1995 Fourth Annual
Turfgrass Symposium

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Director's Opening Remarks:

It is with great pleasure that I welcome you to the fourth annual Rutgers Turfgrass Symposium. The Symposium Planning Committee, comprised of Don Kobayashi, Faith Belanger, and Lisa Lee, has worked hard to make this year's program a success. They have spent many hours arranging the oral portion of the program as well as the poster session and tonight's social. Without their diligence and attention to detail, this year's Symposium would not have been possible. I am sure that I speak for the entire Center Faculty when I extend my congratulations for a job well done.

The topics presented at the Symposium represent a broad range of basic and applied research projects conducted at Rutgers and at other prestigious institutions. I would like to thank the participants from outside the Rutgers Community as well as the Center Faculty who have agreed to present their research at this year's meeting. Their expertise and strong commitment to the advancement of turfgrass science is most appreciated.

This is also an exciting time for the Turfgrass Center. The turfgrass program grew under the leadership of Dr. Daie and Dr. Funk, the first two Center Directors, and is now poised to make a dramatic leap forward. Due to the tremendous support of the Cook College Administration and the Turfgrass Industry in New Jersey, the Center is currently in the process of acquiring four additional faculty. At the same time, Rutgers Cooperative Extension is preparing to hire two new specialists with responsibilities in turfgrass entomology and weed science. These positions represent an unprecedented commitment to the turfgrass program at Cook College/NJAES and will dramatically enhance the Center's ability to conduct premier research, teaching, and service programs in turfgrass science. I look forward to the continued expansion of the Turfgrass Center and the exciting opportunities that lie ahead.

I hope that you will enjoy the 1995 Turfgrass Symposium and will help to make it a resounding success through your active and enthusiastic participation.

Sincerely,
Bruce B. Clarke
Director, Center for Interdisciplinary Studies in Turfgrass Science
January 5, 1995

AN OVERVIEW OF THE CENTER FOR TURFGRASS SCIENCE AND THE TURFGRASS INDUSTRY IN NEW JERSEY

CENTER FOR TURFGRASS SCIENCE

Established - September 1991

Location - The Center is situated on the Cook College campus of Rutgers University in New Brunswick, New Jersey. New Brunswick is a suburban community of approximately 42,000 people. It is located about 30 miles from New York City and 60 miles from Philadelphia. The incomparable educational and cultural resources of these cities are readily accessible by car and mass transportation. Moreover, the State offers a wide array of recreational opportunities within a short drive from campus. These include an extensive network of State and county parks, more than 120 miles of shoreline, and numerous opportunities for golfing, fishing, biking, and hiking.

Mission - To generate and disseminate knowledge and to provide training and education in the turfgrass sciences by fostering nationally recognized, multidisciplinary research, undergraduate, graduate, and continuing professional education, and service programs in support of the turfgrass industry.

Center Faculty - The Center consists of 19 faculty, five adjunct faculty, and seven emeritus faculty. It has also received approval to hire six additional faculty (four research and two extension positions) over the next two years.

Research Emphasis - The central theme for turfgrass research at Cook College/NJAES encompasses germplasm enhancement and turfgrass management. Current studies include host-endophyte associations; biocontrol of white grubs and summer patch; development of herbicide resistant grasses through transformation; reducing pesticide inputs; targeting grasses with acid and aluminum tolerance; controlling patch diseases caused by root-infecting fungi; assessing nutritional needs of turf through spectral analysis; improving turf cultivation techniques; and developing grasses with better stress tolerance and pest resistance.

Competitive Grants Program - Applied and basic research priorities in turfgrass science are funded through an internal competitive grants program ($650,000 per annum). This is a seed money program designed to encourage multidisciplinary research that will lead to the acquisition of external competitive grants at the regional, national, and international level. Center faculty have been very successful in acquiring external funding to support their research programs.

Undergraduate Curricula - In collaboration with the Plant Science Department, the Center recently developed and implemented new undergraduate options in turfgrass science and turfgrass management. The Center is committed to expanding its support of the undergraduate teaching program in Plant Science as well as the Continuing Professional Education Turfgrass Teaching Program at Rutgers University.

Outreach - The Center conducts annual research symposia, field days, workshops, and educational seminars in association with Rutgers Cooperative Extension, the Office of Continuing Professional Education, and the turfgrass industry in New Jersey. These programs have been very well attended and have received excellent evaluations.

Linkages - Attempts have been made to establish and maintain collaborative relations with other scientists and turfgrass professionals at the local, regional, national, and international level. These efforts have resulted in several productive research collaborations.

LABORATORY FACILITIES

Foran Hall - New office and laboratory facilities will soon be available in a new, three story, 154,000 sq. ft., plant science building called Foran Hall (anticipated date of occupancy, March 1995).

Foran Hall will house the Center for Turfgrass Science, the Department of Plant Science, the Department of Plant Pathology, and the Ag Biotech Center. The building will contain new growth chambers, cold rooms, a teaching laboratory, a large seminar room, and a new agricultural library.

GREENHOUSES AND GROWTH CHAMBERS

A greenhouse facility (completed in 1991) serves as a focal point for applied research in the agricultural sciences. The 27,000 sq. ft., computer controlled facility is used extensively by the Center's faculty and contains the following features:

- 16 (40' x 40') greenhouse zones

- 3 (20' x 20') and 3 (10' x 20') contained greenhouse zones for genetic engineering and research
- 16 state-of-the-art controlled environment chambers (totalling more than 500 sq. ft. of bench space)
- a large plant preparation area

RESEARCH FARMS

Three research farms, representing a wide range of climatic and edaphic conditions, are available for turfgrass research.

- **Adelphia Plant Science Research Station -** A 200+ acre farm dedicated to research in turfgrass science and field crops. Approximately 33 acres is currently utilized for turfgrass research. This facility has an excellent field crew and a full complement of equipment to establish and maintain turf research plots. (Location - Adelphia, NJ; approximately 22 miles southeast of campus).
- **Horticulture Farm II -** A 32 acre research farm dedicated almost exclusively to turfgrass research. This farm boasts a laboratory-conference building; a new 5,000 sq. ft. equipment storage facility (anticipated completion date spring, 1995); 75,000 sq. ft. of bentgrass; a small green, fairway, and tee used for teaching and demonstration purposes; and an excellent field crew. (Location - North Brunswick, NJ; approximately 1 mile from campus).
- **Snyder Research and Extension Farm -** A 390+ acre research farm that is the newest research facility at Rutgers University. Currently, only five acres are utilized for turf research, and most of this area has been devoted to the development of grasses and management practices for "low maintenance" turf areas. The Snyder Farm is well-funded by the State and has ample equipment and personnel to establish and maintain turf research plots. Each year, the farm hosts a turfgrass field day for homeowners with large rural lots. (Location -Pittstown, NJ; approximately 45 miles northwest of campus).

