PROCEEDINGS OF THE FIFTEENTH ANNUAL RUTGERS TURFGRASS SYMPOSIUM

Bruce B. Clarke, Director
William A. Meyer, Associate Director

January 12-13, 2006
Cook College

Symposium Organizing Committee

Daniel Giménez, Chair
Stacy A. Bonos
Bruce B. Clarke
Barbara Fitzgerald
Bradley Park

Proceedings of the Fifteenth Annual Rutgers Turfgrass Symposium

Bradley Park and Barbara Fitzgerald, Editors

Associate Director's Remarks:

Welcome to the Fifteenth Annual Rutgers Turfgrass Symposium. This Symposium was established in 1991 to provide Rutgers faculty, students, and staff and their collaborators with an annual forum for the exchange of ideas on a wide range of topics in turfgrass science. The format was expanded several years ago to include presentations by colleagues at other institutions. This year we are honored to have Dr. Lisa Vaillancourt (University of Kentucky) present the keynote address entitled, "Anthracnose Diseases of Grasses: Lessons to be Learned from the Maize System." I would also like to thank Dr. Frank Wong (University of California – Riverside), Dr. David Huff (Penn State University), Dr. Christopher Williamson (University of Wisconsin), and the Center faculty and students who have agreed to present their research findings at this year's Symposium. Without the efforts of the Symposium Planning Committee, composed of Dr. Daniel Giménez (Chair), Brad Park (Editor), Dr. Stacy Bonos, Dr. Bruce Clarke, and Barbara Fitzgerald (co-Editor), this Symposium would not have been possible.

The last few years have been an exciting time for the Rutgers Center for Turfgrass Science. Center faculty continue to be recognized for excellence in turfgrass breeding, management, biotechnology, physiology, pest science and many other fields. In 2005, Dr. Bruce Clarke became only the second faculty member at Cook College to be named to an Endowed Chair. At the conclusion of the investiture ceremony at Kirkpatrick Chapel on November 28, 2005, he was recognized as the first holder of the Ralph Geiger Endowed Chair in Turfgrass Science. I was also pleased to hear that Dr. Stacy Bonos received the Young Crop Scientist Award from the Crop Science Society of America (CSSA), and that Dr. Randy Gaugler was named an Albert Einstein Visiting Professor by the Chinese Academy of Sciences and was elected a Fellow by the Entomological Society of America. In addition, Dr. James White was named a Fellow by the American Association for the Advancement of Science and I received the C. Reed Funk Breeder's Award from the Turfgrass Breeders Association and the Recognition Award from the New Jersey Turfgrass Association.

Three of our students also received national recognition. Michelle DaCosta took first place in the Graduate Student Poster contest at the CSSA annual meeting in November, John Inguagiato received the Best Graduate Student Presentation award at the Northeastern Division of the American Phytopathological Society meeting in October, and Yan Xu won the Minority Graduate Student Poster Competition at the tri-society meeting of the CSSA, the Soil Science Society of America, and the American Society of Agronomy in Salt Lake City.

I hope that you enjoy this year's Symposium and that you take full advantage of the opportunity to exchange ideas and forge new collaborations. Thank you in advance for your participation.

Sincerely,

William A. Meyer
Associate Director

Table of Contents

FIFTEENTH ANNUAL RUTGERS TURFGRASS SYMPOSIUM

Cook College, Rutgers University
January 12-13, 2006
Foran Hall - Room 138

Thursday, January 12, 2006

7:00 - 7:30 PM	Registration
7:30 - 7:40 PM	Welcome and Introduction: **Dr. Bruce Clarke, Director - Center for Turfgrass Science**
7:40 - 8:30 PM	Keynote Address: **Dr. Lisa Vaillancourt** (Department of Plant Pathology, University of Kentucky) *Anthracnose Diseases of Grasses: Lessons to be Learned from the Maize System*
8:30 - 10:00 PM	Wine and Cheese Reception

Friday, January 13, 2006

8:30 - 9:00 AM	**Registration, Coffee and Donuts**
9:00 - 10:00 AM	**SESSION I: TURFGRASS MANAGEMENT** (Moderator: Dr. Daniel Giménez)
9:00 – 9:20	**Dr. Steve Hart** (Department of Plant Biology and Pathology, Rutgers University) *Impact of Golf Course Cultural Practices on the Efficacy of Bispyribac Sodium*
9:20 – 9:40	**Dr. James A. Murphy** (Department of Plant Biology and Pathology, Rutgers University) *Cultural Management of Newer Velvet Bentgrass Cultivars*
9:40 – 10:00	**Han Han** (Department of Ecology, Evolution and Natural Resources, Rutgers University) *Hydrological Properties of Root Zone Mixes*
10:00 - 10:30 AM	**Discussion and Coffee Break**
10:30 - 11:30 AM	**SESSION II: TURFGRASS PHYSIOLOGY AND STRESS MANAGEMENT** (Moderator: Dr. Thomas Gianfagna)
10:30 – 10:50	**Dr. Frank Wong** (Department of Plant Pathology, University of California - Riverside) *Fungicide Resistance in Colletotrichum cereale: Development, Management and Implications*

10:50 – 11:10 **Dr. Bingru Huang** (Department of Plant Biology and Pathology, Rutgers University) *A Holistic Approach to Improving Bentgrass Heat Tolerance*

11:10 – 11:30 **Michelle DaCosta** (Department of Plant Biology and Pathology, Rutgers University) *Changes in Carbon Partitioning and Accumulation Patterns During Drought and Recovery for Three Bentgrass Species*

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

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

1:30 – 2:30 PM **SESSION III: BREEDING AND CULTIVAR EVALUATION**
(Moderator: Dr. William A. Meyer)

1:30 – 1:50 **Dr. David R. Huff** (Department of Crops and Soil Sciences, Penn State University) *Parasitic Castration by a Stinking Smut Leads to a Path of Separate Sexes in Buffalograss*

1:50 – 2:10 **Dr. Stacy Bonos** (Department of Plant Biology and Pathology, Rutgers University) *The Identification of Quantitative Trait Loci for Dollar Spot Resistance in Creeping Bentgrass*

2:10 – 2:30 **Bradley Park** (Department of Plant Biology and Pathology, Rutgers University) *Response of Kentucky Bluegrass to Seasonal Applications of Simulated Wear*

2:30 - 3:00 PM **Discussion and Coffee Break**

3:00 – 4:00 PM **SESSION IV: TURF PEST SCIENCE**
(Moderator: Dr. Bruce B. Clarke)

3:00 – 3:20 **Dr. Bradley Hillman** (Department of Plant Biology and Pathology, Rutgers University) *Colletotrichum cereale, the Causal Agent of Turfgrass Anthracnose: Some Properties of the Pathogen in Agronomic and Wild Grasses*

3:20 – 3:40 **Dr. Albrecht M. Koppenhöfer** (Department of Entomology, Rutgers University) *Management of the Annual Bluegrass Weevil on Golf Courses: Developing New Approaches*

3:40 – 4:00 **Dr. Christopher Williamson** (Department of Entomology, University of Wisconsin) *Alternative, Non-Pesticide Management of Earthworm Casts in Golf Course Turf*

4:00 - 4:30 PM **Discussion/Closing Remarks**

Dr. Faith Belanger
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. Marshall Bergen
Dept. Plant Biology & Pathology
Foran Hall, 59 Dudley Road
New Brunswick, NJ 08901

Mr. Jonathan Bokmeyer
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. Stacy Bonos
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Ms. Emily Chi
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. Chee-Kok Chin
Dept. Plant Biology & Biology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Joe Clark
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. Bruce Clarke
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Ms. JoAnne Crouch
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Ms. Michelle DaCosta
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Dennis Fitzgerald
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. C. Reed Funk
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Eugene Fuzy
Dept Entomology
Blake Hall
93 Lipman Drive
New Brunswick, NJ 08901

Dr. Thomas Gianfagna
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. Daniel Gimenez
Dept. Plant Biology & Pathology
Dept. Environmental Sciences
14 College Farm Road
New Brunswick, NJ 08901

Mr. Alan Habiak
Adelphia Research Center
594 Halls Mill Road
Freehold, NJ 07728

Ms. Han Han
Ecology, Evolution & Natural
Resource Sciences
14 College Farm Road
New Brunswick, NJ 08901

Dr. Stephen Hart
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. Joseph Heckman
Dept. Plant Biology & Pathology
Foran Hall, 59 Dudley Road
New Brunswick, NJ 08901

Dr. Zane Helsel
Dept. Extension Specialist
Martin Hall
88 Lipman Drive
New Brunswick, NJ 08901

Dr. Bradley Hillman
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Josh Honig
Dept. Plant Biology & Pathology
Foran Hall 59 Dudley Road
New Brunswick, NJ 08901

Dr. Bingru Huang
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. David Huff
Penn State University
Dept. Crop & Soil Sciences
409 Agricultural Sciences & Industries
Bldg.
University Park, PA 16802

Dr. Richard Hurley
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. John Inguagiato
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. Susan Jones-Held
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. Donald Kobayashi
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. Albrecht Koppenhöfer
Dept. Entomology
Blake Hall
93 Lipman Drive
New Brunswick, NJ 08901

Ms. Christine Kubik
Dept. Plant Biology & Pathology
Foran Hall 59 Dudley Road
New Brunswick, NJ 08901

Mr. T. J. Lawson
Dept. Plant Biology & Pathology
Foran Hall59 Dudley Road
New Brunswick, NJ 08901

Mr. Pradip Majumdar
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Patrick McCullough
Dept. Plant Biology & Pathology
Foran Hall, 59 Dudley Road
New Brunswick, NJ 08901

Mr. Ben McGraw
Dept. Entomology
Blake Hall
93 Lipman Drive
New Brunswick, NJ 08901

Dr. William Meyer
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Thomas Molnar
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. James Murphy
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Ms. Cynthia Nezames
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Brad Park
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Pedro Perdomo
RCE - Morris County
P. O. Box 900
Morristown, NJ 07963-8195

Ms. Lynne Pitcher
Dept. Plant Biology & Pathology
Foran Hall, 59 Dudley Road
New Brunswick, NJ 08901

Ms. Mary Provance-Bowley
Dept Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. James Quinn
Dept. Ecology,Evolution & Natural Resources
1050 George St.
Apt. # 8K
New Brunswick, NJ 08901-1050

Dr. Shimon Rachmilevitch
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. David Rotter
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Ms. Hiranthi Samaranayake
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Robert Shortell
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Jim Snow
USGA Green Section
P. O. Box 708
Far Hills, NJ 07931

Dr. Lisa Vaillancourt
University of Kentucky
Dept. Plant Pathology
201F Plant Science Building
Lexington, KY 40546

Dr. Aurea Vasconcelos
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Eric Weibel
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Dr. James White
Dept. Plant Biology & Pathology
Foran Hall 59 Dudley Road
New Brunswick, NJ 08901

Dr. Christopher Williamson
University of Wisconsin – Madison
Dept. Entomology
246 Russell Laboratories
1630 Linden Drive
Madison, WI 53706

Dr. Frank Wong
University of California - Riverside
Dept. Plant Pathology
2317 Webber Hall
Riverside, CA 92521

Dr. Jinpeng Xing
Dept. Plant Biology & Pathology
Foran Hall 59 Dudley Road
New Brunswick, NJ 08901

Dr. Jichen Xu
Dept. Plant Biology & Pathology
Foran Hall, 59 Dudley Road
New Brunswick, NJ 08901

Ms. Yan Xu
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. John Zajac
Mountain View Seeds
P. O. Box 8
Berlin, MD 21811

Mr. David Zaurov
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. Eddie Zhang
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

Mr. George Ziemienski
Adelphia Research Center
594 Halls Mill Road
Freehold, NJ 07728

Dr. Barbara Zilinskas
Dept. Plant Biology & Pathology
Foran Hall
59 Dudley Road
New Brunswick, NJ 08901

PLENARY PRESENTATIONS

Anthracnose Diseases of Grasses: Lessons to be Learned from the Maize System

Lisa Vaillancourt
Department of Plant Pathology, University of Kentucky

Although only recently a serious concern on turfgrass, anthracnose disease caused by species of the fungal genus *Colletotrichum* are a huge problem on various host plants worldwide. Virtually every agronomic, horticultural, and ornamental crop is susceptible to one or more species of *Colletotrichum*. Symptoms of infection include postharvest rots, and anthracnose spots and blights of aerial plant parts. The members of this genus cause major economic losses, especially of fruits, vegetables, and ornamentals. In addition to their considerable economic importance, some of the *Colletotrichum* fungi have become highly significant as experimental models in studies of many aspects of fungal development, infection processes, host resistance, signal transduction, and the molecular biology of plant-pathogen interactions.

