PAST, PRESENT & FUTURE

In its fullest sense, turfgrass pathology is an integration of the concepts and principles of the science of plant pathology with those of the practice of turfgrass culture. Consequently, the level of understanding of the nature and control of turfgrass diseases at any point in time is a direct reflection of the extent of knowledge in these two areas of activity, and the degree of skill that has been employed in bringing this information together.

The Past

In Europe, lawns of pure stands of grass were first purposely established in the thirteenth century. It was during this time that the game of "bowls" became popular. The original bowling green was the forerunner of the modern golf course green. Near the close of this century, "club ball", an early form of crickett, came into being.

By the sixteenth and seventeenth centuries, gardens had become more elaborate. Also, more care was being taken in the establishment of bowling greens. In Northern Europe, lawns had become fairly common features of home grounds and village squares. Most towns had a turfed "common" or "green". A form of soccer was being played on these public greens. The height of the grass in these areas was maintained at a low level by the grazing of sheep and goats.

During this same time period, the concepts and practices related to the development and control of diseases of plants were also in a primitive state. The autogenic concept of disease was the order of the day. This was an outgrowth of the theory of spontaneous generation. Its view of disease causality held that maladies of plants were due to internal disturbances, and that the fungi found in association with these disorders were the product, not the cause, of the diseases in question.

Certain inventions and discoveries of this period contributed materially to efforts directed toward mounting a successful challenge to the autogenic concept of disease causality. Among these was the development of the compound microscope in 1590. Improvements were made in the microscope in 1665, and there followed within the next 25 years a series of studies that laid the foundations needed for the progressive and systematic study of plant anatomy and the establishment of the science of microbiology.

Dusting a putting green *in 1922 with Bordeaux mixture for disease control. This was the first fungicide in general use for controlling turfgrass diseases on golf courses.*

With the advent of the eighteenth century, specific biological evidence for the disproof of autogenesis began to accumulate at a more rapid pace. In 1705, the view was expressed that fungi reproduced by developing spores. As the century progressed, the concept that fungi are autonomous organisms was reinforced by a succession of studies and observations. By 1785, the evidence that they were indeed distinct biotic entities in their own right had been well established.

The information that had been gained in the eighteenth century relative to the nature of fungi found direct application in the development of an expanded concept of disease in the nineteenth century. In 1807, the first report giving clear evidence that fungus spores could germinate and infect a plant was published. With this, the allogenic view of disease causality was given a firm, scientific base. Allogenesis perceives disease as being engendered by forces from without the plant, rather than from within. Through its applications, research on the nature and control of plant disease was placed on the proper course. While it would still be some 50 years before the total weight of evidence in support of this concept would finally reduce the voices of the advocates of autogenesis to a faint whisper in the scientific community, the stage had now been set for the development of the science of plant pathology.

During the eighteenth century, turf maintenance became more sophisticated. Instructions for the proper care of grass walks and bowling greens called for them to be rolled and mowed every 15 days. Many of the gardening books of this period contained instructions on the mowing, rolling, edging and weeding of lawns.

A single event of this century that had a significant effect on the promotion of the development of the art of turfgrass culture was the establishment of the Royal and Ancient Golf Club of St. Andrews in Scotland in 1754. With this, the game that was to become universally known as "golf" received recognition as an established, on-going sport. The evolution of golf through the years, and the various requirements it has placed on turf for play, has served as a major impetus for the development of the framework of the basic concepts now used in various aspects of turfgrass culture.

The equipment used in turfgrass culture during this time was borrowed from the farm. Cutting of the grass, for example, was accomplished with hand scythes and cradles. The early part of the nineteenth century brought the invention of the first mowing machine for turf. The device was patented in 1830, and its manufacture began two years later.