NEW JERSEY TURFGRASS INDUSTRY

With annual revenues of more than $500 million, the New Jersey Turfgrass industry represents a significant component of the State's economy. There are more than 865,000 acres of maintained turf in New Jersey, including 227 golf courses, 27 sod farms, and more than 2 million home lawns. The New Jersey turfgrass industry:

1-)co-sponsors annual equipment and research field days and the Turfgrass Expo, which is one of the largest educational turfgrass conferences and trade shows in the Northeast;

has funded several major building projects at Cook College, including a turf conference room and laboratory facility, a 5,000 sq. ft. equipment storage building, and Project DREAM (a small green, fairway, and tee established for demonstration and educational purposes);

2-)supports turfgrass research through annual faculty grants and student scholarships ($50,000+ per year);

3-)and provides input to the Turfgrass Center and Rutgers University via a Turfgrass Advisory Board. The Board consists of members of the following organizations:

- New Jersey Turfgrass Association
- Golf Course Superintendents Association of New Jersey
- Cultivated Sod Association of New Jersey
- New Jersey Cemetery Association
- Irrigation Association of New Jersey
- New Jersey Agribusiness Association
- United States Golf Association

THE FOURTH ANNUAL RUTGERS TURFGRASS SYMPOSIUM

Douglass College Campus Center
Douglass College, Rutgers University

January 5-6, 1995

Thursday, January 5, 1995

6:30 - 10:00 PM

6:30 - 7:00 **Registration**

7:00 **Welcome and Introduction -- B. Clarke**, Director, Center for Interdisciplinary Studies in Turfgrass Science

7:05 **Opening Remarks --L. Meagher**, Associate Director of Research, Cook College

7:10-8:00 **Keynote Address -- Dr. Charles Bacon**, USDA, Athens, GA. *Future Uses and Problems with Endophyte Enhanced Turf and Pasture Grass Species*

8:00-10:00 **Wine and Cheese Reception**

Friday, January 6, 1995

8:00 AM - 4:30 PM

8:00 - 9:00 **Registration, coffee and donuts**

9:00-10:00 **Session 1: Turf Physiology** (B. Zilinskas, Moderator)

9:00-9:30 **R. Gaugler**, Ecogen, Inc. *Host Selection in Insecticidal Nematodes*

9:30-9:45 **G. Berkowitz**, Dept. of Plant Science, Rutgers. *Endophyte-mediated Water Stress Resistance in Turf*

9:45-10:00 **F. Belanger**, Dept. of Plant Science, Rutgers. *Characterization of an Endophytic Fungal Proteinase That is Abundantly Expressed in the Infected Host Grass*

10:00-10:30 **Discussion and coffee break**

10:30-11:30 **Session 2: Turf Pathology** (B. Hillman, Moderator)

10:30-11:00 **J. Henson**, Montana State University. Gaeumannomyces graminis *var.* graminis *Melanin*

11:00-11:15 **B. Clarke**, Dept. of Plant Pathology, Rutgers. *Development of an Integrated Summer Patch Control Program for Fine Turfgrass Areas*

11:15:11:30 **D. Kobayashi**, Dept. of Plant Pathology, Rutgers. *Biological Control of Summer Patch Disease*

11:30-12:00 **Discussion and Poster Session**

12:00-1:30 **Lunch and Poster Session**

1:30-2:30 **Session 3: Turf Improvement** (L. Lee, Moderator)

1:30-2:00 **J. Snow**, United States Golf Association, Green Section. *Future Research*

Directions of the USGA

2:00-2:15 **G. Freeman**, New Jersey Dept. of Agriculture. *Biochemical Testing for Cultivar Purity in the New Jersey State Seed Laboratory*

2:15-2:30 **R. Funk**, Dept. of Plant Science, Rutgers. *Research Perspectives in Turfgrass Breeding*

2:30-3:00 **Discussion and coffee**

3:00-4:00 **Session 4: Turf Management** (R. Hurley, Moderator)

3:00-3:30 **H. Indyk**, Turfcon, Inc. *New Concepts for Athletic Fields*

3:30-3:45 **J. Murphy**, Dept. of Plant Science, Rutgers. *Overview of Turfgrass Management Research*

3:45-4:00 **J. Heckman**, Dept. of Plant Science, Rutgers. *Turfgrass Tolerance of Aluminum in Acid Soil*

4:00-4:30 **Discussion**

Pre-registered Participants

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Oral Presitation

- Future Uses and Problems with Endophyte-Enhanced Performance of Turf and Pasture Grass Species *Charles W. Bacon, USDA ARS, Athens, GA*
- Host Selection in Insecticidal Nematodes *Randy Gaugler, Ecogen, Inc*.
- Endophyte-Mediated Water Stress Resistance in Turf *Gerald A. Berkowitz, Department of Plant Science, Rutgers University*
- Characterization of an Endophytic Fungal Proteinase That is Abundantly Expressed in the Infected Host Grass *Faith C. Belanger, Ponaka V. Reddy, and Cuong Lam, Plant*

Science Department, Rutgers University

- Gaeumannomyces Graminis var. Graminis Melanin *The Can Caesar-TonThat, Barbara Frederick and Joan M. Henson, Department of Microbiology, Montana State University*
- Development of an Integrated Summer Patch Control Program for Fine Turf Areas *Bruce B. Clarke, David Thompson, Jim Murphy, and Pradip Majumdar, Department of Plant Pathology, Rutgers University*
- Biological Control of Summer Patch Disease *D. Kobayashi and N. El-Barrad, Department of Plant Pathology, Rutgers University*
- Turf Improvement for Golf: The Role of the USGA Green Section *James T. Snow, USGA Green Section*
- Biochemical Testing of Turfgrass in the New Jersey Department of Agriculture *Glenn Freeman, New Jersey Department of Agriculture*
- Progress, Opportunities and Challenges In Turfgrass Breeding *C. Reed Funk, James Murphy, Ronald Bara, and Dirk Smith, Plant Science Department, Rutgers University*
- New Concepts For Athletic Fields *Henry W. Indyk, GSI Consultants - Turfcon*
- Overview of Turfgrass Management Research *J. Murphy, Department of Plant Science, Rutgers University*
- Turfgrass Tolerance of Aluminum In Acid Soil *J.R. Heckman and H. Liu, Department of Plant Science, Rutgers University*