Intercellular hemibiotrophy appears to be an important feature of *Colletotrichum* pathology. Following penetration of the host epidermis, most *Colletotrichum* species grow biotrophically and feed initially on living plant cells, without penetrating the host cell plasma membrane or causing widespread cell death. After a variable period of time (the length of which depends on the species) the growth habit switches to necrotrophy, and host cell death occurs in advance of fungal colonization. The transition to necrotrophy is dramatically marked by the initiation of a destructive tissue rot. This switch in lifestyle has been associated with changes in hyphal structure, and in fungal gene expression. Many *Colletotrichum* species have the capacity to produce asymptomatic latent (quiescent) infections on various plant tissues, including unripe fruits, which places them among the most important postharvest pathogens. *Colletotrichum* fungi are also frequently found as endophytic colonizers of non-host species. Because necrotrophy is not induced at all times or in all host tissues, it is clear that there must be signals from the host and the environment that trigger the production of enzymes and other pathogenicity factors necessary for necrotrophic development. The long-term goal in my laboratory is to elucidate these signals, and to unravel the fungal response to them.

Work aimed at understanding what makes *Colletotrichum* so successful has focused on a small number of model pathosystems. One of these, the only one involving a monocot host, is maize anthracnose, caused by *C. graminicola*. Although the pathogen causing turf anthracnose has also been referred to by this name, significant evidence has now accumulated showing that the two diseases are actually caused by different species. Phylogenetic analyses indicate that both belong to a monophyletic clade comprised of several closely related falcate-spored species affecting various monocot hosts. *C. graminicola* has been the subject of intensive study since the early 1970s, when it suddenly began to cause severe epidemics on maize in the United States. Although the removal of highly susceptible germplasm from commercial maize varieties has successfully limited its impact, anthracnose is still ubiquitous in the north and central Corn Belt.

We have taken two basic approaches to understanding *C. graminicola* pathogenicity. One is to identify genes that play important regulatory roles in the ability of *C. graminicola* to colonize maize necrotrophically. We created a bank of nearly 2000 random insertional mutants of *C. graminicola*. More than 1200 of these were screened for pathogenicity to leaves and to detached stalk pieces. Three nonpathogenic mutants of *C. graminicola* were identified. One of these has become the focus of our research, because this mutant initiates the biotrophic phase of the disease normally, but fails to persist or induce rot in leaves or stalks. The affected gene (which we have called CPR1) encodes a predicted protein that is similar (30%) to one component of the eukaryotic signal peptidase enzyme, a key component of the protein transport system, which is located in the endoplasmic reticulum (ER) membrane. It is easy to understand why protein transport would be important for necrotrophic growth and especially rotting, but it is harder to see why it would not also be essential for saprophytic growth and for the early stages of infection and biotrophic colonization. Yet, curiously, the mutant is almost normal in these aspects, and secretion in vitro also appears to be almost normal. Although our experiments are still incomplete, they suggest the interesting possibility that the CPR1 gene product may be involved in quantitative and qualitative regulation of fungal secretion in response to environmental (e.g, nutritional) cues. The mutant has also provided evidence for the efficacy of basal resistance pathways in controlling pathogen ingress, and has indicated that these basal pathways must be suppressed either by pathogen activity or by host stress (e.g. low light, drought, reproduction, aging) for necrotrophic colonization to occur.

We have also been working on more thoroughly characterizing the interaction of *Colletotrichum* with maize on a cellular level. The combination of cytology with molecular genetics is particularly powerful. We have used various means, including expression of heterologous fluorescent proteins, to visualize fungal structures in host tissues. We have observed that hyphae associated with necrotric tissues have a particular morphology that is distinct from the hyphae that are initially responsible for invading living cells. We have also found that the colonization of fibers is extremely important in rapid colonization and spread of the pathogen in leaves and stalks. We have been surprised to that, even after the necrotrophic switch has occurred, tissues at the margins of lesions apparently continue to be invaded biotrophically. This appears to differ from descriptions of hemibiotrophic development in *C. lindemuthianum*, a pathogen of the dicot *Phaseolus*. However, it is similar to infection by *C. sublineolum*, a pathogen of sorghum. It is possible that there are important differences between the monocot-infecting clade of *Colletotrichum* fungi and other groups within this genus.

Impact of Golf Course Cultural Practices on the Efficacy of Bispyribac Sodium

Stephen E. Hart and Patrick M. McCullough
Department of Plant Biology and Pathology, Rutgers University

Bispyribac-sodium (BS) selectively controls annual bluegrass in creeping bentgrass but turfgrass chlorosis following applications warrants research to mitigate these effects without reducing efficacy for annual bluegrass control. Field and greenhouse experiments were conducted in New Jersey to investigate effects of nitrogen (N) and trinexapac-ethyl in application programs with BS. In greenhouse experiments, ammonium nitrate was applied to creeping bentgrass at 6, 12, or 24 kg N/ha/wk beginning two weeks before BS applications at 0, 74, 148, and 296 g a.i./ha. Increased N rate enhanced quality of non-BS treated bentgrass but exacerbated chlorosis from BS. In field experiments on creeping bentgrass and annual bluegrass fields, N treatments included: (1) withholding N 2 or 4 weeks before BS treatments, (2) increasing N to 24 or 48 kg/ha 2 weeks before BS treatments, or (3) continually applying N at 12 kg N/ha every 2 weeks. Applications of BS were 0, 74, or 148 g a.i./ha and all treatment combinations were used. N by BS interaction was not detected for creeping bentgrass chlorosis as continually applying 12 kg/ha biweekly provided the best overall quality. Increased N rates enhanced bentgrass quality the day of BS applications but did not influence bentgrass response to BS. Creeping bentgrass chlorosis generally increased with BS rate but was < 20% of untreated and recovered within 2 to 3 weeks. All N treatments reduced dollar spot from unfertilized turf by approximately 50% while BS applied at 74 and 148 g/ha reduced dollar spot coverage by 43 and 71% from non-BS treated, respectively. Annual bluegrass, grown in a monostand indigenous field, receiving increased N rates had reduced chlorosis from BS applied at 74 g/ha but not BS at 148 g/ha. Annual bluegrass chlorosis from sequential BS applications in mid-June generally was not affected by N applications in July likely because N was only increased prior to initial applications. Continually applying N at 12 kg/ha biweekly provided best annual bluegrass quality but did not reduce BS control. Annual bluegrass seedhead cover was reduced from non-BS treated by 70 and 95% from BS at 74 and 148 g/ha, respectively. By early July, sequential BS applications at 74 and 148 g/ha controlled annual bluegrass by 40 and 95%, respectively.

Greenhouse experiments with trinexapac-ethyl (TE) applied at 0 or 0.05 kg/ha at 0, 1, or 2 weeks prior to BS applications reduced creeping bentgrass chlorosis when applied prior to BS applications. Field experiments conducted on creeping bentgrass and annual bluegrass fields revealed no BS by TE interaction for any parameters measured. Applications of TE at 0.05 kg/ha had no influence on BS efficacy for annual bluegrass control when applied before or tank mixed with BS at 111 g/ha while TE applied before or tank mixed enhanced creeping bentgrass tolerance to BS. Tank mixing BS with TE in emulsifiable concentration, microencapsulated concentration, or as a wettable powder all equally mitigated bentgrass chlorosis from sequential BS treatments. In June and July, creeping bentgrass treated with TE on 1 June and 21 June had 50% less dollar spot coverage than non-TE treated while BS reduced dollar spot coverage approximately 80% from non-BS treated. Applications of BS in June reduced annual bluegrass cover 98% by July. Overall, applying TE at 0.05 kg/ha before or tank mixed with BS appears to mitigate creeping bentgrass chlorosis from BS without compromising annual bluegrass control while maintaining moderate N fertility (12 kg/ha/2 wks) provided best bentgrass quality without influencing annual bluegrass control from BS.

Cultural Management of Newer Velvet Bentgrass Cultivars

James A. Murphy, T.J. Lawson, Hiranthi Samaranayake, and John Inguagiato
Departments of Plant Biology and Pathology, and Extension Specialists, Rutgers University

Velvet bentgrass (*Agrostis canina* L.) is a prostrate, stoloniferous grass that produces a turf with fine-leaf texture and very high shoot density. H.B. Sprague (1945) stated that velvet bentgrass "…has the widest range of usefulness of any species". Others, however, have indicated the adaptation of velvet bentgrass is rather narrow, limited to mild temperate climates. More recently, trials in New Jersey indicated that velvet bentgrasses warrant further study. Thus, research is needed to better describe the adaptation of velvet bentgrass before this species will gain wider acceptance in the industry. Issues needing attention include assessment of factors related to a seedling disease that hinders establishment and management techniques required to produce acceptable playing surface quality on putting greens.

Establishment of velvet bentgrass can be difficult due to a seedling disease tentatively identified as a *Pythium* species. Two trials were conducted on Nixon sandy loam to assess 1) impact of soil pH, cultivar and seeding rate and 2) mefenoxam (Subdue) fungicide and seeding rate on disease development. Seeding rates of 2.4 g m^{-2} (0.5 pound per 1000 ft^2) or lower had substantially less damage from disease than 4.9 or 9.8 g m^{-2} of seed (1 and 2 pounds per 1000 ft^2, respectively). Soil pH had no obvious effect on the disease but a subtle increase in cover was observed at the lowest soil pH. The two cultivars evaluated in the study had a similar response to the disease; however, the amount of cover established varied due to 'EFD' having lower viable seed content than 'Greenwich'. Mefenoxam fungicide did not control the *Pythium* seedling disease nor did this fungicide affect ground cover during establishment in 2003 and 2004. Thus, an effective fungicide control for this *Pythium* disease on velvet bentgrass remains unknown. Limiting the seeding rate for velvet bentgrass to no more than 4.9 g m^{-2} can reduce development of this seedling disease. Seeding at rates less than 2.4 g m^{-2} will hinder establishment.