The impact this machine had on the development of turfgrass culture as a systematic endeavor in which the various practices are centered on basic principles was equivalent to that of the establishment of the concept of allogenesis on the science of plant pathology. The capacity to maintain both specified and uniform heights of cut continuously with rather low investments in labor was the innovation needed in order for the unique features of the turfgrass plant to be fully utilized in a wide range of landscape and utilitarian situations. The motivation to exploit these now-recognized potentials led to the systematic programs of research and testing that have in turn established the various concepts and principles that comprise the art of turfgrass management.

As the nineteenth century progressed, the science of plant pathology developed both form and substance. A continuing series of discoveries firmly reinforced the allogenic concept of disease causality. In 1858, the first book based entirely on this concept was published.

Through the course of the century, the fungal incitants of several of the more important diseases of plants were identified. In addition to fungi, certain species of bacteria came to be recognized as being pathogenic to plants. At the close of the century, research was begun on determining the nature of what was being referred to as a "contagious living fluid". The pathogenic principle of this fluid would later become known as "virus", a previously unknown biotic entity.

It was during the final quarter of the nineteenth century that a major breakthrough in the area of chemical control of plant diseases was made. In 1882, Bordeaux mixture was discovered. With the advent of this very effective, low cost fungicide, the era of systematic research for the purpose of developing programs of plant disease control through the use of pesticides was ushered in.

While these various events were making their contributions to the nurturing of plant pathology into a mature science that would be fully capable of addressing itself to the task of determining the nature and control of disease, turfgrass culture was also becoming more clearly defined—both in the expectations from its efforts and its capacity to respond to these requirements. By the latter part of the nineteenth century, golf had become a very popular sport throughout the British Isles.

The year 1885 stands as a hallmark in the United States for both turfgrass culture and plant pathology. The first official golf club in the country was established in Yonkers, New York in 1885. This was also the year that turf research started in the United States. The location of this work was the Olcott turf gardens in Connecticut. It was also in 1885 that the United States Department of Agriculture's Division of Botany was established. This unit was to serve as the first administrative base for plant disease research in this country.

By the close of the nineteenth century, there were over 80 golf courses in the United States, and the first games of two other turf-dependent sports, football and baseball, had been played. The United States Golf Association had been formed. Research on turf management was being conducted on a much broader scale, and the nature and control of plant disease was being investigated at many of the state agricultural experiment stations.

As the twentieth century began to unfold, then all of the components needed for the establishment of the field of turfgrass pathology were in place. Many of the basic methods and techniques of turfgrass culture had been defined, and the science of plant pathology had matured to the extent that it could address itself constructively to identifying the causes of specific diseases and developing programs for their control. All that was needed to bring the parts together was a clear and present need. Ideally, this would be a disease capable of combining high incidence with high severity within a short span of time. While we now know of several diseases of turfgrasses that could have functioned well in this capacity, the lot fell to Rhizoctonia brown patch.

In 1914, a disease was observed to be causing extensive damage to a turf garden in Philadelphia, Pennsylvania. The owner of the garden, F. W. Taylor, was keenly interested in turfgrass culture and was active in both the development of management techniques and in the search for superior strains of grass. He was particularly interested in bentgrass culture, and his garden in Philadelphia contained several selections he had obtained from the Olcott turf gardens in Connecticut.

In his efforts to determine the cause of the disease at hand, Mr. Taylor secured the assistance of C.D. Piper, a member of the administrative staff of the United States Department of Agriculture and Director of the United States Golf Association Green Section. Isolations from the diseased plants yielded the fungus *Rhizoctonia solani* and it was determined that this organism was the incitant. Based on its characteristic clinical symptom pattern of foliage blighting and death of plants in irregular patches measuring up to 1 meter in diameter, Taylor assigned the disease the name "brown patch". The climatic conditions in 1915 were again particularly conducive to the development of the disease, and with the experience in diagnosis gained from the previous year, it was determined that brown patch was capable of causing severe damage to bentgrass putting greens.

