Early detection of turf disease through direct sensing

The human eye gets some assistance in discovering the first signs of disease in turf.

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High humidity often combined with high temperatures makes the Midwest a prime environment for turfgrass disease. Unless golf courses are located in open areas where prairie winds provide almost continual air movement, disease is often one of the biggest challenges superintendents face. While scouting and treating for turf diseases is time consuming, it is an essential part of turf maintenance. Even a brief delay can result in major turf damage.

Pythium blight (*Pythium aphanidermatum* (Edson) Fitzpatrick) is a disease that spreads rapidly and can cause extensive turf loss. Another important disease of turf, brown patch (*Rhizoctonia solani* Kuhn), progresses more slowly, allowing the superintendent more time to react.

Direct sensing, a method of measuring radiation (light) reflected from plant foliage at specific wavelengths, may be useful for early detection of such diseases. For example, disease may cause changes in pigment concentration and variations in canopy gas exchange, leading to differences in color and temperature that can alter canopy reflectance characteristics (2).

In previous research, the normalized difference vegetation index (NDVI), an equation that combines reflectance measured in the red and near-infrared portions of the electromagnetic spectrum, was used to measure nitrogen responses in a Penncross creeping bentgrass (*Agrostis palustris*) canopy four days before differences in turf quality were visible and eight days before differences in turf density became visible (3).

Researchers induced herbicide injury to a Tifway bermudagrass turf and measured differences in NDVI 24 hours before there were visible differences in turf quality and color and three days before differences in turf density ratings were visible (3). In 1996, differences in the ratio of reflectance measured in the red and far-red portions of the electromagnetic spectrum occurred 16 days before visible symptoms of herbicide-induced stress in loblolly pine (*Pinus taeda* L.) tree canopies (1). The ability to detect turfgrass disease before loss of visual quality would give superintendents more time to evaluate turf stands and schedule chemical applications. This "advance notice" might also reduce the amount of preventive chemical applications used in turf maintenance.

The objective of this study is to determine whether differences in spectral qualities measured from a creeping bentgrass canopy inoculated with fungal mycelium occur before the onset of visible symptoms or signs of disease.

Methods and materials

Experimental design

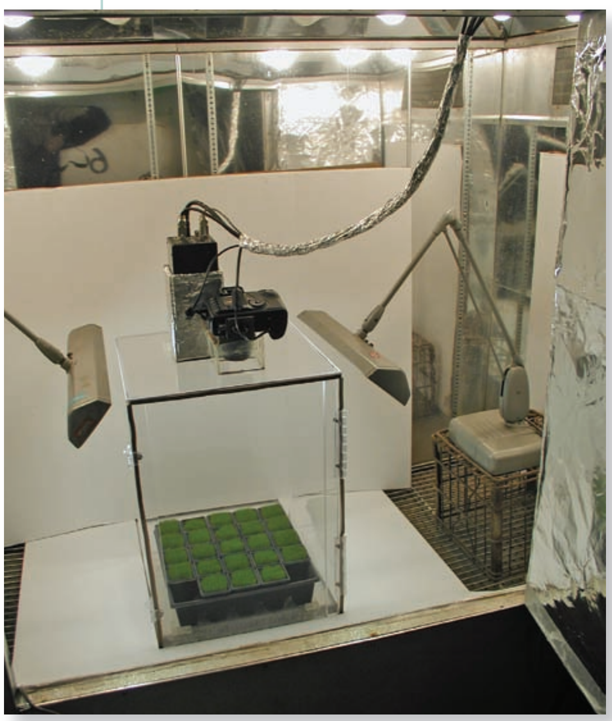
Four growth chamber experiments were conducted on the University of Illinois Urbana-Champaign campus in 2004. Pythium blight experiments started on May 10 (pythium blight 1) and May 20 (pythium blight 2) and lasted less than 48 hours. Brown patch experiments began on June 24 (brown patch 1) and Aug. 16 (brown patch 2) and lasted less than 72 hours. The experimental design for each experiment was completely randomized with two treatments and 15 replications per treatment.