A trial area seeded to 'Greenwich' velvet bentgrass on a Nixon sandy loam in 2003 was established during 2004 as a putting green turf. The objective of this trial was to evaluate the management techniques of nitrogen fertilization, light-weight rolling, grooming, and growth regulation for effects on the quality of the putting green playing surface. The trial was initiated June 2005 and included the treatment factors and levels of:

- i) N fertilization at 4.9 g m^{-2} wk^{-1} or 4.9 g m^{-2} $month^{-1}$
- ii) Rolling 3 times wk^{-1} or no rolling
- iii) Grooming (0.05 inch depth) 2 times wk^{-1} or no grooming
- iv) Growth regulation with trinexapac-ethyl (Primo MAXX 1MC) at 0.4 L ha^{-1} every 14-d or no growth regulation

Plots were mowed daily with a triplex greens mower bench set at 3.2 mm. Irrigation was applied as needed to prevent wilt stress. Topdressing was applied every 2 weeks and incorporated with a coca drag mat. Playing surface quality was evaluated on each plot by measuring ball roll distance and turf quality and color.

All management factors produced obvious and expected affects on turf color. Except for N fertilization, color differences had no correspondence with visual putting quality ratings; greater N fertilization improved both color and putting quality on 7 June 2005. Application of trinexapac-ethyl and grooming reduced turf color and rolling improved turf color, yet, as mentioned previously, these practices did not initially affect visual putting quality. Ball roll distance data from late June generally supported the visual ratings on 7 June; that is, management factors (except rolling on 20 June) did not affect ball roll distance (a measure of putting green quality).

N fertilization and grooming were significant main effects on ball roll by 27 July when grooming and lower N fertilization increased ball roll distance. Application of trinexapac-ethyl did not alter ball roll distance on the velvet bentgrass putting green turf. Grooming had the largest effect on ball roll and increased ball roll by as much as 0.3-m (12 inches) for this initial set of ball roll data.

Moreover, this initial data set indicated that velvet bentgrass can be managed to attain ball roll distances that would be acceptable at many golf course facilities. A ball roll distance range of 2.9 to 3.2 m (114 to 126 inches) is a common management target recommended for putting greens in the northeastern United States. Our data indicated this range for ball roll distance would not be difficult to achieve on Greenwich velvet bentgrass.

Hydrological Properties of Root Zone Mixes

Han Han[1], Daniel Giménez[2], and James A. Murphy[3]
[1]*Department of Ecology, Evolution and Natural Resources, Rutgers University*
[2]*Department of Environmental Sciences, Rutgers University*
[3]*Department of Plant Biology and Pathology, Rutgers University*

Saturated hydraulic conductivity, K_s, is an essential parameter for predicting transport processes through soils. Measurements of K_s are notoriously variable. Thus, it is desirable to have predictive models of K_s based on available soil properties (texture, bulk density, particle size distribution and porosity) to facilitate modeling efforts at a regional scale and as a check of potential disparate measurements. Among the most successful K_s models are those that use a characteristic particle diameter or effective porosity raised to a constant or variable power and modified by a linear constant. One such model is the one proposed by Rawls *et al*. (Trans. ASAE 41: 983-988; 1998) that uses effective porosity (defined as air-filled porosity at a matric potential of -33 kPa) modified by a power representing a pore distribution index (defined as the change in porosity between -33 kPa and -1,500 kPa) and by an empirical linear constant . Our hypothesis is that the prediction of K_s can be improved by using information of water retention at relatively low matric potentials (indicative of macroporosity). A recently proposed theory that relates soil physical quality to the inflection point of water retention curves can be used to generate information at low matric potentials, which is generally absent in large databases. Consequently, our objective was to modify Rawls *et al*. (1998) model by redefining effective porosity, the power (pore distribution) index, and the linear constant with a combination of parameters derived from water retention information at low matric potentials.

Twenty-three sandy materials from New Jersey were sampled and measured for particle-size distribution, water retention curves, and K_s. The same properties of 213 New Jersey horizons, 77 horizons from the UNSODA database, 13 rootzone mixes, and 48 Alabama horizons were added to the original database. Water retention curves were fitted with the van Genuchten (Soil Sci. Soc. Am. 44: 892-898, 1980) model and the parameters of the model used to analytically determine the water retention inflection points. Modifications introduced to the Rawls *et al*. (1998) model included: 1) defining a new effective porosity (as air-filled porosity at the inflection point) and power index (change is porosity between saturation and the inflection point), and 2) expressing the linear constant as a function of the pore diameter at inflection point and of the power index. All samples were grouped into 17 textural classes. The coefficient of correlations between the measured values of K_s and those predicted with the proposed model was $R^2 = 0.95$ when comparing the 17 textural averages, and $R^2 = 0.72$ when comparing all 374 values. Further testing of the model with 1,729 data points (grouped in 11 textural classes) from the European HYPRES database produced similar results ($R^2 = 0.98$). The residuals of the fitting were randomly distributed indicating no apparent bias in the prediction. The proposed model is physically sound, contains no fitting parameters, and uses information that can be obtained from pedotransfer functions. With site specific data the model has the potential to be used in investigations at the field scale.

Fungicide Resistance in *Colletotrichum cereale*: Development, Management and Implications

Frank P. Wong, Sharon L. Midland and Karla de la Cerda
Department of Plant Pathology, University of California Riverside

Turfgrass anthracnose has become more prevalent and more difficult to manage on annual bluegrass and creeping bentgrass putting greens in many locations in the U.S.. A partial cause for this is the development of fungicide resistance that has made a number of available chemistries and spray programs less than effective in controlling the diseases. In addition to a number of multi-site, contact fungicides, there are five classes of site-specific fungicides that are registered currently for anthracnose control which are at risk for resistance development: benzimidazoles, phenylpyrroles, polyoxins, Qo-inhibitors (QoIs), and sterol biosynthesis inhibitors (SIs).

In our work, we have focused primarily on evaluating the occurrence, distribution and mechanisms of benzimidazole, QoI and SI resistance in California populations of *C. cereale*. Five hundred fifty eight isolates of C. cereale were collected from 10 locations across California from annual bluegrass affected by anthracnose. Two of these populations were baseline populations that had not been treated with fungicides, while the other eight were locations with a record of chronic anthracnose and poor control with fungicide spray programs.

For QoI sensitivity, isolates were tested by use of a mycelial expansion assay with azoxystrobin amended media. The mean 50% effective dose (ED_{50}) of the baseline populations was 0.038 µg/ml. For the remaining eight fungicide exposed locations, nearly all of the isolates recovered were highly insensitive to azoxystrobin, with ED_{50} values above 8 µg/ml (> 200 × decrease in sensitivity). Cross resistance to pyraclostrobin and trifloxystrobin was demonstrated as well for 40 isolates taken from a resistant population. Mitochondrial cytochrome$_b$ sequences obtained from QoI-resistant isolates (corresponding to amino acid residues 98 through 170) indicated a guanine to cytosine replacement at nucleotide 427 corresponding to glycine to alanine replacement at amino acid residue 143 of the protein. No other mutations or amino acid replacements were detected in sequences of the characterized isolates, including any at amino acid position 129.

To examine sensitivity distributions to benzimidazoles, isolates were tested against thiophanate-methyl using fungicide amended media. Mean baseline ED_{50} values were 0.75 µg/ml, but isolates from the eight exposed locations did not respond to concentrations as high as 30 µg/ml. Subsequent sequencing of a 459-bp fragment of the beta-tubulin 2 gene from insensitive isolates covering amino acid residues 137 to 290, revealed a guanine to adenosine replacement in nucleotide 592, corresponding to a glutamic acid to lysine substitution at amino acid residue 198.

Isolates were tested for sensitivity to the SI-fungicide propiconazole. The two baseline population mean ED_{50} values were 0.0094 and 0.15 µg/ml. The remaining eight population means ED_{50} values were 2 to 9 × greater, indicating a shift in population sensitivities. The impact of these shifts is not completely understood, but does indicate selection for SIinsensitivity. Sensitivity to myclobutanil, tebuconazole and triadimefon were also tested, and generally, sensitivities were positively correlated. ED_{50} values were 0.75, 0.090 and 5.6 µg/ml, respectively, showing clear differences in SI-intrinsic activity, suggesting that more active SI-fungicides be used when possible.

Sensitivity distributions for fludioxonil have been partially completed, and the results suggest that there us a large range of sensitivities for *C. cereale* to this fungicide. Field studies suggest that this fungicide can be effective for anthracnose management in locations with resistance to benzimidazoles, QoIs and SIs.

The overall impact of these studies implicates fungicide resistance as one reason for the lack of control for this disease in California. As a result, caution should be used in using QoI and benzimidazole chemistry as resistance appears common in some locations. For SI-fungicide use, it does appear that the shifts in sensitivity are not as strong as compared to QoIs and benzimidazoles. There are clear differences in the intrinsic activity of the four tested fungicides which implies that ones with the highest intrinsic activity be used preferentially. Other chemistries are available for anthracnose control and no resistance issues have yet been identified; these should be used judiciously and wisely as resistance development can occur with these as well. The potential lack of fungicidal options for anthracnose control does underline the need to use as many cultural and non-fungicidal controls as possible to manage the disease.

A Holistic Approach to Improving Bentgrass Heat Tolerance

Bingru Huang
Department of Plant Biology and Pathology, Rutgers University

Plants growing in natural environments are constantly subjected to environmental stresses. High temperature is a major factor limiting growth of cool-season grass species in many areas during summer months. Grass species and cultivars vary in their tolerance to heat stress. The question is why some grasses thrive under stressful conditions while others fail. Once the mechanisms of plant tolerance to heat stress are understood, management strategies can be developed to enhance these mechanisms; and breeders/biotech methods may be able to impart or enhance these in the next grass generation. A holistic approach has been taken in my lab to explore mechanisms of heat tolerance in *Agrostis* species at whole-plant, cellular, and molecular levels. Leaf senescence is a typical symptom of heat injury in turfgrass species. Delaying leaf senescence or stay-green is one of the most desirable traits for improving turf quality. Using a gene encoding isopentenyltransferase (ipt) controlling cytokinin synthesis, we successfully transformed bentgrass with Agrobacterium-mediated transformation technique. Some transgenic plants exhibited increased or maintained cytokinin content in leaves exposed to heat stress. Detached leaves from transgenic plants exhibited delayed senescence and improved heat tolerance. Whole-plant heat tolerance is yet to be tested. Our molecular work has identified some unique gene fragments associated with heat tolerance in thermal *Agrostis scabra*, which could be used as markers to select for heat tolerant creeping bentgrass and other cool-season turfgrass species.

