease management, especially when considering the use of a fungicide. For example, if a turfgrass manager misidentifies Pythium blight as Rhizoctonia blight, and then applies ProStar (a fungicide specifically targeted to the Basidiomycete fungal group, to which the *Rhizoctonia spp*. belong), the Pythium blight actually infecting the turfgrass will not be controlled.

Also, the fungal mycelium that is observed colonizing the leaf tissue can help in identifying which fungal pathogen is responsible for causing the disease. when environmental conditions are conducive to disease development, the best time to see the mycelium infecting turfgrass is in the early morning hours in the presence of dew or high relative humidity conditions. Even the best plant pathologist will not diagnose the fungal mycelium from a visual observation with the naked eye, but will want to confirm the identity of the fungus under the microscope. For example, the color of the mycelium infecting the turfgrass of Rhizoctonia can range from gray to white (Fig. 4) and Pythium and Sclerotinia can range from white to a "cottony-white" appearance. Therefore, testing an infected turfgrass sample with the ELISA method will help confirm which pathogen is causing the disease.

Fig.4 The actual sign of the fungal pathogen—mycelium of Rhizoctonia solani—colonizing and infecting perennial ryegrass.

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Simulated traffic on turfgrass topdressed with crumb rubber

By John N. Rogers III, J. Timothy Vanini and James R. Crum

Topdressing performs many functions in enhancing the turfgrass environment. Benefits include thatch control, a smoother surface, modified surface soil and winter protection.(1)

Goss defined topdressing as a surface application of any growth medium intended to perform on or more of the following functions: correct uneven putting surfaces; develop firmer, drier surfaces; increase infiltration rates of water; help relieve hard, compacted surfaces; increase air porosity (noncapillary pore space); aid thatch decomposition; prevent surface puddling; provide cover for overseeding; supply nutrients and modify topsoils.

Putting greens and sports fields benefit from topdressing primarily because they are high-traffic areas and a smooth and uniform playing surface is essential. Topdressing has been called the most important practice under high-traffic conditions (3) due to the aforementioned qualities. Davis in 1983 reported that sports fields tend to become heavily trafficked and the need for heavy topdressing was important. (4)

In sports such as football and soccer, however, by mid season the most intensively worn areas are often past the point of repair in terms of turf regeneration, and topdressing will generally not alleviate the problem. Sand is a popular choice for topdressing material, but it is abrasive and can lead to scarification of the plant. Gibeault found that topdressing applied too frequently and/or at heavy rates can produce a hard layer that is abrasive to the turfgrass plant (5). The abrasive action of sand can be detrimental to turfgrass if the plant is weak and not actively growing, or is in areas under low light conditions (i.e., shade) and with subsequently reduced growing and recuperative conditions. This effect is magnified on high- to medium-use sports fields. In the absence of turf, the playing quality and aesthetics are dramatically reduced by sand topdressing, which can ultimately lead to player injuries (6,7,8).

Ball roll and ball bounce can be directly influenced by the smoothness and resiliency of the playing surface (9).

The crown tissue of the turfgrass plant is the area where leaves, roots, stolons and/or rhizomes regenerate. Damage to the crown tissue can adversely affect growth and regeneration. Thurman and Pokorny found that damage to the crown tissue in Bermudagrass [Cynodon dactylon (L) Pers.cv. Tifgreen] was proportional to the intensity of the traffic applied. (10)

Shearman and Beard were able to quantify wear tolerance among seven species of cool-season grasses, citing verdure (% cover) as the preferred method to quantitatively assess wear tolerance. (11)

Ward investigated the use of chipped tires (1-6mm) as a soil amendment for improving turfgrass areas, but did not include crumb rubber as a topdressing material (12). Rogers et al. also reported on the use of crumb rubber amended into the soil profile (13).

Our objective was to investigate the use of crumb rubber from recycled tires as a topdressing into turfgrass under simulated athletic field traffic. Our hypothesis was that, by reducing surface hardness and decreasing the susceptibility of wear injury and turfgrass abrasion with the use of crumb rubber topdressing, the playing field would be improved in playability and turfgrass quality, potentially reducing surface-related injuries.