Poster Presentation

- Phylogenetic Relationship of Magnaporthe spp. and Other Pathogenic Fungi of the Turf Environment *Tracy E. Bunting, Bruce B. Clarke, Bradley I. Hillman, Department of Plant Pathology, Rutgers University*
- Teaching Plant Soil Relationships With Color Images of Rhizosphere pH *J.R. Heckman and J.E. Strick, Department of Plant Science, Rutgers University*
- Invertase Activity in Epicholë/Acremonium Fungal Endophytes and its Possible Role in Choke Disease *Cuong K. Lam [1], Faith C. Belanger [1], James F. White, Jr. [2], Jaleh Daie [3], Plant Science Department [1], Rutgers University, Department of Biology [2], Auburn University at Montgomery, Department of Botany [3], University of Wisconsin*

- Field Performance of Herbicide Ignite Resistant Creeping Bentgrass (Agrostis palustris L.) *Lisa Lee, Christina Hartman, Cynthia Laramore, John Grande*, Stephen Johnston**, C. Reed Funk, James Murphy, Peter Day, and N.E. Tumer, Agbiotech Center and the Department of Plant Pathology, *Snyder Research and Extension Farm, **Rutgers Research and Development Center - Bridgeton, Rutgers University*
- Greenhouse Screening Kentucky Bluegrass for Aluminum Tolerance *Haibo Liu, Joseph R. Heckman, James A. Murphy and C. Reed Funk, Department of Plant Science, Rutgers University*
- Screening Fine Fescues for Aluminum Tolerance *Haibo Liu, Joseph R. Heckman, James A. Murphy and C. Reed Funk, Department of Plant Science, Rutgers University*
- Evidence for a Genomic Region Involved in the Release of Pyrrolnitrin from Burkholderia cepacia M53 *E.H. Margulies and D.Y. Kobayashi, Department of Plant Pathology, Rutgers University*

Future Uses and Problems with Endophyte-Enhanced Performance of Turf and PastureGrass Species

Charles W. Bacon
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Grass species associated with fungal endophytes are numerous and this association may result in enhanced performance under stressful conditions. Enhanced performance of grasses is not uniform within the infected population but is biotype specific, and readily observed when compared to uninfected ramets of the nonendophyte associated grass species. Endophyte enhanced performance includes increased tiller and shoot density, improved drought tolerance, increased root length, insect and other pest deterring properties, improved competition, increased nitrogen efficiency, and higher scores over endophyte-free grasses in terms of turf and quality and color ratings. These highly desirable enhanced characteristics suggest that endophytic fungi should represent a highly exploitable tool for improving endophyte infected and noninfected grass species, particularly turf grass species. Since most of these enhancements are recent and observational, there are several problems that should be addressed before the use of endophytes can reached fruition. The major problems relative to the biotechnological exploitation of grass endophytes will be the focus of this address. Examples will be presented to indicate a need for continued research into this curious group of fungi. There are indications that endophytes are not completely genetically stable for one of several desirable physiological traits. Further, the contribution of the grass partner within the association is unknown by apparently essential. The identity and precise nature of the desirable mechanisms responsible for increased performance have not all been defined. There are indications of one of several fungus-grass host compatibility factors, none of which are known certain. Knowledge of these and other uncertainties is required before we can intelligently transfer information based on endophyte enhancements to grasses devoid of endophytes, or modify endophytes for use in other grasses species.

Host Selection in Insecticidal Nematodes

Randy Gaugler
Ecogen, Inc.

A key issue concerning the use of insect-killing nematodes (Steinerematidae and Heterorhabditidae) as biological insecticides against soil insect pests is the question of whether these parasites will impact non-target organisms. Despite an exemption from insecticide regulations in virtually every country (e.g., FIFRA), insecticidal nematodes are often regarded as indiscriminate generalist predators, so that regulatory agencies are increasingly reluctant to approve international, and in some cases interstate (e.g., Hawaii) movement of insecticidal nematodes. It is important that we are able to make predictions regarding nematode host specificity by understanding how nematodes select hosts.

The four sequential steps in host selection are (1) host habitat-finding, (2) host-finding, (3) host acceptance, and (4) host suitability. The first step is the most significant because it eliminates the most species from any potential host list, yet it is the least studied for insect nematodes. Insecticidal nematode species are, however, known to respond with directed orientation toward plant roots, the microhabitat for many soil insects.

Most insecticidal nematodes species fall into one of two host-finding strategies. Cruisers tend to be highly mobile, search within the soil, and respond to host volatiles. Ambushers tend to be sedentary, are found near the soil surface, respond poorly to host volatiles, and attach to passing insects. Thus, ambushers appear best adapted to parasitize mobile hosts adapted to the soil surface, whereas cruisers attack sedentary insects within the soil. Insects are not passive participants in the selection process: nematodes on the insect cuticle induce insect grooming behavior that can remove or even kill the attackers.

Once host contact is made, recognition must occur (host acceptance). The conventional wisdom is that insecticidal nematode are indiscriminate, yet our data demonstrates that these parasites reject many potential hosts. Moreover, insect morphological barriers to penetration include sieve plates and peritrophic membranes. Chemical defenses in the insect gut can inactivate attackers.

Once found and recognized, an attack may not succeed if a potential host responds with an effective immune response (host suitability). In Japanese beetles, some nematode species are not recognized by the immune system, others are initially entrapped but subsequently escape, and some are invariably heavily encapsulated. Encapsulation, however, does not always prevent host death.

Are insecticidal nematodes opportunists? Yes. Are they biocides? No. Despite a broad experimental host range, the twin constrains of host habitat-finding and host-finding come into play in the field, imposing ecological and behavioral barriers that greatly augment the morphological and physiological defenses that operate in petri dishes, thereby restricting host range. This is why nearly all predators and parasites have broader host ranges in the laboratory than the field: host habitat-finding and host-finding are bypassed. Thus many insect species are physiologically but not ecologically susceptible to nematode parasitism.

Endophyte-Mediated Water Stress Resistance in Turf

Gerald A. Berkowitz
Department of Plant Science

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Previous work from this laboratory has demonstrated altered water relations in water- stressed turf (perennial ryegrass; *Lolium perrene*) infected with an endophyte (*Acremonium lolii*). In plants exposed to water deficits, lower leaf s (i.e., greater solute accumulation) and, as a result, greater turgor pressure was maintained at a given relative water content. These results suggest that under water stress, endophyte infection may lead to greater leaf stomatal conductance (g**s**). Recent field studies suggest that the maintenance of leaf g**s** may be an important physiological mechanism which ameliorates the effects of summer stress on turf.

The objective of the current work is to identify specific physiological responses and their underlying molecular mechanisms which transduce altered water relations in endophyte- infected turf into enhanced water stress resistance. Initial studies are focusing on big bluegrass (*Poa* *ampla*). Preliminary results suggest that in endophyte infected plants, altered water relations does lead to maintenance of greater g**s** under stress. Generation of subtractive cDNA libraries from water stressed infected and non-infected plants should identify specific plant genes whose translation products are associated with endophyte- induced stress resistance.