Changes in Carbon Partitioning and Accumulation Patterns During Drought and Recovery for Three Bentgrass Species

Michelle DaCosta and Bingru Huang

Department of Plant Biology and Pathology, Rutgers University

Efficient carbon distribution and utilization may enhance drought survival and recovery ability for perennial grasses. The objectives of this study were to examine changes in carbon partitioning and carbohydrate accumulation patterns in shoots and roots of colonial (*Agrostis capillaris* L.), creeping (*A. stolonifera* L.), and velvet (*A. canina* L.) bentgrasses in response to drought and re-watering following drought, and to determine whether species variation in drought tolerance and recuperative potential is related to differences in the patterns of carbon partitioning and accumulation. The experiment consisted of three treatments: (i) well-watered control; (ii) drought, irrigation completely withheld for 18 d; and (iii) drought recovery, a group of drought-stressed plants were re-watered at the end of the drought treatment (18 d). Drought tolerance and recuperative ability of three species was evaluated by measuring turf quality and leaf relative water content. These parameters indicated that velvet bentgrass was most drought tolerant while colonial bentgrass had highest recuperative ability among the three species. Plants were labeled with $^{14}CO_2$ to determine carbon partitioning to shoots and roots. Carbohydrate accumulation was assessed by total nonstructural carbohydrate (TNC) content. The proportion of newly photosynthesized ^{14}C partitioned to roots increased at 12 d of drought compared to the pre-stress level, to a greater extent for velvet bentgrass (45%) than for colonial (35%) and creeping (30%) bentgrasses. In general, the proportion of ^{14}C was highest in roots, intermediate in stems, and lowest in leaves at 12 d of drought treatment for all three bentgrass species. As drought duration and severity increased (18 d), ^{14}C partitioning increased more in leaves and stems relative to that in roots for all three species. Stem TNC content was significantly greater for drought-stressed plants of colonial and velvet bentgrasses compared to their respective well-watered control plants, whereas no differences in stem TNC content were observed between drought-stressed and well-watered creeping bentgrass. Our results suggest that increased carbon partitioning to roots during initial drought stress represented an adaptive response of bentgrass species to short-term drought stress, and increased carbon partitioning and carbohydrate accumulation in stems during prolonged period of drought stress could be beneficial for rapid recovery of turf growth and water status upon re-watering.

Parasitic Castration by a Stinking Smut Leads to a Path of Separate Sexes in Buffalograss

Ambika Chandra and David R. Huff

Department of Crop and Soil Sciences, Pennsylvania State University

Here we present a smut fungus-perennial grass system of parasitic castration that down-regulates a female-sterility gene, *Tasselseed2* (*Ts2*), resulting in the formation of female sex organs (pistils) in otherwise male plants of dioecious buffalograss; a condition known as induced hermaphrodism. Because the fungus also dramatically increases pistil production in both male and female plants and only sporulates in pistil ovaries, we refer to the stinking smut fungus as "pistil smut". We found that pistil smut increases host sexual reproductive allocation by altering meristem determinacy and resource partitioning within infected plants. The fungus also diverts allocation from male sex organs towards female pistils thereby enhancing its survival through sporulation. Therefore, it seems reasonable that if only one sex is parasitized then any host mutation that would allocate resources to the opposite sex would have a selective advantage. We postulate that such a selective advantage enabled *Ts2* to evolve as a post-infection basal resistance gene against pistil smut virulence in the hermaphroditic ancestor of buffalograss. If true, the establishment of a female-sterility gene within a population would result in an androdioecy (males and hermaphrodites). We present a model detailing the further evolution of buffalograss from androdioecy towards dioecy citing other developmental, mutation, and population genetic models. The ensuing coevolution of an over-riding virulence mechanism by pistil smut, down-regulating *Ts2* in buffalograss, thus reverts male host plants back to a more primitive morphological state resulting in a "retrophenotype".

The Identification of Quantitative Trait Loci for Dollar Spot Resistance in Creeping Bentgrass

Stacy A. Bonos, Christine Kubik, Joshua Honig and Eric Weibel
Department of Plant Biology and Pathology, Rutgers University

The objectives of the project were to create a genetic linkage map of creeping bentgrass using genomic SSRs (microsatellites) and subsequently identify Quantitative Trait Loci (QTL) associated with dollar spot disease (caused by the fungus *Sclerotinia homoeocarpa*) resistance. To do this, an intra-specific pseudo F_2 mapping population of creeping bentgrass was created from a cross between a dollar spot resistant and a susceptible genotype. Approximately 180 microsatellite markers have been identified. Sixty-eight are currently being genotyped in the mapping population. One hundred and twelve have been completed and were used to develop the genetic linkage map presented. The data for the 112 genotyped SSR markers were transformed into Single Dose Allele (SDA) markers. A genetic linkage map was developed for each parent using JoinMap 3.0. The dollar spot susceptible parent linkage map consisted of 96 SDA markers assigned to 15 linkage groups (8 markers unlinked) covering 640cM. The dollar spot resistant parent linkage map consisted of 101 SDA markers assigned to 14 linkage groups (9 markers unlinked) covering 661cM. Additional markers will be necessary to saturate the linkage map however these markers were sufficient to develop an initial SSR linkage map of creeping bentgrass.

Additionally, a field trial containing replicated plants of the 180 pseudo F_2 progeny and 450 F_3 and backcross progeny was planted in the fall of 2002 and inoculated with one isolate of the dollar spot fungus in the spring of 2003 and evaluated for dollar spot disease in 2003 and 2004. Phenotypic dollar spot data of the mapping population was compared to molecular marker data to identify QTLs associated with dollar spot resistance. Three putative QTL loci (one in the susceptible parent and two in the resistant parent) have been identified using interval mapping in MapQTL 5.0 and confirmed with one-way ANOVA and Kruskal-Wallis analysis.

As more markers are added to the map these results may change slightly. The ultimate goal will be to identify 14 distinct linkage groups and cover a larger percentage of the genome. This research will be useful to the advancement of turfgrass breeding and genetics. The SSR markers developed can be used as simple, easily automated markers to compare and join other creeping bentgrass maps. Once QTL's are confirmed, marker-assisted selection can be incorporated into a breeding program to quickly screen germplasm for resistant plants.

Response of Kentucky Bluegrass to Seasonal Applications of Simulated Wear

Bradley S. Park, James A. Murphy, T.J. Lawson, Hiranthi Samaranayake,
Robert Cashel, and Vincent Campbell
Department of Plant Biology and Pathology, Rutgers University

Kentucky bluegrass (*Poa pratensis* L.) is often established on highly used sports fields and individual cultivars may differ greatly in their responses to traffic. Many better performing Kentucky bluegrass cultivars tested under traffic during summer months have a long winter dormancy. Thus, evaluation of cultivar performance under traffic during spring and fall is also needed since these are the seasons when the majority of traffic (i.e., soccer, football, and lacrosse) occurs on sports fields. Cultivars of Kentucky bluegrass were seeded in 2002 on a Nixon sandy loam and a study was initiated in spring 2004 with the objective to determine seasonal wear tolerance and recovery among Kentucky bluegrass cultivars. The experimental design was a split-plot with three replications. The whole (main) plots were the season of traffic (none, spring, summer, and fall); subplots were the cultivars. Wear was applied to Kentucky bluegrass cultivars using a modified Sweepster in 2004 and 2005. Sixteen passes of a wear simulator were applied per week over a six-week period (96 total passes) for each season (spring [April-May], summer [July-August], and fall [October-November]). All plots were visually rated for turfgrass performance and recovery throughout the test period. Turfgrass performance was assessed visually utilizing a 1-9 scale (9=best performance). Fullness of turfgrass cover was also visually rated on a 0-100% scale (0%=complete defoliation of turfgrass cover; 100%=full turfgrass canopy). Cores (surface area=8.0 cm^2) were sampled from nine Kentucky bluegrass Types immediately after wear treatment. The cultivars sampled included: 'Princeton 105', 'Midnight', 'Langara', 'Jefferson', 'Julia', 'Brooklawn', Cabernet', 'Coventry', and 'Touchdown'. Verdure (aerial shoots remaining after mowing) and tiller numbers were determined from core samples. Initial data analysis indicated that the performance of some cultivars was dependent on the season in which wear was applied.

Data analysis is underway. Initially (2 weeks after the initiation of treatment), wear during the spring was more damaging than wear in the summer or fall. However, as wear treatment continued (weeks 4 and 6) damage was less under spring wear than summer and fall. This was probably due to the greater vigor of turf after dormancy was completely broken in mid-spring compared to the vigor of turf during the summer and fall. Cultivar response to wear differed; however, the relative differences among cultivars was dependent on the season of wear. For example, the loss of verdure after wear varied among cultivars for spring and summer wear but there were no differences among cultivars for fall wear treatment. Julia lost the least amount of verdure compared to all other cultivars when wear was applied in the summer 2004. The verdure lost after spring wear in 2004 was least for Julia and four other cultivars and greatest for Touchdown, Langara, and Cabernet. The poor response of Touchdown to wear was notable since this cultivar has been commonly recommended for use on sports fields. Results from the complete data analysis are expected to provide the basis for season-specific Kentucky bluegrass cultivar recommendations for sports turf.

Colletotrichum cereale, the Causal Agent of Turfgrass Anthracnose: Some Properties of the Pathogen in Agronomic and Wild Grasses

Bradley I. Hillman, Jo Anne Crouch, and Bruce B. Clarke

Department of Plant Biology and Pathology, Rutgers University

Anthracnose basal rot and foliar blight are diseases of increasing importance on annual bluegrass (*Poa annua*) and creeping bentgrass (*Agrostis stolonifera*) nationwide. As anthracnose diseases have increased in prevalence, their variability in terms of symptom severity and responses to control measures have become increasingly apparent. We have been investigating whether some of the variability in these diseases is attributable to variability in the causal agents themselves. This has led us to examine the fungus in highly managed golf course settings and in more natural prairie settings.

When we initiated this project a few years ago, the causal agent of anthracnose disease of pooid grasses was designated *Colletotrichum graminicola*, the same species as the pathogen that causes anthracnose of corn. Research from several laboratories had suggested that there were sufficient differences between the pathogens of pooid grasses and corn to classify them separately, but this question had not been answered systematically. We have used a variety of molecular and morphological tools of to compare more than 100 *Colletotrichum* isolates from turfgrasses and several prairie grass species in the *Pooideae* with established *Colletotrichum* isolates of other species. These studies show unambiguously that the turfgrass pathogens are not the same species as either the corn or the sorghum pathogens. We have resurrected the original name *C. cereale* for pathogens of pooid grasses. Whether or not *C. cereale* will be further subdivided remains to be determined. There are now more than 800 monoconidial *Colletotrichum* isolates in our collection to help determine the structure of the species.

The first tool we used to examine the diversity of this fungus within and among populations was repetitive genetic elements such as transposons and retrotransposons. From two distinct fungal *C. cereale* lineages, four novel transposable element sequences were identified and developed as tools to characterize population variability through RFLP fingerprinting. In addition to their use initially to differentiate between fungal lineages, RFLP banding patterns were used to support the phylogenetic analysis described above. One of the preliminary conclusions from the RFLP analysis was that some of the fungal isolates appeared to represent hybrids between the two main lineages. Interestingly, highly elevated AT-nucleotide composition was observed in many of the transposons, suggesting that cycles of repeat induced point mutations (RIP), a genome defense system employed by fungi against repetitive DNA, was active at some point during the species evolution. Since RIP acts only during the sexual cycle, this observation provides evidence that recombination played a role in the evolutionary history of this organism. This is interesting both at the theoretical level and at the practical level: *C. cereale* is currently classified as an asexual fungus, with no sexual stage having been identified in nature or in the laboratory. If host range differences have been one of the drivers in the evolution of this fungus, the ability of these lineages to recombine sexually may have important implications for host range.