Materials and methods

Experiments were conducted at the Hancock Turfgrass Research Center at Michigan State University, East Lansing, Mich., July 29, 1993. Crumb rubber was topdressed in a 2x5 factorial randomized complete block design with three replications on an 80% sand/20% peat (v/v) soil. Particle size in the rootzone was primarily coarse to medium (1.0-0.25 mm particle size; see Table 1).

Plot sizes were 3.0 by 3.6 m. Two crumb rubber sizes were evaluated: the large size had 93.3% of particles between 2.0 and 6.0 mm in diameter and the small size had 79.3% of particles between 2.0 and 0.25 mm (Table 1). The five crumb rubber topdressing rates were 0.0, 17.1, 34.2, 44.1 and 88.2 t ha -1.

The corresponding depth for these rates are: 0.0; 3.8; 7.6; 9.5; and 19.1 mm.

A crumb rubber bulk density of 0.48 g cm -3 was used to make this conversion.

Each rate was split into three applications made on July 29, September 11 and October 5 , 1993. Crumb rubber was topdressed with a rotary spreader and raked for as even distribution as possible on a one-year old turfgrass stand seeded with 85% Kentucky bluegrass (Poa pratensis L.cv. Argyle, Rugby and Midnight) and 15% perennial ryegrass (Lolium perenne L. cv. Dandy, Target and Delray).

The plots were mowed three times per week at a height of 38 mm, with clippings returned, using a Ransomes triplex mower in 1993 and a Toro rotary deck mower (1.5 m deck) in 1994. Irrigation was applied to insure turfgrass was actively growing.

Turf was fertilized with 49 kg N ha-1 (25-0-25/N-P-K) in May, June, July, August and October of 1993 and 1994, for a total of 245 kg N ha-1.

Simulated traffic was applied across plots with the Brinkman traffic simulator (12). The simulator weighs 336 kg and has two heavy, studded rollers geared to move at different speeds and impose both compactive and tearing forces on the turf. Traffic was applied from August 26 to November 14 in 1993 and from September 5 to November 15 in 1994. Eight to 10 passes were made per week in twice-weekly applications, for a total of 96 passes. On May 16, 1994, areas trafficked within plots were slit-seeded with Dandy perennial ryegrass at 53.9 kg ha-1.

Surface data was collected in 1993 and 1994. Data included: surface hardness; impact absorption characteristics, peak deceleration and impact duration, surface and soil temperatures and ball bounce measurements using a FIFA soccer ball.

Clipping yields and turf cover ratings were also recorded.

Results and discussion

In 1993 there were no statistically significant differences in peak deceleration values between crumb rubber sizes, except on September 20. There were significant differences in peak deceleration among crumb rubber rates in 1993 (Table 1). Peak deceleration values were 10 to 20% lower than the control at the highest crumb rubber rate (88.2 t ha-1, 19.1 mm).

In 1994 there were no significant differences in peak deceleration values between crumb rubber sizes. There were also no significant differences among crumb rubber rates, except on December 30, 1994. One possible explanation for the lack of peak deceleration value differences in 1994 is that the crumb rubber particles were more fully integrated into the turf surface after a year. there was no additional topdressing in 1994 and it is assumed that the crumb rubber fully settled into the turf surface. (Peak deceleration is the measure of the impact energy absorbed by the surface. The higher the peak deceleration value the more energy being returned to the object contacting the surface, or the harder the surface.)

For all dates in 1993 and 1994, shear resistance values for the turfgrass topdressed with the small crumb rubber size were higher than the larger crumb rubber size. Three of these dates were statistically significant. There were significant differences among crumb rubber rates for every testing date.

In 1993, as crumb rubber rates increased, shear vane values decreased by as much as 40% less than the control plots, a potential indication of poor footing, as lower shear vane values have been associated with poor field conditions (15).

In 1994 however, as crumb rubber rates increased, the trend of 1993 was reversed and shear vane values increased up to 10 to

TABLE 1. EFFECTS OF CRUMB RUBBER PARTICLE SIZE AND TOPDRESSING RATE ON PEAK DECELERATION (G-MAX) ON A TRAFFICKED KENTUCKY BLUEGRASS/PERENNIAL RYEGRASS STAND, EAST LANSING, MI