Characterization of an Endophytic Fungal Proteinase That is Abundantly Expressed in the Infected Host Grass

Faith C. Belanger, Ponaka V. Reddy, and Cuong Lam
Plant Science Department

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We are characterizing an interesting *Acremonium typhinum* proteinase which is expressed in the endophytic infection of the grass *Poa ampla*. This proteinase is abundant in endophyte-infected leaf sheaths and may constitute over 2% of the total leaf sheath protein. Since the fungal hyphae are a small fraction of the total leaf sheath material, the abundance of the fungal proteinase suggests that it may be an important component in the symbiotic interaction of the plant and fungus. Because of this possibility we are further characterizing the proteinase.

N-terminal and internal amino acid sequence data have been obtained and reveal sequence homology with proteinase K, a well known fungal protease. The amino acid sequence was used to design degenerate oligonucleotides which were used in PCR to obtain a 300 bp clone. This clone was then used to screen a cDNA library prepared from polyA+RNA extracted from endophyte-infected leaf sheath tissue. We are currently sequencing a potentially full-length cDNA clone.

We are excited about the possible biological significance of the fungal proteinase. In other systems, proteinase K homologues are believed to be important in the ability of pathogenic fungi to infect their hosts (insects or other fungi). The endophyte proteinase may also be important in the infection of its host grass.

Gaeumannomyces *Graminis* var. *Graminis* Melanin The Can Caesar-Ton That

Barbara Frederick and Joan M. Henson

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Gaeumannomyces graminis var. *graminis*, a filamentous, soil Ascomycete, synthesized more melanin when exposed to as little as 0.01 mM $CuSO_4$ in minimal broth culture. Because its synthesis was inhibited by tricyclazole, melanin produced in response to copper was dihydroxynaphthalene (DHN) melanin. An additional hyphal cell wall layer was visualized by electron microscopy of hyphae treated with copper and fixed by cryotechniques. This electron dense layer was between the outer cell wall and the inner chitin layer and doubled the total wall thickness. In copper-grown cells that were also treated with tricyclazole this layer was absent. Hyphopodia grown in copper medium had a melanin layer twice as thick as hyphopodia grown without copper. In addition, hyphopodia grown in copper, unlike those grown without copper, were capable of penetrating mylar membranes. A silver enhancement method to determine the cellular location of CuS was developed. Silver staining demonstrated that in Cu-treated, melanized cultures, CuS was present in cell walls and septa of hyphae, and in hyphopodia. Electron microscopy of silver stained cells suggested that CuS was associated with the melanin layer of cell walls. *G. graminis* mutants that produced either more or less melanin were isolated and results of pathogenicity tests on rice will be presented.

Development of an Integrated Summer Patch Control Program for Fine Turf Areas

Bruce B. Clarke, David Thompson, Jim Murphy, and Pradip Majumdar

Department of Plant Pathology,
Rutgers University, New Brunswick, NJ 08903

Summer patch, caused by the root and crown-infecting fungus *Magnaporthe poae*, is one of the most destructive diseases confronting turf managers in North America. A recent survey of golf course superintendents in the Northeast indicated that at least two-thirds of the courses in this region have been damaged by this disease. Although summer patch is usually associated with Kentucky bluegrass (*Poa pratensis*) turf, annual bluegrass (*Poa annua*) and fine fescues (*Festuca* spp.) are also highly susceptible to infection. Research conducted at Rutgers University during the past six years has focused on the development of chemical and cultural management practices that reduce the incidence and severity of summer patch while limiting fungicide usage. In particular, recent studies involving soil compaction and aerification, methods of fungicide application, and interactions between nitrogen sources and fungicides have yielded the most promising results.

Soil Compaction/Aerification: The impact of soil compaction and core aerification on summer patch development was evaluated on an annual bluegrass fairway maintained at the Echo Lake Country Club in Springfield, NJ. During the 1991 to 1994 growing seasons, a positive relationship between soil compaction and enhanced incidence and severity of summer patch was demonstrated. In comparison to heavily compacted, non-aerified turf, aerification significantly decreased soil compaction and disease severity. Between 1993 and 1994, deep tine (17.8 cm depth) and shallow tine (8.5 cm depth) aerification reduced the diameter of infected patches up to 79% and 58%, respectively. Both types of aerification reduced soil compaction, increased percolation, and improved turfgrass quality throughout the study. Spring, and spring plus fall aerification schedules were more effective in reducing disease severity than were fall treatments alone.

Fungicide Spray Volume versus Post-Treatment Irrigation: Field studies were conducted on Nassau Kentucky bluegrass to assess the impact of water volume (applied with a fungicide) and post-treatment irrigation on the incidence and severity of summer patch. Disease control was significantly improved by increasing the water volume from 1,019 to 2,037 L water/ha. This effect was independent of the level of post-treatment irrigation. No differences in disease suppression were observed between the 2,037 and 4,074 L treatments at any of the post-treatment irrigation levels tested. In general, post-treatment irrigation (0, 0.64, 1.27, and 2.54 rates) did not improve the level of disease control. For several of the fungicides tested, however, suppression of summer patch was significantly reduced at the 1.27 cm and 2.54 cm treatments. This response was presumably due to the excessive fungicide dilution.

Nitrogen Fertilization and Fungicide Usage: The impact of nitrogen source and fungicide rate on summer patch development was evaluated on an annual bluegrass/creeping bentgrass green at the Little Mill Country Club in Marlton, NJ. This green was naturally infested with *M. poae* and was maintained under commercial golf course conditions. Over the three year study, ammonium sulfate (AS) and sulfur-coated urea (SCU) were most effective in reducing the severity of summer patch (85% and 43%, respectively). Nutralene and urea, however, were ineffective in reducing the incidence and severity of this disease. Compared to the untreated controls, the sterol biosynthesis-inhibiting fungicides tebuconazole (Lynx), propiconazole (Banner), and cyproconazole (Sentinel) reduced disease severity from 74 to 91%. The AS and SCU treatments reduced soil pH from 6.5 to 6.0 and 6.2, respectively. After four years of application, the AS treatment was as effective as the fungicide treatments in reducing disease severity. Moreover, the AS plus fungicide treatments increased the population of bentgrass 11 to 20% during this period. Compared to the other nitrogen sources, AS alone increased bentgrass populations 5 to 13%. This is the first study to document that acidifying nitrogen sources can be utilized to decrease the severity of summer patch and subsequently reduce the need for fungicide applications under commercial golf course conditions.