With the pathogen identified, the symptoms known, and the scope of the disease defined, the next step was to search for a control. In 1917, field tests were begun by the United States Golf Association to determine the feasibility of using Bordeaux mixture for brown patch control. Although it was found that the material had certain limitations due to its toxicity to bentgrass after repeated applications, it was effective in controlling the disease, and there were no alternatives. By 1919, Bordeaux mixture was in general use on golf courses for control of brown patch.

Through this 5 year period, then, the "rest disease" had appeared. The extent of its occurence had been established, its incitant was identified, and control measures had been worked out. The components had been brought together and they had matched. The practice of turfgrass pathology had begun.

By the end of this decade, another turfgrass disease and its causal agent had been identified. This malady was first recognized on putting greens. Its symptom pattern was somewhat similar to Rhizoctonia brown patch, and it occurred at about the same time in the growing season. However, the individual blighted areas of turf were usually lighter in color and smaller in diameter. The two were distinguished from each other in name, then, by referring to the former malday as "large brown patch" and the latter disease as "small brown patch". Small brown patch (or "small patch") eventually became known as "dollar spot", and the pathogen was finally given the name *Sclerotinia homoeocarpa*.

During the 1920's, the clinical symptoms were described, the incitants identified, and the epidemiological patterns worked out for several newly recognized turfgrass diseases. In 1920, mercuric chloride was used successfully in the Chicago, Illinois area for control of Rhizoctonia brown patch on bentgrass putting greens. An organic mercury, Semesan (chlorophenol mercury) was tested in 1924 on the putting greens of a golf course near Yonkers, New York, and found to be very effective in the control of Sclerotinia dollar spot. By the end of the decade, the inorganic mercury chlorides and Semesan had become the primary fungicides used in the field control of turfgrass diseases.

In 1929, a turfgrass research and advisory service was established in Great Britain. The work was conducted under the auspices of the Board of Greenkeeping Research. The name of the organization was later changed to the British Sports Turf Research Institute. From the outset, the staff addressed itself to the solution of a broad range of problems in turfgrass culture, including determining the nature and control of certain diseases. The papers that have been published on the subject of turfgrass pathology in its journal are a valuable addition to the body of knowledge in this field.

The First Publication

The first comprehensive publication on the nature and control to turfgrass diseases was published in 1932. It was issued as an entry in the Bulletin of the United States Golf Association under the title TURF DISEASES AND THEIR CONTROL. The authors, John Monteith and Arnold S. Dahl, were two of the primary researchers in the field of turfgrass pathology in the late 1920's and early 1930's.

This publication stands as a classic, both for the thorough manner in which it integrates the principles and concepts of plant pathology with those of the practice of turfgrass culture, and the completeness of detail in its descriptions of the nature of many of the more important diseases of turfgrasses. Consideration was given to diseases incited by both biotic and abiotic entities. Control was approached from the standpoint of the use of resistant varieties and cultural methods, as well as through the use of fungicides .

The contribution of TURF DISEASES AND THEIR CONTROL to the development of the field of turfgrass pathology was far more reaching than bringing together in one volume a compilation of disease symptoms and control procedures. During this time, in plant pathology teaching and research the strongly pathogen-oriented school of thought of the nineteenth century was giving way to plant disease concepts centered more directly on the nature of the response of the suscept. The thinking of this more contemporary view of disease was very skillfully employed in the development of this publication. As the result, in addition to serving as a model for the design of the turfgrass disease research of its time, it also effectively set the stage for moving these investigations toward the holistically-oriented studies of the future.

As the 1930's began, turfgrass disease control programs were almost entirely dependent on either Semesan or the inorganic mercury chlorides. In 1931, however, it was discovered that thiram, an organic compound that had been developed as an accelerator in the manufacture of rubber, had fungicidal properties. Field tests showed that this material was effective in controlling several of the more important diseases of turfgrasses. Within a few years, thiram was in general use in turfgrass disease control programs.