Management of the Annual Bluegrass Weevil on Golf Courses: Developing New Approaches

Albrecht M. Koppenhöfer and Benjamin A. McGraw
Department of Entomology, Rutgers University

The annual bluegrass weevil (*Listronotus maculicollis*) (ABW) is a highly destructive pest of well maintained, short turfgrass in the northeastern United States. The weevil will feed upon many species and varieties of grasses, but damage is most evident on annual bluegrass (*Poa annua*). Larval feeding early in the year can leave patches of bare turf in high value turf areas around the golf course. Turfgrass managers rely heavily upon the use of chemical pesticides to manage weevil populations from reaching damaging levels.

Optimizing the use of presently available and new synthetic insecticidal compounds

As a base for our further studies, we have summarized data from insecticide efficacy tests published between 1993 and 2003 (Arthropod Management Tests Vols. 18 – 28). The summary shows that pyrethroids were the most effective insecticides with no significant difference among the different compounds (bifenthrin, 93%, cyfluthrin, 87%; Deltamethrin, 84%; lambda-cyhalothrin, 97%; overall average, 90%). To achieve the best ABW control rates, it is presently recommended to apply pyrethroids against the overwintered adults between full bloom of forsythia and full bloom of flowering dogwood. However, our summary revealed no difference between pyrethroid applications in late April (4/15 – 5/3; 89%) and early May (5/4 – 5/15; 93%). In addition, recent research has shown no difference in bifenthrin efficacy between applications in late April (87%), early May (91%), or late May (88%), indicating that at least this pyrethroid has also very good efficacy as a curative application against the larvae (Koppenhöfer, unpublished data). For chlorpyrifos, the old standard for ABW control, the summary indicated that this organophosphate was more effective when applied in early May (83%) or late May (80%) than in late April (62%), indicating a combined effect on adults and larvae. In contrast, the organophosphate trichlorfon was ineffective when applied in late April (0%) and early May (25%) but provided 79% control as a curative in late May.

Many golf courses with ABW infestations use multiple sprays in spring to achieve adequate suppression of the adult stage and to avoid damage from feeding from the larvae produced from the eggs they lay. In some areas more applications are needed against later generation adults and larvae. Multiple sprays against each weevil generation strongly suggest the development of insecticide resistance, particularly to the predominantly used pyrethroids. Most of the newer less hazardous chemistry appears to lack the efficacy and consistency to replace pyrethroid applications, i.e., the neonicotinoids imidacloprid (52%) and clothianidin (69%, but highly variable and limited data thus far) and the insect growth regulator halofenozide (48%). However, a new compound from a new insecticide class, the anthranilic diamides, has shown great promise in recent trials with 80 / 95 / 84% control when applied in late April / early May/ late May (Koppenhöfer, unpublished data).

Entomopathogenic nematodes for ABW management

With the increasing pressure from government agencies and the general public to reduce pesticide use on golf courses and the absence of any alternatives at this time, there is a dire need to develop effective ABW control options with reduced environmental and health hazards and that are more IPM-compatible and, ideally, more sustainable. Entomopathogenic nematodes (EPN) have provided good to excellent control of various other weevil pests such as citrus weevils in citrus, black vine weevil in ornamentals, and billbugs in turfgrass. EPN also have the potential to provide control of more than one pest generation. A limited number of tests against ABW indicate that *Steinernema carpocapsae* is more effective when applied as a curative against the larvae in late May (51%) than against the adult in late April or early May (30% and 44%, respectively).

Since *S. carpocapsae* has achieved up to 98% in late May applications, we are planning to further investigate this species as we believe that we may be able to optimize its use. In addition, we are planning to test various other nematode species that are already commercially available, i.e., *Heterorhabditis bacteriophora*, *H. megidis*, *S. feltiae*, *and S. kraussei*. The latter three species are active at lower temperatures than *S. carpocapsae* and may therefore also be tested against adult ABW in late April/early May. We have initiated laboratory studies to determine the virulence of these EPN species against the various ABW life stage and to test the effect of temperature on their virulence. Ultimately, we are planning to field-test the most promising EPN under field conditions.

A statewide survey of New Jersey golf courses was initiated in June of 2005 in order to find entomopathogenic nematodes (EPNs) that naturally infect annual bluegrass weevil (ABW). Nematode field-isolates may prove to be better adapted to ABW as a host and/or the golf course environment and will therefore be included in our above described virulence studies. Soil samples were collected from historically ABW infested sites on 11 golf courses in 5 counties in central and northern New Jersey. Seven of the sites had ABW present in the samples and two of the sites contained larvae infected by EPNs. EPN-infected stages were late-instar larvae or pupae. 98% were infected by *Heterorhabditis* sp. (probably *bacteriophora*) and 2% by *Steinernema* sp. (probably *carpocapsae*). EPNs were detected in the soil of 29% of all samples with 34% of isolates being *Heterorhabditis* sp. (probably *bacteriophora*) and 66% *Steinernema* sp. (probably *carpocapsae*).

Interactions between endemic ABW and EPN populations

Seasonal dynamics of ABW and native EPN were monitored weekly on a golf course in Monmouth County with high densities of ABW. The course did not apply pesticides in the fairways to control ABW and consequently, large numbers of larvae and infected individuals were found in several areas across the course. Transects were established on three fairways in order to describe the relative abundance and distribution of ABW and endemic EPNs, as well as interactions between the two. The ecology and spatial distributions of endemic EPN are poorly understood and epizootic outbreaks are rarely documented, however, such information could prove useful in the selection of biocontrol agents and development of future management plans.

The density of ABW adult populations exhibited three peaks from June until September. Peaks occurred on June 16 for the 1st generation (produced from eggs laid by overwintered adults), 5 weeks later (July 21) for the 2nd generation, and another 3 weeks later (August 11) for the 3rd generation. Densities of adult were significantly higher in the 1st generation than in the following two generations (148 weevils per m^2 vs. 15 and 9 per m^2). No adult weevils were found in the fairways after August 11.

Peak density for 1st through 4th instars (L1 – 4), 5th instars (L5) and Pupae (P) occurred on the first sampling date (June 6). It is difficult to assess the overall seasonal dynamics for the immature stages since a significant part of the year's data (egg laying from the overwintering adult population and subsequent progeny) was uncollected. Nevertheless, the peak of larvae in our data correlates well with degree day models (150 DD) established in the laboratory.

Alternative, Non Pesticide Management of Earthworm Casts in Golf Course Turf

Christopher Williamson
Department of Entomology, University of Wisconsin-Madison

Earthworms can be highly problematic on golf course turf due to the earthen casts that they produce. Earthworm casts often disrupt uniformity, appearance, and playability of the surface. Additionally, casts can drastically impede the ability of turfgrass plants to photosynthesize due to surface sealing which can result in turf damage or death. *Lumbricus terrestris* is the predominant earthworm species on golf courses in the northern United States. The objective of this research project was to evaluate the effectiveness of several non-pesticide management strategies for suppression of earthworm casts on golf course turf. Two field studies, 2002-03, were conducted on golf course fairways where an endemic population of earthworms occurred. The results of the 2002 study revealed that Black Jack (processed coal slag) was statistically similar to a convention fungicide and insecticide in suppressing earthworm casts. In 2003, the fungicide treatments were significantly more effective in suppressing earthworm population compared to all other treatments, regardless of spray volume (407.3 and 814.6 liters of water per ha^{-1}). All of the angular soil aggregates tested resulted in significantly fewer earthworm casts than the untreated control. Lastly, no significant difference occurred among the three soil aggregates tested, regardless of fractionation size or time of application (spring, fall, or a combination of spring and fall). This study provides valuable information to golf course superintendents seeking alternative, non-chemical control options for suppression of earthworm casts.

POSTER PRESENTATIONS

Selection for Brown Patch Resistance in Tall Fescue

Jonathan M. Bokmeyer, Stacy A. Bonos, and William A. Meyer
Department of Plant Biology and Pathology, Rutgers University

Tall fescue (*Festuca arundinacea*) is a cool season turfgrass used widely in home lawns, parks, and athletic fields. Brown patch, caused by the fungus *Rhizoctonia solani*, is one of the most devastating diseases that occurs on tall fescue. Currently, applications of chemical fungicides are the only effective management practice to reduce disease severity. An alternative solution to the use of chemical treatments would be through the development of resistance cultivars by modern breeding techniques. Breeding cultivars for resistance to turfgrass pathogens has been successful for gray leaf spot (*Pyricularia grisea*) resistance in perennial ryegrass and dollar spot (*Sclerotinia homoeocarpa*) resistance in creeping bentgrass. Replicated field trials of experimental clonal selections of tall fescue were conducted at two locations in central New Jersey to evaluate the broad sense heritability of brown patch resistance. Two field trials were planted in April of 2005 as mowed spaced-plants at Adelphia and North Brunswick and consisted of 270 genotypes replicated 6 times in a randomized complete block design. To ensure uniform disease pressure, each field trial was inoculated with two isolates of *Rhizoctonia solani* that were grown on sterilized Kentucky bluegrass seed at a rate of 0.2g/m^2. After inoculation, cultural practices that favored the disease were implemented. Visual disease ratings were taken on a weekly basis when symptoms of the disease appeared using a scale of 1-9, with 9 representing the least amount of disease. Significant differences among tall fescue genotypes to brown patch were observed. Disease ratings ranged from an average of 7.2 to 3.7. While there was a large amount of variation among the different tall fescue genotypes, disease ratings were consistent over both locations for most individual genotypes. The broad sense heritability of brown patch resistance was calculated at H= 0.76. This result indicates that brown patch resistance in tall fescue is under genetic control and selection for resistance should be possible.

Evaluating the Interaction Between the Gray Leaf Spot Pathogen *Magnaporthe grisea* and the Biocontrol Bacterium *Lysobacter enzymogenes.*

Emily Chi, JoAnne Crouch, Donald Y. Kobayashi, and Bradley I. Hillman

Department of Plant Biology and Pathology, Rutgers University

The bacterium *Lysobacter enzymogenes* has been previously examined as an antagonist of the turfgrass root pathogen *Magnaporthe poae*, the causal agent of summer patch disease. In addition to the application of *L. enzymogenes* for biocontrol of *M. poae*, this research yielded exciting results regarding the mechanisms of pathogenesis of a bacterium on a fungal host. Although the control of *M. poae* in turfgrass systems is of practical interest, in general this organism has not been well studied and thus represents a poor model for the examination of molecular bacterial-fungal interactions, whereas its close relative *Magnaporthe grisea* (synonym: *Pyricularia oryzae*) is an ideal fungal pathogen in this respect.