Biological Control of Summer Patch Disease

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An enrichment culture procedure was developed to isolate potential biological control agents for summer patch disease of Kentucky bluegrass, caused by *Magnaporthe poae*. The enrichment procedure involved continuous growth of bacteria in a minimal salts medium supplemented with mycelia of *M. poae* as a sole carbon source. Using this method, several bacteria were recovered that were capable of suppressing summer patch disease in growth chamber studies. All bacteria that significantly reduced disease were found to express activity of one or more of the following degradative enzymes: chitinase, glucanase, protease or lipase. In addition, all isolates were capable of colonizing roots of Kentucky bluegrass at significantly high levels of greater than 104 colony forming units (CFU)/g root tissue.

Two chitinolytic bacteria, *Serratia marcescens* 9M5 and *Xanthomonas maltophilia* 21C6, reduced summer patch disease by more than 50% and 70%, respectively. Disease suppression by these isolates was significantly affected by bacterial inoculum concentrations between 108 and 1010 CFU/ml. Increased concentrations of *X. maltophilia* resulted in higher levels of disease control. Similarly, disease control increased as concentrations of *S. marcescens* increased from 108 CFU/ml to 109 CFU/ml. However, at concentrations above 109 CFU/ml, an inverse relationship was observed between levels of disease suppression and concentrations of *S. marcescens*. Populations of these bacteria in the soil over a 35 day period were directly influenced by inoculum concentration. In contrast, populations within the turfgrass rhizosphere appeared not to be influenced by inoculum concentration.

The role of chitinase in disease suppression by both *X. maltophilia* 21C6 and *S. marcescens* 9M5 was assessed. The *chiA* gene cloned from *S. marcescens* 9M5 was mobilized into BF92-14, a previously identified, root-colonizing bacterium with summer patch suppressive ability. Expression of *chiA* in BF92-14 improved levels of disease control by this bacterium. In related studies, mutagenesis of the chitinase gene from *X. maltophilia* 21C6 resulted in less disease control compared to the wild type strain. The role of chitinase, combined with the effect of bacterial concentration on disease control and bacterial populations, provide supporting evidence that disease suppression is a result of a direct effect of these bacteria on pathogen inoculum within the soil.

Turf Improvement for Golf: The Role of the USGA Green Section

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National Director
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The USGA Green Section has a long history of improving turfgrasses through implementation and funding of breeding programs, developing improved cultural practices, investigating pest problems and control measures, and instituting educational programs for turf managers. A few highlights follow:

Green Section scientists investigated the basic biology of many common turfgrass pests and developed the first or improved chemical controls for weeds, insects and diseases during the 20s and 30s.

Green Section personnel researched and published the first comprehensive compendium of information about turfgrass diseases and their control (1932).

The USGA published three comprehensive books concerning turfgrass management for golf courses (1917, 1951, 1982).

Since 1921 the Green Section has published volumes of technical and practical information about turfgrass science and golf course management through a series of periodicals, including today's *Green Section Record* magazine.

The Green Section was responsible for collecting, evaluating and disseminating improved grasses that became the most widely used grasses on greens, tees and fairways during the 30s, 40s and 50s. These grasses became the gene pool for university breeding programs (many of them USGA-supported) that produced the next generation of improved grasses in the 50s, 60s, 70s and 80s.

USGA-funded research led to significantly improved playing conditions in the South through the development of improved grasses for greens, tees, and fairways. These grasses, developed in the 40s, 50s and 60s, remain today the most widely used grasses on golf courses in the South.

Green Section research in the 20s and 30s investigated fertilizer sources for turfgrass use and developed sound fertilization programs for golf courses at a time when none existed.

The Green Section researched and published the first scientifically-based specifications for putting green construction in 1960. They were considered to be a radical departure from the norm at the time, but are the standard today. The principles on which they are based are used in the construction of athletic fields, race tracks, bowling greens and other intensively trafficked areas.

Turfgrass research funded by the USGA served as a model for the establishment of turfgrass plots at several state universities in the 1920s, including California, Florida, Massachusetts, New Jersey, Nebraska, Ohio, and Pennsylvania. The USGA funded projects at many of these institutions, allowing the turfgrass knowledge base to grow more quickly than it otherwise could have.

The success of the Green Section spurred the establishment of turfgrass research studies in England, New Zealand, Australia, and South Africa during the 20s, 30s, 40s and 50s. Turfgrass research institutions eventually grew out of these initial studies in several countries.

During the 1940s and 50s, the Green Section coordinated and funded a program of providing Turf Research Fellowships to students leading to Ph.D. degrees. Many of the leaders in the turfgrass industry and in academia received their scientific training through this program and from the many research projects funded by the Green Section since that time.

From 1983 through 1994, the USGA spent $6.3 million on turfgrass improvement research projects at 22 universities. They focused on turfgrass breeding and cultivar evaluation, cultural practices, alternative pest control methods, plant stress mechanisms and screening procedures, turf improvement through biotechnology, and establishment of the Turfgrass Information File (a comprehensive turfgrass database) at Michigan State University.

From 1991 through 1993, the USGA spent $3.2 million investigating the effects of golf courses on people, wildlife and the environment. Studies focused on pesticide and nutrient fate, turfgrass benefits, and alternative pest control methods. Projects planned through 1997 will involve work on pesticide and nutrient fate modeling, including the role of turf thatch on pesticide degradation.

Looking ahead, the USGA's turfgrass research efforts will focus on using traditional breeding and biotechnology to produce new grasses for golf that use less water, require less pesticide use, and are more tolerant of environmental stresses such as cold, heat, salt and shade. Emphasis also will be placed on basic research pertaining to pest resistance and stress tolerance, and the use of this information in developing screening techniques for germplasm assessment.

Biochemical Testing of Turfgrass in the New Jersey Department of Agriculture Plant Industry Laboratory

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The technology involved in the breeding, production and marketing of plant products is expanding at a remarkable rate due to biotechnology and automation. The New Jersey Department of Agriculture (NJDA) must be able to keep pace with the expansion as it addresses its goals of protecting food crops, forests and other plant resources against injurious plant pests, and to safeguard the farmer and the public against contaminated or mislabeled seed or other plant products through inspection and certification programs.

The NJDA/Division of Plant Industry laboratory must be able to identify and regulate varietal differences in plants and plant pests. This can be done most efficiently through the use of more advanced laboratory technologies, including DNA and protein analysis, gas and liquid chromatography, and electrophoresis.

The advanced testing technology will ensure quick and accurate laboratory analysis of plants and plant pests that will enable regulators and producers to make quick and accurate decisions regarding plant production practices or regulatory enforcement actions.