The impact of thiram on turfgrass disease control programming was an interesting one in that it provided a basis for expanding rather than replacing the use of the organic and inorganic mercuries. It was found that when this compound was used as a tank mix with either mercuric chloride or Semesan, in addition to providing its own spectrum of fungicidal activity, it reduced to some extent the phytotoxic potential of the mercuries. As the result, the introduction of thiram established a new dimension in disease control — greater efficiency with less possibility of injury to the grass.

The transition to the present era in turfgrass pathology occurred during the 1950's and early 1960's. This was a time of major and highly innovative developments in both the field of turfgrass culture and the science of plant pathology. The Kentucky bluegrass cultivar 'Merion' was released in 1952. This was the first of what was to be a continuing series of releases of new genotypes of *Poa pratensis*. Within the following two decades, it would be joined with similar series of releases of bentgrasses, fine bladed perennial ryegrasses, tall fescues, Bermudagrasses, and zoysia. Each cultivar brought with it certain peculiarities of management requirements, and each had its own pattern of response to the various pathogenic entities.

New formulations of nitrogen-based fertilizer for use in turfgrass culture began to be tested and placed into field use. Each had its own rate of nitrogen release, and each had its own set of requirements for release.

New types of turf maintenance equipment began to make their way into field use. Each made its own contribution to the enhancement of grass growth and each placed its own forms of stress on the plants.

Each of these innovations added to the latitude of selectivity within the field of turfgrass culture for producing particular types of turf. However, they also presented to the turfgrass pathologist extremely complex patterns of mobility where the expression of disease was concerned.

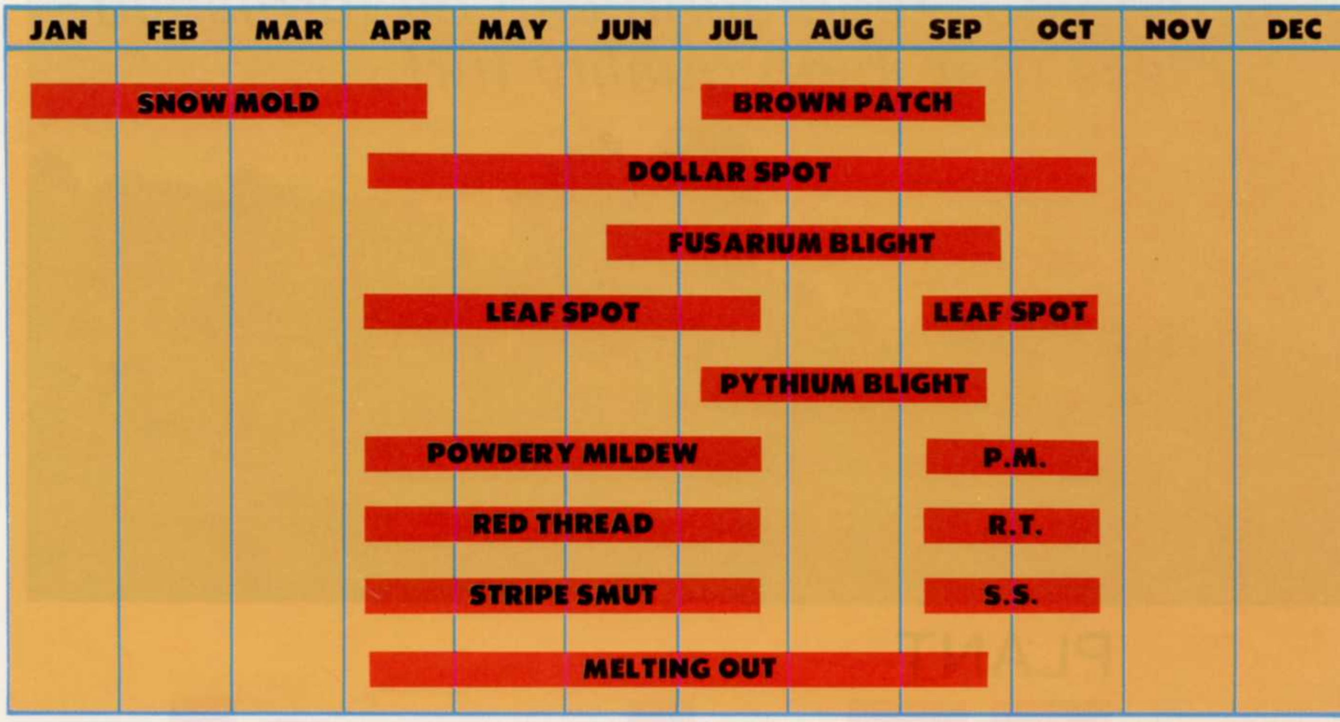
The basis for the pathologist's capacity to respond to the newly developing pattern of turfgrass culture also came into being during this decade. The English translation of Principles of Plant Infection by Ernst Gaumann was printed in 1950. This action gave a much broader exposure within the scientific community to what was unquestionably the most significant publication in plant pathology in the first half of the twentieth century.