The fungus *M. grisea* is the causative agent of gray leaf spot in tall fescue, St. Augustinegrass, annual and perennial ryegrasses, and other divers turfgrass species, constituting a serious problem for the turfgrass industry. *M. grisea* also causes rice blast in *Oryza sativa* and parasitizes a number of other cereals. It is often considered the most important disease of rice, which is the number one staple crop worldwide. Consequently, research on *M. grisea* has been vigorous; the pathogen is well-characterized as a model system, the genome has been sequenced, and a large-scale expressed sequence tag (EST) library has recently been made available.

Interaction between *M. grisea*, which can be cultured and induced to sporulate and initiate infection away from the host plant, and *L. enzymogenes* will be analyzed using microscopy, growth assays, and molecular methodology. In particular, we will assess conidial adhesion, conidial germination and appressorium formation, and pathogenicity as measured against a standard disease severity index. Preliminary characterization of single-spore isolates from four sampling sites included assays for vegetative growth and conidiation rates, determination of mating type, and sequencing of the ITS gene for taxonomic positioning purposes. We expect that insight into the *Lysobacter*-*Magnaporthe* interaction may aid in the development of novel approaches for the management of plant diseases caused by fungal agents.

Assessing Population Structure Among Divergent Lineages of *Colletotrichum cereale* Pathogenic to Cool-Season Turfgrass Species in North America

Jo Anne Crouch[1], Frank Wong[2], Lane P. Tredway[3], Tom Hsiang[4], Bruce B. Clarke[1], and Bradley I. Hillman[1]

[1]*Department of Plant Biology and Pathology, Rutgers University*
[2]*Department of Plant Pathology, University of California Riverside*
[3]*Department of Plant Pathology, North Carolina State University*
[4]*Department of Environmental Biology, University of Guelph, Ontario, Canada*

Colletotrichum cereale (formerly known as *C. graminicola* [2]) is a filamentous fungus that inhabits a wide range of cool-season grasses and causes anthracnose disease in turfgrass species, particularly *Poa annua* and *Agrostis stolonifera*. Although *C. cereale* was first described in association with members of the Pooideae grass family in 1909 (5), this organism was considered of no real consequence: it rarely if ever caused disease, and was generally limited to the northeastern part of the United States. The fungus was described intermittently throughout the 20th century, making transitory appearances in turf, rye, wheat, oats and orchardgrass (e.g. 1, 3, 4, 5, 6). Today, anthracnose disease on turf is present in all parts of North America and since the early 1990s is considered one of the most significant threats to *P. annua* turf. Despite its increasing importance as a pathogen and the potential for far-reaching impacts to both natural and agro-ecosystems, surprisingly little is known about genetic diversity and geographic distribution within the species.

In this collaborative study, we investigate *C. cereale* population structure and demographic history in turfgrass ecosystems by means of detailed spatial sampling of contemporary populations. An extensive culture collection of *C. cereale*, catalogued according to longitude and latitude coordinates, has been assembled from 97 stands of cultivated turf from the United States and Canada, with 530 strains currently in pure culture. Four main lineages of *C. cereale* have been recognized through multi-locus nucleotide sequence analysis, and a single haplotype has been identified as the ancestral genotype for the numerically dominant lineage in North America (2). A set of novel simple sequence repeat (SSR) markers (microsatellites) has been developed using a hybrid capture protocol to generate hypervariable genotypic data for fine-scale population analyses: 54 SSR loci have been identified, and primer pairs from 21 polymorphic loci have been readied. Using traditional measures of population diversity, Bayesian estimates of population subdivision and coalescent-based analyses of microsatellite variation, this research assesses effective population size, migration, patterns of dispersal and local demes, recombination rates and gene flow across the four extant *C. cereale* lineages. The results from this study will be compared to similar data drawn from a sample of ~800 *C. cereale* strains collected from cool-season grass species in 18 prairie grasslands and 15 wheat fields across seven states, providing an excellent contrast of pathogenic vs. non-pathogenic *C. cereale* population structure. This detailed examination of *C. cereale* in turf, cereal crops and natural grassland communities will significantly advance our understanding of how this important pathogen is distributed across North America.

References

1. Baxter, A.P., G.C.A. van der Westhuizen, and A. Eicker. 1983. Morphology and taxonomy of South African isolates of *Colletotrichum*. South African J. Bot. 2:259-270.

2. Crouch, J.A., B.B. Clarke, and B.I. Hillman. 2006. Unraveling evolutionary relationships among the divergent lineages of *Colletotrichum* causing anthracnose disease in turfgrass and corn. Phytopathology 96(1): 46-60.

3. Kemp, G.H.J., Z.A. Pretorius, and J. Smith. 1991. Anthracnose of wheat in South Africa. Phytophylactia 23:177-179.

4. Minussi, E., and H. Kimati. 1979. Taxonomy of *Colletotrichum graminicola* (Ces.) Wils. (sensu Arx, 1957). Rev. Centro Cienas Rurais 9:171-187.

5. Selby, A.D., and T.F. Manns. 1909. Studies in diseases of cereals and grasses. Ohio Agr. Expt. Sta. Bul. 203:186-236.

6. Smith, J.D. 1954. A disease of *Poa annua*. Journal of the Sports Turf Research Institute:344-353.

Genetic Improvement of Perennial Plants for Food, Feed, Fiber, Timber, Bioenergy, and Environmental Enhancement

C. Reed Funk and Thomas Molnar

Department of Plant Biology and Pathology, Rutgers University

Agricultural scientists and practitioners have made remarkable contributions during the past 60 years in increasing world food production. During the 50-year period from 1950 through 1999, world population increased 2.3 times from 2.6 billion to 6.0 billion. Grain production increased 2.9 times, soybean 9.1 times, meat 4.9 times, fertilizer use 9.6 times, and oil 7.3 times, natural gas 12.3 times, automobiles in use 9.8 times, and carbon emissions 3.9 times. Nutritious, highly palatable food and other agricultural products are available today at the lowest real cost in human history. More has been added to agricultural productivity during the past 60 years of the Green Revolution than was previously added since the dawn of history. This remarkable achievement has been vital to whatever peace, prosperity, and progress we now enjoy. The need to produce enough food for an additional 3 billion people projected to populate the earth in the next 50 years, eliminate world hunger, provide the kinds of food desired by increasingly affluent societies, stabilize climates, and reduce the use of fossil fuels by dramatic increases in production of biofuels will require not only a continuation of the Green Revolution, but also a very significant expansion.

This expanded Green Revolution should involve the genetic and cultural improvement of hundreds of species of perennial grasses, legumes, shrubs, and trees. These perennial species can be grown sustainably on millions of hectares unsuited for the production of cultivated annual crops. Their continual ground cover, deep root systems, season-long photosynthesis, nutrient storage and recycling abilities, etc., allow them to be potentially more productive than cultivated annuals, reduce or eliminate erosion by wind and water, recharge water into the atmosphere to increase precipitation in dryer regions, prevent floods, resist short-term droughts, prevent leaching and runoff of nitrates and pesticides, provide windbreaks, shade and wildlife habitat, increase diversity and beauty, and harvest carbon dioxide to mediate, reduce, or perhaps even reverse global warming.

Planting trillions of genetically improved trees in their rapid growth stage, and restoring soil organic matter and fertility would greatly increase world biomass production. Tree crops have a high labor requirement compared to cultivated monocultures of corn, soybeans, wheat, cotton, sorghum, etc. Individual trees must be planted, cared for, and harvested. This makes them well suited for perennial polycultures and intercropping with native vegetation. It is readily adaptable to small land holders and stable small communities. This would be of great benefit to providing useful employment to millions of producers and service personnel including teachers, health care professionals, merchants, bankers, etc. It would help equalize world incomes, reduce poverty, and promote peace and prosperity. It could reduce excessive population growth by giving women freedom, prosperity, education, and security.

The future prosperity of the turfgrass industry is dependent on future peace and prosperity; fertile soil; ample water, fuel and other resources; and a benign climate. As individuals we are interested in conserving resources and making the world a better place for our children and all the future generations. The challenges of accomplishing these goals make this an exciting future for all engaged in agricultural research, education, practice, and leadership.

At Rutgers, exciting progress is being made in the genetic improvement of underutilized perennial crop plants for improved nutrition, ample amounts of bioenergy, environmental enhancement, timber, and soil improvement. Valuable new sources of germplasm are being assembled and very promising plants are being identified in field, laboratory, and greenhouse trials. These include attractive plants with many ornamental characteristics; black walnuts, Persian (English) walnuts, and hazelnuts producing nuts within two or three seasons after direct seeding in the field; genetic resistance to many diseases and insect pests; greater winter-hardiness; later bud break to escape spring frosts and the walnut blight disease; dramatic increases in nut size and kernel fill; better flavor; greater biomass production; etc. Three recent papers have been published as feature articles in HortScience, one a cover article. Other articles and research proposals addressing critical issues of food security, agricultural sustainability, bioenergy, and global warming are being prepared. These programs could be of significant importance to the nursery industry and residents of New Jersey, agricultural and environmental research and practice throughout the world, human health and nutrition, energy independence, and global prosperity.

Development of Best Management Practices for Controlling Anthracnose and Maintenance of Ball Roll Distance

John C. Inguagiato, James A. Murphy, and Bruce B. Clarke
Department of Plant Biology and Pathology, Rutgers University

Annual bluegrass (*Poa annua*) putting green turf can be extensively damaged by anthracnose caused by the fungus *Colletotrichum cereale*. The objective of this field study was to evaluate anthracnose severity and ball roll distance in response to selected putting green mowing and rolling practices during 2004 and 2005. Treatments were arranged in a factorial combination using a split-split plot design with four replications. Mowing height (2.8-, 3.2-, and 3.6-mm) was the main plot, mowing frequency (7 times wk^{-1} or 14 times wk^{-1}) was the subplot, and lightweight vibratory rolling (rolling every other day vs. no rolling) was the sub-subplot. The area was maintained according to standard putting green management practices for the Northeast region. Nitrogen (ammonium nitrate) was applied at 4.9 kg N ha^{-1} every 7- or 14-d. The study was treated with trinexapac-ethyl (Primo MAXX 1MC) at 0.4 L ha^{-1} every 14-d to facilitate low mowing. Dollar spot and brown patch were controlled with vinclozolin (Curalan 50 EG; 3.1 kg ha^{-1}) and flutolanil (ProStar 70W; 6.1. kg ha^{-1}) applied as needed every 7- to 14-d (previous studies had determined that neither fungicide controlled anthracnose). The area was lightly sand topdressed and brushed with a Coco mat every 14 days. Hand watering was done as needed to prevent wilt stress.

Symptoms from a naturally occurring outbreak of anthracnose were apparent by 29 July 2004 and 15 June 2005. Disease severity was greatest at the 2.8-mm mowing height, while plots mowed at 3.6-mm incurred the lowest levels of disease in both 2004 and 2005. Raising mowing height from 2.8-mm to 3.2-mm or 3.6-mm reduced anthracnose 7-38% or 22-74%, respectively, over the two year study. A significant interaction between mowing height and frequency on four rating dates in 2004 was noted, which generally indicated that no difference in anthracnose was observed when mowing at a 2.8- or 3.2-mm height on the 7 times wk^{-1} schedule, whereas turf maintained at 2.8-mm had more disease than the 3.2-mm height of cut at the 14 times wk^{-1} mowing frequency. A mowing height by frequency interaction was not observed in 2005. There was no effect of mowing frequency on anthracnose in 2004 except on one date when disease severity was lower under 3.2-mm mowing at 14 times wk^{-1}, compared to 3.2-mm mowing at 7 times wk^{-1}. Mowing frequency did not effect disease development in 2005. Lightweight rolling every other day consistently reduced anthracnose 9-24% compared to non-rolled plots in 2004. Rolling also reduced disease severity in 2005 under moderate disease pressure; however, rolling had no effect by August 2005 when disease pressure became overwhelming (i.e., 75-95 % turf area infected).