	GMAX						
	1993			1994			
Treatment	Sept. 20‡	Oct. 22	Dec. 3	Sept. 15	Oct. 17	Nov.10	Dec. 30
	g						
Rate, t ha^{-1}							
0	71	69	67	66	67	58	193
17.1	70	72	72	68	70	60	160
34.2	72	71	73	67	71	62	136
44.1	68	66	70	67	69	61	114
88.2	63	56	60	63	68	62	78
LSD (0.05)	**3**	**3**	**5**	**NS**	**NS**	**NS**	**18**
Particle size							
large (2-6 mm)	67*	67	68	66	69	60	139
small (2.0-0.05 mm)	70	67	69	67	69	62	133
	Soil water, kg kg $^{-1}$						
	0.174	0.218	0.202	0.163	0.121	0.123	0.132

*Significant at the 0.05 probability level.
‡ On Sept. 20 1993, crumb rubber rates were 0.67 times the listed rate

20% over the control plots. In 1993, crumb rubber particles were still in and around the turf canopy and still had not reached the soil surface. After a full growing season, the crumb rubber particles had reached the soil surface. The assumption is that the wide range of particle sizes of crumb rubber (especially with the small crumb rubber size) offered additional strength. Those subjecting turfgrass to heavy traffic after topdressing with crumb rubber should be aware of this phenomenon. Although not statistically significant in this study, small rubber particles should be considered under these conditions.

The differences in soil temperatures provided by crumb rubber sizes were minimal in this study and there were no consistent trends regarding differences among crumb rubber rates. Surface temperatures were not affected by crumb rubber size. As crumb rubber rates increased from 0.0 to 88.1 t ha-1 in October 1993 and 1994 there was a 2° C increase in surface temperature. This could be significant in terms of providing a favorable growing environment for turfgrass in early spring and late fall in cool regions, a dilemma for turf managers of fields used for season specific sports. Conversely, in other experiments the authors have noticed adverse effects with crumb rubber in terms of surface temperatures, particularly with spring seedings.

This study was trafficked to simulate fall athletic field wear, so summer stress from crumb rubber was not noted as the turf canopy moderated surface temperatures.

Nutrient analysis was done on clippings taken on October 2, 1993 and April 20, 1994. In 1993, there were no significant differences in nutrient concentrations of clippings between particle sizes or rates treatments except for Cu, with levels directly related to rubber rates. In 1994, there were no significant differences between particle sizes, nor among crumb rubber treatments, for any nutrient tested.

Summary

Our results suggest that crumb rubber from used tires has the potential to alter surface characteristics and subsequently increase wear tolerance of turfgrass exposed to traffic. These positive effects were best noted at rates of 44.1 and 88.2 t ha-1. It is likely that the best crumb rubber rate for cutting heights above 18mm is between these two values, perhaps 60 t ha-1. The small size was more effective than the large size immediately after application, and therefore it appears the size of the rubber is critical if utility of the area under traffic is immediate. Shearing values the first season after applications were low before the crumb rubber worked down to the turf surface.

The effectiveness of crumb rubber appeared to increase as growing conditions became suboptimal. One possible explanation is that the rubber particles are generally non abrasive.

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Rhizoctonia control in the field

Yellow patch on fairways is one disease that breaks through the earliest, says Dan Dinelli, CGCS at North Shore CC, Glenview, Ill. A progressive superintendent, Dinellli has been experimenting with biological disease control.

Dinelli is trying mono-sacharide sugars as a biostimulant, with BioJect and compost teas mixed in-house through the irrigation system.

"It seems like these simple sugars may actually promote *Rhizoctonia cerealis*," suggests Dinelli. "It seems like when we do inject the sugar cane molasses, our cool-weather brown patch gets worse. (We were hoping we could inject the food source for the microorganisms that we're trying to deliver through the irrigation system side-by-side hoping that they would proliferate.)

"We picked the molasses because it's an inexpensive sugar source. It just seems that for Rhizoctonia it's not working quite as well as we had hoped."

Dinelli cautions others that it's still too early to tell if sugars promote the disease, and it would be premature to make any hard decisions based on his as yet limited observations.

During warm weather, Dinelli's Metos weather station offers three disease forecasting models, one of which is for brown patch, which gives him notice on when to start scouting for Rhizoctonia solani.

For curative control of fairway brown patch, Dinelli uses ProStar, Thiram and Daconil.

"The preventive program is still biological. We've tried to go strictly curative for fairway brown patch."

Greens at North Shore are on a traditional preventive disease control program.

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