The principles put forth by Gaumann in his book established the mentality by which the dynamics of disease development could be viewed with equal clarity at both the reductionist and constructionist levels. They permitted the development of a basic concept of disease that was truly functional in all circumstances. It was a concept that transcended such previously limiting factors as the nature of the incitant and/or the magnitude of the plant's response. The groundwork laid by the nineteenth century concepts, and built upon by the emphasis placed in the research of the first half of this century on determining the nature of the response of the suscept, now found full expression in the concept of disease proneness.

Disease proneness views each plant as being genetically endued with its own innate capacity to become diseased. Expression of the various facets of this proneness is made manifest when the appropriate combinations of the physical environments are brought into being. Through this concept, disease is seen in its absolute reductionist sense as simply the moment of the initiation of aberrent metabolism, and in its absolute constructionist sense it is seen as the moment of expression of the most salient features of its clinical symptoms.

Both of these moments of disease, and the acceptance of the legitimacy of their being, establishes the means by which all of the factors relating to the ultimate outcome of the pathogen-suscept interactions can by given proper perspective. Disease proneness, then, becomes the route to a truly holistic view of disease. Within the concept of disease proneness, for example, the causality of disease is seen as a matrix of events rather than a single episode. This means that the determination of the etiology of a disease is more than a search for a single entity. Rather, the objective of research on disease etiology is to determine the order of occurence of these events and how they interrelate in both the initiation of the process of disease and in the fostering of the development of its clinical phase.

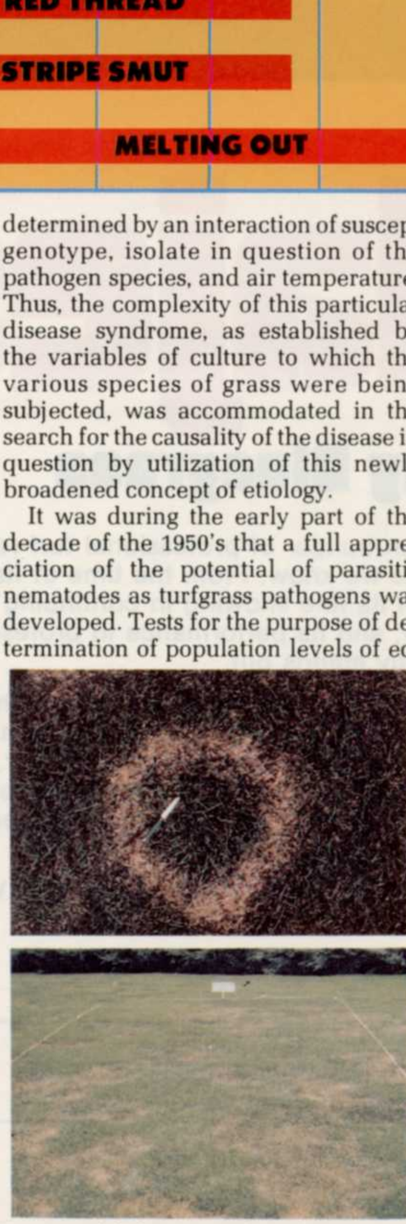
The opportunity to apply these concepts to research on a turfgrass disease of unknown etiology came during the first years of the following decade. In 1959, a previously undescribed disease of Kentucky bluegrass characterized in



