Current Status of U.S. Turfgrass Pathology Research

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Turfgrass pathology has played a critical role in successful turfgrass management over the years. Yet, many believe turfgrass pathology to be a secondary discipline, with breeding and agronomic aspect of turfgrass science being the most applicable and important to turfgrass management. Certainly, without the many scientific achievements of turfgrass pathologists, the management of golf turf at the level it is managed today would not be possible.

My intent with this article is to provide a broad overview of turfgrass pathology from its early beginnings to the present. My hope is that it will provide readers with a better appreciation of the accomplishments and contributions of turfgrass pathologists today as well as where research in this field is heading.

Historical Development of Turfgrass Pathology

To understand the current stature of turfgrass pathology research in the United States, one has to look back at the evolution of the discipline and the forces that have shaped the science over the past 100 years. Developments in both Europe and the U.S. have had major influences on the field. Although the roots of turfgrass pathology can be traced to Europe as far back as the 16th century, it is the late 1800s that clearly mark the beginnings of turfgrass pathology as a distinct scientific discipline in the United States.

A number of major developments in both plant pathology and turfgrass culture have had monumental effects on the science of turfgrass pathology. Many of these major developments occurred in the late 19th century and set the direction for much of the research conducted over the past few decades. A number of important events in the history of turfgrass pathology are described in Table 1 but only a few key developments will be highlighted below.

One of the more important developments came in 1882 with the development of the first effective chemical treatment for plant diseases. This new material, called Bordeaux mixture, was a concoction of copper sulfate and lime and was effective in controlling a number of major diseases of agricultural crops. For the first time, the ability to easily control plant diseases became a reality. This development also was the impetus for a national research emphasis on the study of chemical pesticides for the control of plant diseases. This trend has continued today and has dominated a vast amount of research in turfgrass pathology over the past 70 years.

Another important development was the establishment of the Division of Botany within the U.S. Department of Agriculture in 1885. This organization was charged with overseeing plant disease research programs across the U.S. Three years later, most of the Agricultural Experiment Stations were also established across the country. These developments established a pattern of funding and administrative direction for research in turfgrass pathology as well as other agricultural sciences.

Also in 1885, and continuing a trend that began in 1754 with the establishment of the Royal and Ancient Golf club of St. Andrews in Scotland, the first golf course was built in the United States. Over the years, it has been the game of golf that has had the greatest influence on turfgrass culture and hence the need to address disease problems in turfgrass management.

By 1894, the United States Golf Association was established, in part, to support research for the improvement of golf turf management. This organization has traditionally been one of the major sponsors of turfgrass research and information in the United States and continues to be today.

Throughout the late 1800s, the science of plant pathology had been growing and becoming recognized in the academic community as an important and unique discipline. In 1905, the first Department of Plant Pathology in the United States was established at Cornell University by the fungal biologist H. H. Whetzel. Since that time, departments of Plant Pathology have flourished in land grant universities in all 50 states.

During this time, the science of turfgrass pathology was continuing to grow. Although fairy rings and red thread had been described in Europe prior to the 1900s, the first turfgrass disease in the United States was described from a privately owned turf garden in Philadelphia in 1914. In the next few years following that observation, studies were undertaken by Piper and Coe to examine the etiology of the disease. For a number of years after that first observation, a considerable amount of research went into developing effective chemical controls for brown patch. It was this initial research effort by Piper and Coe that officially marked the beginning of formal turfgrass pathology research programs in the United States.

Research Has Emphasized Chemical Control

As can be seen from the historical progression of turfgrass pathology as a discipline, there are several factors have been key to the direction of turf pathology research in the United States. Perhaps the most important factor has been the popularity of the game of golf. The intensity of management and plant stress coupled with the need to maintain blemish-free turf has been the major impetus for developing control strategies for turfgrass diseases.

Another major factor was the knowledge that fungi were incitants of turfgrass diseases. With this came a mycological emphasis to research and an important link to plant pathology. Because of this and developments already underway in plant pathological research, the major research emphasis was directed toward a search for effective fungicides to control diseases. Given the proven efficacy of Bordeaux mixture as a treatment for plant diseases, the greater part of the 20th century has been devoted to the discovery of new and more effective fungicides.

From its origins around the turn of the century until the present, research has continued to emphasize the chemical management of fungal diseases of golf course turf. Because of the early success of broad-spectrum fungicides such as mercury and cadmium, there was little need to know the precise etiology of turfgrass diseases. This chemical emphasis on disease control, coupled with the ever-present demands of the golf industry to maintain disease-free turf, has molded turfgrass pathology into a discipline largely focused on short-term chemical-based solutions to immediate and pressing problems associated with golf turf. This narrow focus has been facilitated by the fact that extension efforts in turfgrass pathology have been emphasized more than basic research efforts, resulting in relatively few long-term studies of the biology, ecology, and epidemiology of turfgrass pathogens and diseases.