Varietal identification is an area where biochemical "fingerprinting" is applicable. The following technologies are either in use in the laboratory or are about to be implemented. There are a series of "quick" chemical tests which are useful for varietal identification to a limited degree. The phenol test for Kentucky bluegrass is an example of a quick test where the varieties can be broken down into subgroups based on the color changes of the caryopsis upon exposure to phenol. More sophisticated testing involves protein and DNA analysis. Liquid chromatography of alcohol soluble seed proteins is being explored as a means of automating varietal identifications. Biochemical methods are also useful in endophyte testing. DNA analysis is useful for identification of endophyte strains. Liquid chromatography and thin layer chromatography are an important means of identifying endophyte alkaloids. Immunological techniques are useful to determine the presence of endophyte in plant tissue.

The New Jersey Plant Industry Laboratory is very interested in applying the basic research developed in the area of biotechnology at Rutgers and other universities to its regulatory and service programs.

Progress, Opportunities and Challenges In Turfgrass Breeding

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Dramatic progress has been made in the development of turf-type perennial ryegrasses and tall fescues using many cycles of phenotypic and genotypic recurrent selection on a very limited germplarm base. The most advanced breeding populations and cultivars are much darker green, lower-growing, easier-to-mow, more attractive, and produce a much denser turf. Significant advances have been made in resistance to stem rust, *Rhizoctonia* brown patch, and many leaf spot diseases; increased tolerance of wear, heat, cold, close mowing, and shade; and the effective use of *Acremonium* enhanced insect resistance. Additional improvements are needed in developing a stable resistance to crown and stem rusts, much higher levels of resistance to red thread, pink patch, and continued improvement in resistance to *Rhizoctonia* brown patch and some leaf spot diseases. New sources of elite germplasm and more effective screening and selection techniques are needed to accomplish these objectives.

Significant opportunities exist for the genetic improvement of a number of fine fescues including strong creeping red fescues, hard fescues, blue fescues and sheeps fescues. Current breeding populations of strong creeping red fescues show substantial improvements in seed yield, darker color, lower growth, and greater tolerance of close mowing and summer stress. They show moderate improvements in resistance to net blotch and good resistance to powdery mildew. New germplasm sources and more efficient selection techniques are needed to develop needed higher levels of genetic resistance to red thread and dollar spot. Strains of *Acremonium* endophytes have been found that dramatically enhance resistance to dollar spot, chinch bugs, billbugs and sod webworms. We have developed hard and Chewings fescues with a very attractive dark green color, a lower growth, a denser turf, moderate improvements in heat tolerance, improved net blotch resistance, and higher seed yields. Selected strains of endophyte have shown an ability to enhance resistance to many harmful insect pests and are also associated with a significant reduction of damage from both the dollar spot and *Magnaporthe* summer patch diseases. A better understanding and a greater utilization of endophyte - enhanced disease resistance in fine fescues and perhaps other plants is an important challenge and opportunity.

Population improvement techniques have proven to be very effective in the progressive improvement of turf performance and appearance of rough bluegrass. The development of cultivars with improved resistance to seed shattering and dollar spot are important challenges that would increase the usefulness of this specialty turfgrass.

The genus *Agrostis* contains a number of attractive low-growing species suitable for turf use. Considerable progress continues to be made in the development of cultivars of creeping bentgrass for putting-green use. However, additional improvements in pest resistance would allow substantial reduction in the amount of pesticides currently being applied to golf course greens, tees, and fairways.

Large, persistent, attractive clones of colonial bentgrass and rhizomatous types of dryland bentgrass exist in many old low maintenance turfs throughout Europe and the eastern United States. Some perform well as far south as Atlanta, GA and Birmingham, AL. All currently available cultivars of these species were developed in cold summer climates and generally perform poorly in New Jersey and other regions having warm, humid summers. All are highly susceptible to the large brown patch disease. We have initiated collection, evaluation, and breeding programs with dryland and colonial bentgrass. Future turfgrass breeders at Rutgers may want to continue and expand this program.

We applaud the accomplishments of Drs. Lisa Lee and Christina Hartman and their associates at AgBiotech in the development of exceptionally promising transgenic bentgrasses with herbicide resistance and the work of Dr. Barbara Zilinskas and her associates with enzymes which hopefully will enhance stress tolerance. Such advances will be very useful in future cultivar improvement.

The greatest challenge and opportunity for a future turfgrass breeder at Rutgers is the genetic improvement of Kentucky bluegrass. The complexities, advantages, and limitations of apomictic reproduction offer dramatic opportunities for both fundamental research contributions and practical plant improvement. We have not been able, to date, to use the highly effective population improvement program in the breeding of Kentucky bluegrass that have proven so successful in the continued genetic improvement of perennial ryegrasses, tall fescues, Chewings fecues, rough bluegrass and other cross- pollinated species. Each cycle of population improvement in these cross - pollinated species allows us to exploit and build upon the successes and advances of all previous cycles. In apomictic Kentucky bluegrasses, we essentially go back to square one with each new program of plant collection on hybridization. In fact, plant collection programs are reaching a point of diminishing returns as we continually collect the same isolines and find it increasingly difficult to find new and unique plants. Current programs of hybridization are only gradually becoming more effective as we identify better parents, improve the efficiency of obtaining increased sexual reproduction in highly apomictic plants, and develop more effective techniques to quickly identify the best new hybrids from very large progenies. In an attempt to overcome some the above imitations, we are currently attempting to develop elite populations of highly sexual, cross-pollinated Kentucky bluegrasses with high floret fertility that might be used for population improvement program.

The discovery or development of useful endophytes compatible with Kentucky bluegrass and various bentgrass species is a high priority goal of the Rutgers turfgrass breeding program. The capable assistance and contributions of Dr. James White, Dr. Lisa Lee, Dr. Faith Belanger, Dr. Cuong K. Lam, and Dr. Jon Lindstrom should be very useful.

New Concepts For Athletic Fields

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The escalating interest in sports activities, not only from the perspective of the spectator but also from the participant (athlete) has impacted upon a desire for improved surfaces for certain sports. Problems associated with synthetic surfaces have focused an increasing interest in natural turfgrass fields. Evidence of this interest is reflected in the trend at the professional and collegiate levels in the replacing of costly synthetic surfaces with natural turf.

The sensitivity of natural turf to intensive use and/or unfavorable environmental conditions is a major limitation in the satisfactory performance of turfgrasses for sports activities. Recognizing these limitations, as an employee of the Greenbay Group after retirement as Extension Specialist

In Turfgrass Management at Cook College, concepts were developed to strengthen and improve upon the adaptability of turfgrasses for sports playing surfaces. This efforts was inspired by several major contributing factors:

- An increased desire for natural turf sports playing surface
- Adaptability of sports facilities for multi-purpose use
- Natural turf playing surface mandated for the 1994 World Cup Soccer Tournament in the United States.