its final stages of development by more or less circular patches of blighted grass 0.6-1 meter in diameter was observed in southeastern Pennsylvania. During 1960, 1961 and 1963, the disease became epiphytotic in stands of Kentucky bluegrass and creeping bentgrass in the south central and eastern parts of the state. Also, during this time, the malady was observed on a wide range of cultivars of bluegrass, as well as creeping bentgrass and creeping red fescue in Ohio, New York, New Jersey, Delaware, Maryland and the District of Columbia.

The experiments for the purpose of determining the etiology of the disease were designed to take the candidates through series of multiple factoral tests for levels of pathogenicity. The factors in the respective experiments included variations in (i) air temperatures, (ii) nutritional levels of the test plants, (iii) test plant geneotype, (iv) isolates of the same species of pathogen candidate, and (v) levels of propagule density of the same isolate of pathogen candidate. Isolates taken over a 5 year period were subjected to these series of tests. It was found that the biotic components of the etiology of this disease were *Fusarium roseum* f. sp. *cerealis* 'Culmorum' and *Fusarium tricinctum* f. sp. *poae*, and that these entities were able to function in a primary capacity — both in infection and in colonization of the suscept tissue. In addition, it was found that the degree of resistance to colonization is influenced by the nutrition of the suscept. Also, the level of resistance within *Poa pratensis* was found to be determined by an interaction of suscept genotype, isolate in question of the pathogen species, and air temperature. Thus, the complexity of this particular disease syndrome, as established by the variables of culture to which the various species of grass were being subjected, was accommodated in the search for the causality of the disease in question by utilization of this newly broadened concept of etiology.

It was during the early part of the decade of the 1950's that a full appreciation of the potential of parasitic nematodes as turfgrass pathogens was developed. Tests for the purpose of determination of population levels of ectoparasitic forms in the root zones of turfgrasses soon became commonplace. Midway through this decade, post planting nematicides were being included as regular entries in the lists of plant protectants used in many turf management programs.



Fusarium blight *is most often characterized by a circular area of reddish-brown grass with green grass in the center.*

The close of the 1950's and the beginning of the 1960's was also the time period in which the first books on the nature and control of turfgrass diseases were published. In 1959, the British Sports Turf Research Institute issued FUNGAL DISEASES OF TURFGRASSES by J. D. Smith. Three years later, DISEASES OF TURFGRASSES by H. B. Couch was printed. Smith's book covered the more important diseases of turfgrasses in Great Britain. It went into its second edition in 1965. The book by Couch was a treatment of all known turfgrass diseases, and its second edition was released in 1973.

Throughout the 1950's, and on into the following decade, there was a sharp increase in the frequency of introduction of new fungicides for use in the field control of turfgrass diseases. By 1964, this rapid influx of new pesticides had slowed considerably.

It was in 1963 that the existence of resistance to anilizine by *Sclerotinia homoeocarpa* was reported. This was the first verified instance on the part of a turfgrass pathogen of the development of resistance in the field to a pesticide. Within a few years, episodes of both anilizine resistant and cadmium resistant *Sclerotinia homoeocarpa* had been reported from several locations in central and northeastern

United States and southeastern Canada.

By the end of this decade, the expressions of public concern over the possible harmful side effects of pesticides on the quality of the environment began to be felt in turfgrass disease control programs. In 1970, the manufacturer of Semesan voluntarily removed the product from the market. The use life of this material as a mainstay in turfgrass disease control programs had spanned almost five decades. It had served well in the control of a broad spectrum of important diseases, and its departure was lamented by many.