1980s Marked a Change in Research Directions

It was the research emphasis through the 1920s that set the stage for turfgrass pathology research in the United States for the next 60 years. However, beginning in the 1980s there was a dramatic shift away from traditional chemical evaluation programs to more of an emphasis on pathogen biology, pathogen ecology, and disease epidemiology. There was also renewed interest in exploring the possibilities of utilizing disease resistance among turfgrass cultivars. Although fungicide-screening programs remained a major emphasis of many turfgrass pathologists, particularly those with extension responsibilities, there was renewed interest and funding for research in many of these more fundamental areas.

A major impetus for the change in research direction was the banning of mercury and cadmium fungicides, as well as increasing problems with fungicide resistance. This, coupled with the growing environmental movement across the United States, prompted many in the turfgrass

industry to ask new questions about the management of diseases; questions not only about what alternative strategies might be employed, but also questions about the impact of traditional chemical-based disease control practices on environmental quality. Research initiated in the 1980s to address some of these questions continues today.

It is often surprising that despite the years of research in turfgrass pathology, there are still major informational gaps, particularly in such fundamental areas as pathogen biology and ecology as well as disease epidemiology. Part of this can be explained by the few number of scientists and educators devoted to turfgrass pathology as well as to the distribution and focus of efforts in research, extension, and teaching.

Turfgrass pathology has traditionally been a discipline that has been grossly underrepresented in major U.S. universities relative to other agricultural crops. For example, in crops like corn, soybeans, cotton, potatoes, or wheat, there may be several pathologists in any given university devoted to each of those commodities. However, in nearly all universities, there are few, if any, faculty or staff with full-time

TABLE 1. MAJOR HISTORICAL DEVELOPMENTS IN TURFGRASS PATHOLOGY

Pre-1880s - St. Andrews Golf Club established in Scotland First Agricultural Experiment Station established in New Haven, CT. Infectious nature of plant diseases established. Fairy rings an important curiosity in Europe. Lawn mower invented.

1880s - Bordeaux Mixture discovered. USDA Division of Botany established. Agriculture Experiment Stations established nationwide. First golf club in U.S. established in Yonkers, NY. Red thread disease described in England.

1890s - United States Golf Association established.

1900s - Plant Pathology departments became part of the land grant university system.

1910s - Observations of disease-like symptoms on golf turf. Brown patch disease caused by Rhizoctonia solani described. Research on Bordeaux mixture for control of brown patch. Turfgrass pathology research begins. First publications on turf pathology.

1920s - Descriptions of newly recognized turfgrass diseases and their causal agents (dollar spot, Pythium blight, pink snow mold, numerous leaf spots and leaf blights, rust, striped smut, and powdery mildew). First large scale fungicide testing programs ñ mercury, copper, silver, zinc and sulfur fungicides. Observations on cultural factors affecting diseases.

1930s - Descriptions of newly recognized diseases and their causal agents (Typhula blight and take-all patch). Research on disease resistant bentgrass varieties. Organic fungicides used in turfgrass disease control programs ñ thiram. Publication of Turfgrass Diseases and Their Controlî by Monteith and Dahl.

1940s - Descriptions of newly recognized diseases and their causal agents (anthracnose). Cadmium fungicides introduced.

1950s - Descriptions of newly recognized diseases and their causal agents (copper spot). Release of improved turfgrass cultivars. Research on disease epidemiology. Nematodes recognized as important turfgrass pests. New fungicides introduced (PMAS, cycloheximide, chloroneb, diazoben, ethazole, mancozeb, and anilazine)

1960s - Descriptions of newly-recognized diseases and their causal agents (Fusarium blight, bacterial wilt, Dreschlera leaf blights, yellow patch, pink patch, Sclerotium blight, yellow tuft, and spring dead spot). Fungicide resistance first described (S. homoeocarpa to anilazine and cadmium).

1970s - Research on cultural factors influencing disease severity. Restrictions on the use of mercury fungicides. Iintroduction of new fungicides (chlorothalonil, iprodione, benomyl, thiophanates). More reports of fungicide resistance. First reports on the biological control of turfgrass diseases.

1980s - Descriptions of newly-recognized diseases and their causal agents (necrotic ringspot, Pythium root rot, summer patch). New fungicides introduced (fosetyl Al, vinclozolin, propamocarb, triadimefon, propiconazole, fenarimol, and metalaxyl). Mercury and cadmium fungicides banned. New fungicide application strategies studied. Non-target fungicide effects described. Biocontrol studies expanded.

1990s - Development of disease resistant transgenic turfgrasses. Biological control accepted as an alternative to fungicides. More cases of fungicide resistance documented. Expanding studies on cultural practices affecting disease severity. Studies on pathogen biology. Expanding studies of disease resistance in turfgrass cultivars. Development of pathogen detection techniques. Development of predictive models. New fungicide introductions (cyproconazole, flutalonil, mefanoxam, azoxystrobin, myclobutanil).

research, extension, and teaching responsibilities in turfgrass pathology. Surprisingly, over 15 states have no turfgrass pathologist on the staff of any university in that state. In contrast, other states may have two or more turfgrass pathologists within a single university.