Concepts developed were based upon a natural turf transportable system trademarked as the ITM System (Integrated Turfgrass Management). The System consists of:

- Single Unit-Stadium of the Future (Patent Pending)
- Modular Units - Greentech (Patent granted 2/93)
- Light Weight Root Zone - Greenspec

Distinct advantages provided by the ITM System include:

- Transport and relocation of a natural turf surface
- Instant mature natural turf surface
- Flexibility to super-impose natural turf over a synthetic surface
- Flexibility to interchange configuration
  Flexibility to provide natural turf in difficult situations
- Quick replacement of wear areas
- Provide the most suitable surface for the scheduled activity
- Increased adaptability of stadia for multi-purpose use
- Culture of turf in a controlled environment when not in use

The Modular Unit Concept has been proven by:

1. Research study conducted by Dr. James Beard of Texas A&M University

2. Conversion of the synthetic surface in the Pontiac Silver Dome for World Cup Soccer

3. Rapid restoration of a practice tee for the 1993 U.S. Open Golf Tournament at Baltusral Golf Club, Springfield, NJ

Based upon these experiences in development and use, it is conceivable that concepts of this nature will enhance the adaptability of natural turf sports surfaces for athletic fields and strengthen their performance in accommodating increased flexibility and intensity in their use.

J. Murphy

Turfgrass Tolerance of Aluminum In Acid Soil

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Many turfgrass cultivars in use today are poorly adapted to acid soils. Soil acidity is a major problem in the establishment and maintenance of turfgrasses. About 40% of the world's soils are acid. Aluminum is often toxic in these soils when the pH is below 5.5. Although liming can correct surface soil acidity, subsoils may remain toxic and limit root growth that is needed for drought avoidance. A research program to screen turfgrass germplasms was initiated in January 1994. Greenhouse screening methods using solution culture, sand culture, and acid Tatum soil were used to screen collections of Kentucky bluegrass (150 genotypes) perennial ryegrass (120 genotypes), tall fescue (92 genotypes), and fine fescues (58 genotypes) for Al tolerance. Significant variation in Al tolerance was identified among species and genotypes within species. The ranking of Al tolerance for species was fine fescues, perennial ryegrass, tall fescue, Kentucky bluegrass. The findings of our research should support and strengthen the Cook College/NJAES breeding program in its efforts to develop stress tolerant turfgrass cultivars.

Phylogenetic Relationship of *Magnaporthe* spp. and Other Pathogenic Fungi of the Turf Environment

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Magnaporthe poae is the causal agent of summer patch disease of bluegrasses and fine fescues. This patch disease is difficult to diagnose due to the lack of distinctive fungal structures in nature. Previously the only definitive diagnosis involved mating the fungus in culture, which could take months to achieve. We have produced a method of identifying this fungus utilizing the polymerase chain reaction (PCR) technique. Using this method we are able to amplify DNA specifically from *M. poae* and *M. rhizophila*. The specific DNA is not amplified from the other thirty species of fungi tested. Because *M. rhizophila* is not found in North America, this method can be used to identify *M. poae* for definitive diagnosis of summer patch.

Because *M. poae* and *M. rhizophila* share morphological traits, such as similar dark hyphae which grow on C3 grass hosts and similar ascospores and perithecia, we were interested in the relationship of *M. poae* to other species of *Magnaporthe*. In addition, the cloned DNA fragment of *M. poae* used to produce the primers hybridized to an isolate of *Colletotrichum* (*Glomerella*) *graminicola* in a Southern hybridization. The isolates we focused on for this study were: *M. poae* (3 isolates), *M. rhizophila*, *M. salvinii*, *M. grisea* (2 isolates), *Gaeumannomyces graminis* var. *graminis*, *Gaeumannomyces incrustans*, *C. graminicola*, and *Leptosphaeria* (*Ophiosphaerella*) *korrae*. The spacer region of the nuclear ribosomal DNA was used for the phylogenetic analysis of these fungi because universal amplification primers have been designed which can be used to amplify DNA from a wide range of organisms, and this locus has been used previously for phylogenetic analyses.

The sequence analysis, using maximum parsimony, branch-and-bound algorithms of PAUP software, placed *M. poae* and *M. rhizophila* isolates in a monophyletic group. None of the turf pathogens formed strong unexpected monophylogenies (ie. across genera.) The analysis supports the taxonomic placement of the *G. incrustans*, *G. g.* var. *graminis*, and *M. poae* as distinct species. The close phylogenetic relationship between *M. poae* and *M. rhizophila* explains the difficulty in producing a DNA detection method that would identify all isolates of *M. poae* without detecting *M. rhizophila*.

Currently we are developing a method to transform *M. poae* with foreign DNA. This method involves producing fungal protoplasts through digestion of the cell wall, introduction of DNA, and selection of transformants using benomyl resistance. This transformation method will aid in studying the effects of potential avirulence genes and in "marking" the fungus for better viewing of the infection process. In addition, we are currently screening cultivars of Kentucky bluegrass for variations of resistance to isolates of *M. poae* which may help in studying virulence factors of the fungus.

Teaching Plant Soil Relationships With Color Images of Rhizosphere pH

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Plants and soils often do not receive their share of attention in the biology teaching laboratory despite their significance to human life and the environment. The opportunity to study complex living systems is limited by many constraints. This laboratory exercise was developed to exhibit clear, graphic results within the normal class period using relatively inexpensive materials and reasonable teacher preparation time. The exercise uses a simple imaging technique to illustrate the profound effects that living roots exert on the pH of the surrounding soil environment. Plants are grown in rhizotrons using a sandy loam soil with either nitrate or ammonium N added and with or without a nitrification inhibitor. After 4 weeks of growth, the root system is exposed and treated with fluid agar containing bromocresol purple pH indicator. Within 15 minutes, the color changes outlining the rhizosphere become visible. When N is absorbed as nitrate, an alkalization of the rhizosphere occurs and is exhibited as purple. In contrast, when N is absorbed as ammonium, an acidification of the rhizosphere occurs and is exhibited as yellow. When ammonium N is added without the nitrification inhibitor, the acidification of the bulk soil due to nitrification obscures the development of a distinct rhizosphere image. The exercise achieves visually stimulating results which can be used to reinforce lectures on how rhizosphere pH changes influence nutrient availability, plant tolerance of soil acidity, microbial activity, and plant susceptibility to diseases.

Invertase Activity in *Epicholë/Acremonium* Fungal Endophytes and its Possible Role in Choke Disease

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Subspecies of *Festuca rubra* often host fungal endophytes of the genus *Epichloë*. Endophyte-infection can confer significant advantages, such as insect resistance, to the grass hosts, but in some cases can also result in the pathological condition of choke disease. In choke disease, the developing inflorescence becomes trapped in the fungal mycelium, resulting in reduced seed yields. We have found that the choke stroma tissue contains cell wall and soluble invertase activities which are greater than ten fold higher than the activities in the subtending stem. Most of the invertase activity probably originated from the fungus. High fungal invertase activity in the stroma would improve the sink strength of the fungus for sucrose import from the plant phloem, thus providing the carbohydrate needed for the enhanced fungal growth which occurs in choke disease.