Turfgrass culture

Plastic cones measuring 1.0 inch (2.5 centimeters) in diameter and 6.3 inches (16 centimeters) deep were filled with sterile vermiculite media to roughly 1.0 inch (2.5 centimeters) below the rim of each cone. Approximately 0.055 gram of A-4 creeping bentgrass seed was spread on the surface of the vermiculite in each cone. The cones were then placed on a greenhouse mist bench that applied a mist of water for 15 seconds every 10 minutes. The creeping bentgrass established a dense canopy in 10 to 14 days, and the grass was 12 days old when the experiments were started.

Inoculum production and application

Potato dextrose broth, a medium for culturing fungal inoculum, was prepared and inoculated with 25 squares (0.5 × 0.5 centimeter) of agar containing the mycelium of *P. aphanidermatum* or *R. solani*. Fungal mycelium was allowed to grow in the potato dextrose broth for seven days. The mycelium was then separated from the potato dextrose broth, blended for 30 seconds with 1,000 milliliters of sterile deionized water, and filtered twice through cheesecloth to produce a useable inoculum with consistently sized fragments of mycelium. Half of the inoculum was autoclaved for 20 minutes to kill the mycelium, cooled to room temperature and used to treat the control replications. Three hundred milliliters of live mycelia fragments were sprayed onto the foliage of 15 cones containing creeping bentgrass, and 300 milliliters of sterilized mycelia fragments were sprayed onto the foliage of another 15 cones containing creeping bentgrass.



Above: The Plexiglas humidor is contained in a growth chamber. Image-capturing devices are mounted 15 inches (38 centimeters) above the grass canopies and capture images simultaneously throughout the experiments. **Photo by T. Fermanian**

Above right: A prototype of a device that uses digital images to detect difference in turf quality in the field. **Photo by Z. Anderson**

Growth chamber conditions

Experiments were conducted in a growth chamber with continuous lighting, average temperature of 95 F (35 C) and 93% relative humidity. Inside the growth chamber a water-tight, colorless Plexiglas structure served to create environmental conditions necessary for disease development. The Plexiglas structure contained the cones of creeping bentgrass, black and white tiles for calibration, water-soaked paper towels for humidity and a data logger with a light sensor.

Imaging sensors

Two imaging sensors mounted on top of the Plexiglas structure acquired radiation reflection measurements from 15 inches (38 centimeters) above the creeping bentgrass plants. The sensors collected reflectance in the green, red and near-infrared electromagnetic spectrum regions. NDVI, computed as (near-infrared – red)/(near-infrared + red), is the only data presented in this article.

A standard Canon EOS 10 D digital camera captured full-color JPEG (jpg) formatted images with a resolution of 3,078(H) × 2,048(V) pixels to make visual ratings of disease. This camera measures spectral energy from the blue, green and red portions of the electromagnetic spectrum.

Both imaging sensors and the cones of creeping bentgrass were fixed to prevent movement during experiments. Each sensor collected and saved an image of the creeping bentgrass every 10 minutes during the pythium experiments and every 30 minutes during the brown patch experiments. Experiments ended once disease became clearly visible.

Image processing and data analysis

Image Pro Plus software was used to analyze the images. Because each camera is filtered to measure three separate areas of the spectrum, a total of six data points were generated per replication per image. These values can be used in various indices and ratios, but for simplicity, only the NDVI index generated from the DT 3100 sensor data and the green/red ratio generated from the Canon EOS 10 D sensor data will be discussed in this article.

Statistical difference between treatments was determined at a probability level of ≤0.05.