Most turfgrass pathologists in the United States have responsibilities for a number of agricultural or horticultural crops other than turfgrasses. Their responsibilities are usually split between research and extension. Because of the limited time for research in turfgrass pathology and the more traditionally applied nature of the work, there has been little time for more fundamental research.

Despite the fact that there are currently less than about 11 or 12 equivalent full time scientists in the United States conducting research in turfgrass pathology, there have been remarkable achievements in the past decade; achievements that have conceptually changed how we approach turfgrass management. Many of the advances that have occurred in the past 10 years have come from major shifts in research emphases away from a major fungicide emphasis to more pathogen biology and ecology.

Recent Developments in Turfgrass Pathology

Pathogen Biology - Our knowledge of the basic biology of turfgrass pathogens is rapidly expanding. Work initiated in the 1980s with summer patch and necrotic ringspot diseases set the trend for the kind of research needed to solve important management problems For example, knowledge of when and how the summer patch pathogen, Magnaporthe poae, infects plants, how it survives, the biology of the spores it produces, and, in general, how it behaves in association with turfgrass plants has proven useful in developing logical control strategies for this important disease. Studies on the biology of other turfgrass pathogens are proving to be equally important in disease management.

Biological Disease Control - One of the newest areas of current research in turfgrass pathology has been in the area of biological control of turfgrass diseases. Biological disease control has been well documented in turfgrasses. Numerous laboratory and field studies have demonstrated control efficacy from a wide variety of microbial inoculants and soil microorganisms contained within or stimulated by organic amendments .

In the past five years there has been an explosion of new work in this area, ranging from very basic studies on biological control mechanisms to applied studies looking at application technologies and pesticide compatibility. Currently new microbial-based products are coming onto the market much faster than our understanding of biological control systems is advancing. This increased demand for control alternative is creating a tremendous information gap; one that continues to grow because traditional sponsors of turfgrass research have been reluctant to support much needed longer-term studies. As a result, more biological control research is focused on agricultural crops where more appropriate funding is available. Unfortunately, however, there is often little that can be extrapolated from row crop agriculture to turfgrass systems.

In part because of this information gap as well as the lack of scientists involved in this research, pathologists are finding that moving biological control successes from the laboratory to the field is proving to be difficult, requiring new methods of inoculant formulation, handling, and delivery. However, advances in injection technologies, application strategies, and formulation chemistries are rapidly evolving and will likely change the way biological control strategies are implemented.

We are also learning about the ecology of microbial inoculants and their compatibility with other management practices. This will speed use of biological approaches into turf management programs.

Pathogen Detection - Diagnosing root diseases continues to be a major problem in turfgrasses. Identification of pathogen species growing in and on root

tissues is nearly impossible just from microscopic observations alone. Recent applications of molecular biological methods for detection and identification of root pathogens, particularly *Magnaporthe, Gaeumannomyces,* and *Pythium*, is greatly improving diagnostic abilities and improve our understanding of the ecology of these important pathogens These types of studies are on the increase and are beginning to shed new light on the ecology of the pathogens as well as the epidemiology of the diseases they cause.

Transgenic Plants and Host Plant Resistance - Advances in plant biotechnology are finding their way into turfgrass pathology with the development of transgenic turfgrass varieties resistant to diseases. In the last few years, our ability to transfer genes from one organism into turfgrasses has greatly improved. Studies have now shown that the introduction of genes that encode chitinases (enzymes that can break down fungal cell walls) into creeping bentgrass plants can convert a normally susceptible cultivar into one that is resistant to a variety of fungal pathogens. In addition to biotechnological approaches to disease resistance, there is also renewed emphasis on trying to more fully exploit disease resistance among conventionally-bred cultivars.

Cultural Practices and Turfgrass Diseases

In the past few years, there has been a resurgence in the numbers of types of studies related to cultural practices and their impact on disease severity . Studies such as this have important fundamental implications for the ecology of the causal agents but are also providing useful ways of managing these important diseases. These types of studies are expanding and will likely lead us into an era of more sustainable turfgrass management.

Despite the many advances, our knowledge of the pathology of turf systems remains rudimentary. Relationships between pathogen biomass, inoculum level, and disease severity are still unknown. Our ability to culturally manipulate diseases remains primitive at best. The reasons for these unanswered questions stem directly from the historical evolution of turfgrass pathology. The basic biology and ecology is lacking in turfgrass pathology because of the historically-focused efforts to find new and better chemicals for disease control.

Perhaps our greatest need in turfgrass pathology is to understand how to sustain turfgrass systems with a minimum of external inputs. The challenge in coming years will be to identify management strategies that promote long-term turf health with a minimal human health and environmental impact.