Field Performance of Herbicide Ignite Resistant Creeping Bentgrass(*Agrostis palustris L.*)

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The first field test of herbicide resistant creeping bentgrass in the USA was conducted in the summer of 1994 at the Rutgers Research and Development Center, Bridgeton, NJ. A field test permit was obtained from USDA-APHIS. Trangenic plants from bombardment experiments of three cultivars (Emerald, Putter, and Southshore) were tested for resistance to the herbicide Ignite (gluphosinate) and 1x (0.75 lb Al/A) and 3x (2.25 lb Al/A) the labeled rate. Each treatment was replicated three times in randomized plots. Vegetatively multiplied plants were transplanted into the field on pm June 9, 1994. The first herbicide treatment was applied on July 21 and herbicide tolerance ratings were made two weeks later. A second herbicide treatment was applied on September 14 and tolerance ratings were made two weeks later. More that 30 plants (three tissue clones) of Emerald and Southshore creeping bentgrass were found to be resistant to

the 3x field rate and remained green and healthy similar to untreated plants in the control plots. No control plants (Emerald, Putter, and Southshore grown from seed) survived herbicide treatment.

The resistant transgenic plants will be vernalized in the field and moved to a containment greenhouse next spring for pollination and seed production to determine the inheritance of herbicide resistance. Suitable resistant clones will be used as parents in a traditional breeding program before a resistant cultivar is made available commercially.

Greenhouse Screening Kentucky Bluegrass for Aluminum Tolerance

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Aluminum toxicity is probably the most important growth limiting factor in acid soils for many turfgrasses. The genetic diversity among turgrass cultivars for Al tolerance is not well known. One hundred-fifty Kentucky bluegrass (Poa pratensis L.) genotypes (cultivars, selections, and breeding lines) belonging to seven types were screened for Al tolerance under greenhouse conditions using solution culture, sand culture, and acid Tatum soil (a subsoil commonly used for Al tolerance screening). An Al concentration of 320 µM and a pH of 4.0 were used in solution screening and sand screening. The acid Tatum soil had 80% exchangeable Al and a pH of 4.4. The grasses were seeded to five weeks before harvesting.

Differences were identified among cultivars and the seven types by measuring relative growth. Based on the rank average of the three screening methods, 'Barzan', 'Viva', 'Nassau', '1757' were the most Al tolerant cultivars while 'Ginger', 'South Dakota Cert.' and 'Ronde' were the least. Among the seven types, BVMG types were most Al tolerant while Midwest ecotypes consistently exhibited the least Al tolerance. The results indicate that Kentucky bluegrass cultivars vary genetically in Al tolerance and there is potential to improve the tolerance with breeding and to refine management recommendations regarding soil pH.

Screening Fine Fescues for Aluminum Tolerance

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Fine fescues are generally considered acid tolerant compared to other cool season turfgrass. However, there is a lack of knowledge on aluminum tolerance of fine fescues at both the species and cultivar level. The objective of this study was to identify the cultivars of fine fescues with superior ability to tolerate Al. Those cultivars which tolerate Al will serve as genetic material for breeding more acid tolerant fine fescue cultivars.

A total of 58 cultivars of fine fescues belonging to five species or sub-species (hard fescue: 14 cultivars, Chewings fescue: 25 cultivars, strong creeping red fescue: 15 cultivars, slender creeping red fescue: 2 cultivars, and sheep fescue: 2 cultivars) were selected from the 1993 National Fineleaf Fescue Test and screened under greenhouse conditions using solution culture, sand culture, and acid Tatum soil. An Al concentration of 640 µM and a pH 4.0 were used in solution screening and sand screening. The acid Tatum soil had 80% exchangeable Al and a pH of 4.4. The grasses were seeded and grown for four weeks before harvesting. Relative growth was evaluated for Al tolerance by measuring relative root length, shoot length, root weight, and shoot weight.

Differences in Al tolerance were identified at both the species and cultivar level based on relative growth.

1. Hard fescue and Chewings Fescue were more Al tolerant than strong creeping red fescue, slender creeping red fescue and sheep fesue.

2. Among 58 cultivars, 'WX3-FF54' Chewings fescue, 'Discovery' hard fescue, 'Tiffany Chewings fescue, 'Nordic' hard fescue, and 'Ecostar' hard fescue were the most Al tolerant.

3. Within species, significant differences were found among cultivars of Chewings fescue, strong creeping red fescue, slender creeping red fescue, and sheep fescue; whereas no cultivar difference was observed in hard fescue.

4. A relationship was found between endophyte infection and Al tolerance. Fine fescues with endophyte infection generally exhibited greater Al tolerance at both the species and cultivar levels.

The results indicate that fine fescues vary in Al tolerance and there is potential to improve Al tolerance with breeding and to refine management recommendations regarding soil pH.

Evidence for a Genomic Region Involved in the Release of Pyrrolnitrin from *Burkholderia cepacia* M53

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Burkholderia (formerly *Pseudomonas*) *cepacia* M53 produces an antifungal compound which inhibits several fungal plant pathogens. The antifungal compound produced by strain M53 was identified as pyrrolnitrin by high-performance liquid chromatography(HPLC), thin layer chromatography (TLC) and mass spectroscopy. Pyrrolnitrin is a secondary metabolite which is currently being investigated by several research groups for its potential use as a natural product for control of several plant pathogens, including *Botrytis cinerea*, the causal agent of several post harvest diseases in fruits and vegetables, and *Magnaporthae poae*, the causal agent of summer patch disease in turfgrass. Several transposon Tn*5* mutants of *B. cepacia* M53 have been isolated that were reduced in their ability to inhibit the growth of *B. cinerea*. HPLC and TLC analyses of one Tn*5* mutant, 36AC1, showed a distinct decrease in the amount of pyrrolnitrin present in the culture filtrates. A cosmid clone was obtained from a *B. cepacia* M53 genomic library which restored the ability of mutant 36AC1 to inhibit *B. cinerea* in agar plate assays. The level of pyrrolnitrin in the culture filtrates of the restored mutant was greater than that of the mutant without the cosmid clone. In contrast to the culture filtrates, cell extracts from the wild type, mutant and restored mutant were all shown to contain similar levels of pyrrolnitrin. This data implies that we have isolated a fragment of genomic DNA involved in there lease of pyrrolnitrin from *B.cepacia* M53 cells.