Visual disease assessments

In the study, visibly assessing disease development would mean checking the turf every 10 to 30 minutes for up to 72 hours, an almost impossible task. Digitally photographing the turf with the Canon EOS 10 D at the same time the scanning was done provided an accurate record and eliminated the need to visually check the turf so frequently. The images were used to visually rate the creeping bentgrass cones for visible symptoms

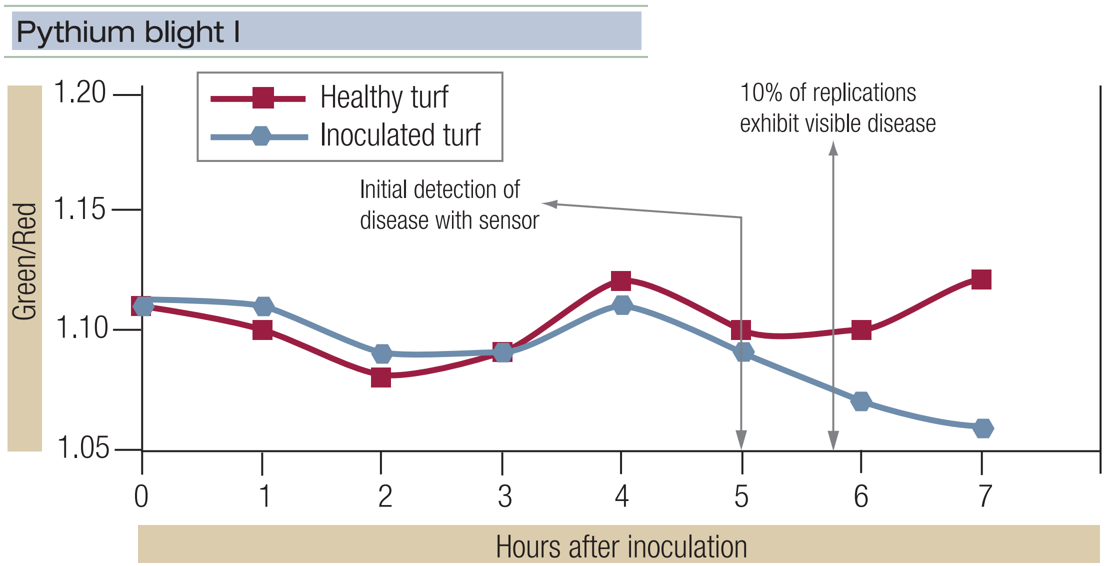


Figure 1. Time-scale graph of pythium blight detection in A-4 creeping bentgrass in the pythium blight 1 experiment. Statistical difference between treatments was determined at a probability level of ≤ 0.05.