Ball roll distance responded to all main effects similarly in both years with no significant interactions observed. All possible combinations of mowing frequency and rolling at the 2.8- and 3.2-mm mowing heights achieved the acceptable ball roll distances established for this study (i.e., 2.9 to 3.2 m). An acceptable ball roll distance at a 3.6-mm mowing height was only obtained under a mowing frequency of 14 times wk^{-1} and/or rolling every other day; however, the combination of double cutting and/or rolling with the 3.6-mm (highest) mowing height also dramatically reduced anthracnose severity.

Irrigation Frequency Requirement for Creeping Bentgrass (*Agrostis stolonifera* L.) Under Golf Course Fairway Conditions

Stephen McCann and Bingru Huang

Department of Plant Biology and Pathology, Rutgers University

'L-93'creeping bentgrass was examined at a fairway mowing heights (3/8 inch) to compare variation in irrigation frequency requirements and to develop Crop Water Stress Index (CWSI) values. The CWSI is a technique that uses the measurement of canopy surface temperature and air temperature to infer water stress status and whether irrigation is needed. Treatments included irrigation at four intervals: 1) three times per week (Monday, Wednesday, Friday); 2) two times per week (Monday and Friday); 3) once per week (Friday); and 4) biweekly (every other Monday). This field project was conducted in a fully automated, mobile rainout shelter (35' x 60') at Rutgers University Horticultural Farm II, allowing for strict control of irrigation frequency and amount. CWSI values were calculated using air and surface canopy temperature measurements and is expressed as the ratio of actual canopy and air temperature difference to the maximum canopy and air temperature difference of a plant. Results demonstrate that CWSI values below 0.40 result in acceptable turf quality. Additionally, irrigating at 100% ET, three times a week may not be necessary to sustain plant growth and physiological processes, and that this can be depended on time of year. Generally, irrigating once or twice a week and replacing 100% of ET was adequate to maintain acceptable turf quality during summer months. Watering at the 14-day interval was not sufficient to maintain acceptable turf quality.

Temperature Influences Efficacy of Bispyribac-sodium, Primisulfuron, and Sulfosulfuron

Patrick E. McCullough and Stephen E. Hart
Department of Plant Biology and Pathology, Rutgers University

As new herbicides are introduced to the turfgrass industry, information is warranted regarding parameters that influence efficacy for weed control and turfgrass safety. Field experiments were conducted from 2002 to 2004 in New Jersey with bispyribac-sodium, primisulfuron, and sulfosulfuron to investigate seasonal application timings of these herbicides. These experiments noted inconsistent herbicide efficacy in spring, summer, and fall which likely resulted from the influence of temperature on herbicide activity. To test this hypothesis, three growth chamber experiments were conducted to investigate influence of temperature on bispyribac-sodium, primisulfuron, and sulfosulfuron efficacy.

Responses of annual bluegrass and creeping bentgrass were tested in experiments with bispyribac-sodium (BS) applied at 0, 37, 74, 148, 222, or 296 g a.i./ha at 10, 20, or 30° C. At 10º C, BS reduced annual bluegrass clippings 20 to 80% from untreated after 4 weeks but caused ≤ 20% chlorosis. Annual bluegrass grown at 20 and 30º had clipping reductions ranging 40 to 100% from the untreated with ≈ 40 to 80% chlorosis. Creeping bentgrass chlorosis ranged 10 to 50% 4 WAT at 10º and clippings were reduced 20 to 60% from untreated turf. At 20º, bentgrass clipping reductions and leaf chlorosis from BS were 0 to 20% of the untreated 4 WAT. Increased temperature to 30º caused 0 to 20% bentgrass chlorosis from BS but clipping yield reductions increased 20 to 40% of untreated turf. Results confirm seasonal BS efficacy variability from field experiments resulted from increased BS efficacy for annual bluegrass control at warmer temperatures with minimal bentgrass discoloration while cooler temperatures had minimal efficacy on annual bluegrass and increased bentgrass chlorosis.

Responses of creeping bentgrass, Kentucky bluegrass, and roughstalk bluegrass were tested with sulfosulfuron at 0, 5.6, 11.2, 22.4, or 44.8 g a.i./ha/3 weeks at 15, 20, or 25º C. Creeping bentgrass tolerance to sequential sulfosulfuron treatments increased with temperature while Kentucky bluegrass generally had minimal (< 10%) chlorosis at all temperatures. Roughstalk bluegrass was most sensitive to sulfosulfuron with greater chlorosis at 15 and 25º (up to 75%) than 20º (up to 65%).

Responses of annual bluegrass, Kentucky bluegrass, and roughstalk bluegrass were tested with primisulfuron at 0, 26, 52, 104, or 208 g a.i./ha/3 weeks at 15, 20, or 25º C. As temperature increased, sensitivity to primisulfuron of all three bluegrasses generally increased. Kentucky bluegrass was most tolerant to primisulfuron but sequential applications at 25° caused 11 to 34% chlorosis from untreated. Sequential primisulfuron applications on annual and roughstalk bluegrass caused substantial leaf chlorosis (40 to 100%) at 15 and 20° but caused complete desiccation at 25° (100% chlorosis) at all rates after 6 weeks. Primisulfuron inhibited Kentucky bluegrass growth ≈50 to 100% from untreated while annual and roughstalk bluegrass growth was inhibited 100% from untreated following sequential applications. Results confirm better primisulfuron efficacy in summer than fall from field experiments in New Jersey resulted from greater leaf chlorosis and growth inhibition at higher temperatures.

Evaluation of Solu-Cal as a Soil Amendment for pH Adjustment

Mary C. Provance-Bowley and Joseph Heckman
Department of Plant Biology and Pathology, Rutgers University

Turfgrass managers are often presented with alternative soil additives; one such product that has come to our attention is called Solu-Cal. This product has been suggested as an alternative to the use of agricultural limestone. A study was, therefore, conducted to evaluate Solu-Cal by comparing how it affects the chemistry of an infertile sandy loam soil with an initial pH of 4.9 to that of common agricultural limestone products. According to the product label, Solu-Cal is described as a material derived from calcium carbonate and calcium oxide, however, no calcium carbonate equivalent (CCE) is listed on the package. The product appears as a gray pelleted material, with a pellet size ranging from 1-4mm. Baker's Pulverized Dolomitic Limestone (CCE=105.6%, ENV=95.0%, Ca=21.4%, Mg=12.1%) and Pelleted Pro Limestone (CCE=97.1%, ENV=85.8%, Ca=34.8%, and Mg=2.4%) were compared to Solu-Cal by applying various rates of the materials to the acidic soil. The amended soils were allowed to incubate for 137 days at 21°C in pots kept moist in the laboratory. Following incubation soil samples were analyzed by the Mehlich-3 soil test and soil pH was measured. Results showed that for an application rate of 10 mg/kg (equivalent to 10 tons/acre) soil pH was increased more by Baker's Dolomitic Pulverized Limestone (pH 7.2), followed by Pelleted Pro Limestone (pH 6.3), and lastly by Solu-Cal (5.5). Although Solu-Cal was less effective at neutralizing soil acidity, the Mehlich-3 soil test results for exchangeable calcium showed that this product supplied similar amounts of calcium to the soil as did traditional liming materials. The Solu-Cal, as compared to the liming materials, did little to increase the level of exchangeable magnesium. The results of this study indicate that Solu-Cal can be a useful calcium source, but it is less effective than traditional liming materials at neutralizing soil acidity.

Carbon and Nitrogen Balance in Relation to Heat Tolerance

Shimon Rachmilevitch[1], Hans Lambers[2], and Bingru Huang[1]
[1]*Department of Plant Biology and Pathology, Rutgers University*
[2]*School of Plant Science, University of Western Australia*

Adjustments in carbon and nitrogen assimilation and allocation patterns may play a role in plant adaptation to environmental stresses. We studied changes in assimilation and allocation patterns of carbon and nitrogen associated with plant tolerance to high soil temperature for two *Agrostis* species: thermal *Agrostis scabra*, a species adapted to high-temperature soils in geothermal areas in Yellowstone National Park, and two cultivars of a cool-season species, *A. stolonifera* (creeping bentgrass), 'L-93' and 'Penncross'. Roots of *A. scabra* and both *A. stolonifera* cultivars were exposed to soil temperatures of 37^{o}C or 20^{o}C, while shoots were exposed to 20^{o}C. Net photosynthesis rate (Pn), photochemical efficiency (Fv/Fm), NO_3^--assimilation rate, and root viability decreased with increasing soil temperatures in both species. However, the decreases were less pronounced for *A. scabra* than for both *A. stolonifera* cultivars. Carbon investment in growth of plants exposed to 37^{o}C decreased more dramatically in both *A. stolonifera* cultivars than in *A. scabra*. Nitrogen allocation to shoots was greater in *A. scabra* than in both creeping bentgrass cultivars at 37^{o}C soil temperature. Better tolerance of *A. scabra* to high soil temperature was related to more efficient carbon- and nitrogen-allocation patterns. Thermal *A. scabra* invested more carbon for growth of roots exposed to high soil temperatures, and more nitrogen for shoots exposed to the low temperature, as compared with both cultivars of *A. stolonifera*. Our results demonstrate that plant tolerance to high soil temperature could be related to efficient expenditure and adjustment of carbon- and nitrogen-allocation patterns for growth and respiration.

Colonial Bentgrass Genetic Linkage Mapping

David Rotter[1], Stacy A. Bonos[1], William A. Meyer[1], Scott Warnke[2], and Faith C. Belanger[1]

[1]*Department of Plant Biology and Pathology, Rutgers University*
[2]*United States Department of Agriculture, Beltsville, MD*

Creeping bentgrass (*Agrostis stolonifera* L.), an important turfgrass species, is highly susceptible to dollar spot disease caused by the fungus *Sclerotinia homoeocarpa* F.T. Bennett. Colonial bentgrass (*A. capillaris* L.) is a closely related species that generally has good dollar spot resistance. Interspecific hybrids between creeping and colonial bentgrass have been made and several hybrids exhibited excellent resistance to dollar spot (Belanger et al., 2004). One hybrid in particular, named TH15, had excellent resistance, as well as many desirable morphological traits. This plant was crossed with a creeping bentgrass plant to create a backcross population, which exhibited a wide range of phenotypical traits. Some of the individuals exhibited excellent dollar spot resistance originating from the colonial bentgrass genome. We are interested in identifying the genetic basis of dollar spot resistance in colonial bentgrass. Our approach is to generate a genetic linkage map of colonial bentgrass using this backcross population. By identifying colonial specific markers and tracking their segregation in this population we can use the colonial component of the hybrid genome to create a genetic linkage map of colonial bentgrass.