The first commercially available systemic fungicides for use on turfgrass were marketed in 1970- 71. These were benomyl and thiabendazole. Later investigation of the interactions of various aspects of the physical environment and certain practices in turfgrass culture on the effects of these materials on both the incidence and severity of target and non-target diseases, as well as the growth patterns of the suscepts, pointed to the need for the establishment of more precisely defined parameters for the field testing of systemic fungicides. Also, within a few years, instances were being reported of resistance in the field of *Erysiphe graminis* and *Sclerotinia homoeocarpa* to members of this benzimidazole grouping. These observations served as an additional impetus to the development of specific guidelines for field use of systemic fungicides in turfgrass culture.

The Future

In the future, the design of major research efforts in turfgrass pathology will become more closely oriented with the concepts of holopathology. Turfgrass culture is unusually well suited for the development of research models based on the holistic view of disease. The wide range of suscept genotypes that have been developed within the various turfgrass species provides a broad array of potential responses to various environmental stresses. The equally wide range of growing conditions to which the plants are systematically subjected establishes the vehicle through which these innate abilities can be brought into full expression. Holopathology is the vehicle by which this matrix of events can be described, and their relative degrees of interdependence and individual roles in the initiation and fostering of the disease process can be defined.

In addition to continued work with Fusarium blight, there are several other known turfgrass diseases that need to be subjected immediately to research that has been designed within the concept of holopathology. The Rhizoctonia-incited diseases, for example, are in much need of research based on these models. Within this grouping is a complex of colonization patterns. Assessment is yet to be made of the degrees of host specificity and types of colonization of different isolates of *Rhizoctonia solani* as determined by environmental conditions, suscept genotypes, and turfgrass management practices.

This same research approach needs to be applied to the Pythium-incited diseases, Sclerotinia dollar spot, Fusarium patch, and Typhula blight. Of the diseases in which the principle components of their causalities have yet to be determined, spring dead spot of Bermudagrass is an example of one that should be studied through multiple factoral experiments designed within the parameters of the holistic concept of disease.

In the near future, the basic principles that have been established in the field of epidemiology will begin to be utilized more widely in research on forecasting the outbreaks of turfgrass diseases. The evident benefits of being able to time applications of fungicides on a disease preventive schedule that has been determined by a system of objective analyses of the physical and biological environments will foster increased research in this area.

The view of the spectrum of entities with pathogenic potential to turfgrasses will continue to expand in the years ahead. Additional viruses and mycoplasm-like organisms that are pathogenic to turfgrass will be included in this list. Also, the role and nature of bacteria as incitants of turfgrass diseases will be clearly defined. Within the realm of abiotic entities, the presently increasing appreciation of the importance of air pollutants as incitants of turfgrass diseases will lead to research on the nature and control of these disorders.

In the area of turfgrass disease control, the development of cultivars will include screening techniques that are based on the presently increasing knowledge of the need to identify the degree of stability of the suscept genotype to nutrition-induced changes in disease susceptibility. Research on the chemical control of turfgrass diseases will become more sophisticated. Techniques of pesticide application will be receiving more attention than has been given to this area in the past. Also tests for the field screening of systemic fungicides and nematicides will include such parameters as (i) possible increase in incidence of non target diseases, (ii) the possibility of latent phytotoxicity, (iii) the relationship of leaf surface temperature, nutrition, and soil moisture stress to phototoxicity, and (iv) the longevity of control.

In the distant future, there will no doubt come another time of transition to a new era in the field of turfgrass pathology. As has been the case in the past, however, its timing will be determined by the nature of the changes in the techniques and procedures of turfgrass culture and the development of principles and concepts in the science of plant pathology that are applicable to the solution of the new expressions of disease that they will have fostered.

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