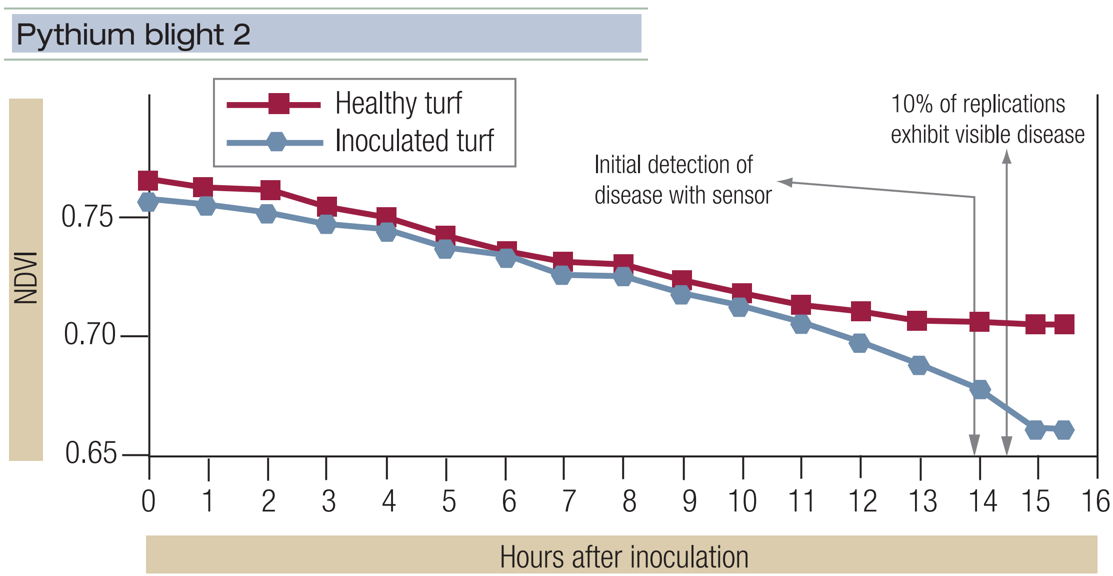


Figure 2. Time-scale graph of pythium blight detection in A-4 creeping bentgrass in the pythium blight 2 experiment. NDVI, normalized difference vegetation index. Statistical difference was figured at a probability level of ≤ 0.05.

Disease detection time

Detection method	Disease assay experiment (hours after inoculation)			
	Pythium blight 1	Pythium blight 2	Brown patch 1	Brown patch 2
Visible evidence†	5.9	14.2	66.0	50.0
NDVI‡	5.1	13.5	46.0	47.0
Green/Red§	5.2	11.4	52.0	41.0

†Detection of disease occurred once 10% of the replicaitons exhibited visible disease.
‡Normalized Difference Vegetation Index = (near-infrared – red)/(near-infrared + red).
§Canon EOS 10 D green/red ratio.

Table 1. Number of hours after inoculation when disease in A-4 creeping bentgrass foliage was first detected by human evaluation (visible evidence), NDVI and the green/red ratio in four experiments.

or signs of disease. The earliest visible detection of disease was declared once 10% of the cones exhibited disease symptoms (color changes in the grass canopy) and/or signs.

Results

Early detection of pythium blight and brown patch occurred in each experiment using NDVI and green/red measurements (Table 1, Figures 1, 2). In each experiment, differences in NDVI occurred 50 minutes (pythium blight 1), 40 minutes (pythium blight 2), 20 hours (brown patch 1) and 3 hours (brown patch 2) before visual detection of disease symptoms in the A-4 creeping bentgrass canopy. Differences in the green/red ratio occurred 45 minutes (pythium blight 1), 170 minutes (pythium blight 2), 14 hours (brown patch 1) and 9 hours (brown patch 2) before visual detection of disease symptoms or signs in the A-4 creeping bentgrass canopy.

Discussion

Direct sensing of A-4 creeping bentgrass foliage with the image sensors and Canon EOS digital camera produced measurable differences in NDVI and green/red ratio before visual ratings indicated changes in the grass color or the presence of disease signs in 10% of the replications. We would expect it to take longer in the field for disease to be detected by traditional scouting methods because this study was done under ideal disease development conditions, the turf area was very small and well-trained individuals were observing the plants. These results support those found by other researchers (1,3), who measured a change in plant responses in the field using NDVI and a reflectance ratio days before changes were seen in visual turf ratings of quality, color and density.

Although no system currently exists for implementing the sensing process in the field, the implications of the study are positive for large turf sites. What is even more interesting is that a high-resolution standard digital camera can be a useful tool for early and nondestructive detection of disease in A-4 creeping bentgrass turf. The standard digital camera is relatively inexpensive, readily available, easy to service, and requires little controlling hardware and software, making it simple to use.

Superintendents can benefit if a system is developed to use the sensing process to detect disease before it can be seen by visual scouting, and allow superintendents to incorporate rapid response into their maintenance program.

The research says

➔ Even a brief delay in scouting and treating for turf diseases can result in major turf damage.

➔ Direct sensing, a method to measure radiation (light) reflected from plant foliage at specific wavelengths, may be useful for early detection of turf disease.

➔ Early detection of pythium blight and brown patch occurred in each experiment using NDVI and Canon green/red measurements.

➔ A high-resolution standard digital camera can be a useful tool for early and nondestructive detection of disease in A-4 creeping bentgrass turf.

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