Expressed sequence tag (EST) libraries of creeping and colonial bentgrass have been made and have been functionally characterized. Using an interspecific hybrid and our backcross population for mapping provides a unique opportunity to take advantage of this sequence information. The sequence data will be mined for single nucleotide polymorphisms (SNPs) between colonial and creeping bentgrass homologous sequences. These SNPs can be evaluated by a technique known as minisequencing. This involves a single base extension of a polymorphic locus by using a fluorescent dideoxynucleotide. The resulting labeled primer can be visualized either by polyacrylamide gel or DNA sequencer. Using this method we can follow the inheritance of colonial bentgrass genes, as identified by colonial bentgrass SNPs, in the mapping population.

This technique is currently being used in combination with other gene based and AFLP based markers to create a genetic linkage map of colonial bentgrass.

Reference

Belanger F.C., S.A. Bonos, and W.A. Meyer. 2004. Dollar spot resistant hybrids between creeping bentgrass and colonial bentgrass. Crop Sci. 44:581-586.

Organic Matter Accumulation on Amended Sand Root Zones

Hiranthi Samaranayake, James Devaney, T.J. Lawson, and James Murphy

Departments of Plant Biology and Pathology, and Extension Specialists, Rutgers University

Sand-based root zones are commonly used for construction of golf course putting greens. The accumulation of organic matter on root zones is one factor influencing cultural management practices on putting greens. The role of the underlying root zone and growing microenvironment in organic matter accumulation is not well understood. The objective of this field study was to investigate organic matter accumulation on 6- and 8-yr old putting green root zones in two microenvironments. Eight root zone treatments were arranged in a randomized complete block design replicated four times in two microenvironments with replications nested within microenvironments. The open microenvironment had good air circulation compared to the enclosed microenvironment. Root zones differed in amendments and included loam, sphagnum or reed sedge peat, clay-based porous ceramic or nutrient-charged clinoptilolite zeolite. The study was seeded with 'L-93' creeping bentgrass (*Agrostis stolonifera* L.) in May 1998 and established to a putting green turf by May 1999. Cultural management of plots was typical for putting green turf in the northeastern United States.

Field water infiltration through the surface 51-mm was lowest on plots amended with the highest rate of loam and peat in 2003; however, saturated hydraulic conductivity of the surface 51-mm in 2003 did not fully corroborate the infiltration data. The amount and concentration of organic matter in the mat layer was greatest on root zones amended with higher rates of loam and peats in 2003 and 2005. Physical property measurements of the mat layer in 2005 indicated that bulk density of this surface layer did not vary across root zone treatments. However, pore size distribution data in 2005 indicated that treatments with a finer pore system in the mat layer corresponded with plots having lower field water infiltration in 2003.

Saturated hydraulic conductivity of the organic matter-rich mat layer was 49% lower than that of the root zone for data averaged over all root zone treatments in 2005. The pore size distribution data indicated that the mat layer had greater air-filled porosity and capillary porosity than the root zone. Thus, pore system of the surface mat layer while larger than the root zone on a per volume basis must be more tortuous.

Organic matter accumulation in the mat layer was greater on root zones grown in the open microenvironment than the enclosed microenvironment in 2003. Yet field water infiltration and saturated hydraulic conductivity through this layer were greatest in the open microenvironment. This suggested that pore system of the mat layer was less tortuous in open microenvironment compared to the enclosed microenvironment. Thus, the biomass accumulation above sand based root zones can substantially impact surface water retention and flow characteristics on putting greens.

The Inheritance of Morphological Characteristics in Kentucky Bluegrass (*Poa pratensis* L.)

Robert R. Shortell and Stacy A. Bonos
Department of Plant Biology and Pathology, Rutgers University

Kentucky bluegrass is a popular turfgrass species with a wide range of genetic diversity. This diversity results in many distinct cultivars that can fill a large number of environmental niches. The purpose of this study was to evaluate the broad-sense heritability of various important morphological characteristics. A Kentucky bluegrass spaced-plant nursery was established in the fall of 2002 at Rutgers University, Plant Science Research Station located in Adelphia, New Jersey. One hundred and seventy-three Kentucky bluegrass cultivars and selections entered into the 2000 National Kentucky Bluegrass test sponsored by the National Turfgrass Evaluation Program (NTEP) were planted in a randomized complete block design with twelve replications. Morphological measurements were taken after anthesis during the late spring of 2004 and 2005. Measurements included: mature plant height, plant spread, panicle length, and flag leaf height, width, and length. Broad-sense heritability estimates were calculated for all morphological measurements. Mature plant height, plant spread, panicle length, and flag leaf height showed high heritability: H = 0.80. Flag leaf length was slightly less heritable, H = 0.71. Flag leaf width was not heritable H = 0.17. The low heritability estimate observed for flag leaf width could have been due to the condition of the plants at the time the measurements were taken. Overall, these results indicated that most of the morphological characteristics in Kentucky bluegrass exhibited high heritability. Since hybrid vigor is fixed in Kentucky bluegrass through apomixis, the broad-sense heritability estimates calculated here are useful for breeding Kentucky bluegrass. Based on these results, it should be possible to select for specific morphological characteristics and fix these characters into new Kentucky bluegrass cultivars through the facultative apomictic breeding behavior of Kentucky bluegrass.

Differential Expression of Genes Associated with Thermaltolerance in *Agrostis*

Jichen Xu, Bingru Huang, and Faith Belanger
Department of Plant Biology and Pathology, Rutgers University

Our previous studies have shown that thermal *Agrostis scabra* collected from the thermal sites in Yellow Stone National Park was better tolerant to heat stress than *Agrostis palustris*. This study was designed to compare their gene expression profiles between these two species using differential display analysis (Delta Differential Display Kit). Total RNA was extracted from leaves exposed to a normal growth temperature (20^{o}C, control) or to 40^{o}C for a week (heat stress). With the transcript cDNA, 20 pairs of primers were tested. Forty-two down regulated and Forty-four up regulated gene fragments were identified in both species. Of the up regulated gene fragments, 13 were found only in the thermal species, *A. scabra*. Sequence analysis of some genes fragments showed that the down-regulated genes are more related within photosystem chain, but up-regulated genes are highly involved in the signaling pathway as other stress, such as signaling/regulatory components, and target gene expression involved in the secondary metabolism. All these cloned fragments are in the confirmation by northern or virtual northern hybridization.

Protein Induction and Degradation Associated with Heat Tolerance in *Agrostis* Species

Yan Xu, Alice T. Gao and Bingru Huang

Department of Plant Biology and Pathology, Rutgers University

Heat stress is a major factor limiting growth of cool-season grasses in the transitional and warm climatic regions. Heat injury involves changes in protein metabolism. Protein degradation often occurs with increasing temperatures, but certain specific proteins such as heat shock proteins (HSPs) may be induced or enhanced in their expression under supraoptimal temperatures. One postulated mechanism for the acquisition of thermotolerance is synthesis of HSPs during exposure to high temperature (Park et al., 1996). The objectives of this study were to determine the critical temperatures that cause protein induction or degradation and to compare protein profiles between two *Agrostis* species contrasting in heat tolerance: heat tolerant *Agrostis scabra* (ecotype 'Ntas') and heat sensitive *Agrostis stolonifera* (cv. 'Penncross').

Plants of both species were exposed to temperatures of 20, 30, 35, 40, and 45 °C for 3, 7 and 14 days. Soluble protein content was measured to evaluate general protein changes. Specific changes in protein profiles were imposed by using SDS-PAGE system. Photochemical efficiency and carotenoid content were also measured to evaluate the extent of heat injury. Our results suggested that protein degradation occurred at 35ºC in *A. stolonifera* and at 40ºC in *A. scabra*, whereas HSP induction was detected at 40ºC in *A. stolonifera* and 35ºC in *A. scabra*. In addition, changes in leaf photochemical efficiency and carotenoid content with increasing temperatures confirmed that *A. scabra* was more heat tolerant than *A. stolonifera*, which could be explained by their differences in protein degradation and induction patterns.

Central Asia as a Source of Turfgrass Germplasm

David E. Zaurov[1], James A. Murphy[1], C. Reed Funk[1], William A. Meyer[1], Hadjamurat H. Kimsanbaev [2], Ruslan A. Astanov[2], Usman Norkulov[2], and Ishenbay Sodombekov[3]

[1]*Department of Plant Biology and Pathology, Rutgers University*
[2]*Tashkent State Agrarian University, the Republic of Uzbekistan*
[3]*Botanical Garden of the National Academy of Sciences of the Kyrgyz Republic*

For several years Rutgers University has had formal ties with the Republic of Uzbekistan and the Kyrgyz Republic. Rutgers University has reciprocal germplasm exchange agreements with a number of prominent research institutions, including Tashkent State Agrarian University, The Uzbek Scientific Research Institute of Fruit Growing, Viticulture and Winemaking named after R. R. Shreder, The Uzbek Scientific Research Institute of Plant Industry (formerly The Vavilov Institute), The Uzbek Scientific Research Institute of Vegetable-Melon and Potato Growing, the Uzbek Scientific Research Institute of Forestry, and The Kyrgyz Agrarian Academy, which comprise of five scientific institutes.

The 2003 - 2005 joint turfgrass project between Rutgers University and Tashkent State Agrarian University was approved by both the Uzbek Ministry of Agriculture and Water Resources and the USDA. Through this project, Rutgers scientists have successfully collected and obtained potentially valuable turfgrass germplasm from Central Asia.

A successful strategy for the genetic improvement of North American turfgrass species has been by the introduction, evaluation, and incorporation of desirable traits from unique accessions from around the world. Turfgrass breeders from both the U.S. and Central Asia continue to focus on collecting on potentially resistant to heat, drought, diseases and insects, as well as shade tolerant grasses, and grasses that appear productive on marginal, overgrazed lands. Until recently, turfgrass germplasm from Central Asian has been not well represented in U. S. collections. Through these efforts, Rutgers University currently possesses the largest and most diverse and unique collection of Central Asian turfgrass germplasm in the U. S. 182 accessions of turfgrass from Central Asia have been collected and sent to Rutgers University for evaluation, (Table 1).

Table1. Turfgrass species collected from Central Asia, 2005.

Country	Species	Number of Accessions
Kyrgyzstan	*Festuca rubra*	44
Kyrgyzstan	*Festuca sulcata*	9
Kyrgyzstan	*Poa pratensis*	7
Uzbekistan	*Lolium perenne*	47
Uzbekistan	*Festuca arundinaceae*	1
Uzbekistan	*Poa pratensis*	74
Total accessions:		182

For the first time field trials of North American cultivars have been evaluated in Uzbekistan as part of a USDA grant supervised by Drs. Reed Funk and William Meyer. This is the first turfgrass breeding and evaluation program in Central Asia. The U. S. scientists provided seeds of turfgrass cultivars for these trails and also provided technical assistance in setting up the field plots for partners in Uzbekistan. The preliminary results of this trial have been published in the International Agronomy Journal of Uzbekistan, and in Turfgrass Proceedings (2004).

Since 1999 Rutgers University has hosted delegations from both Uzbekistan and Kyrgyzstan for a special mini-training program. In addition, tours were set-up to show researchers how to establish a turfgrass collection, nursery, and breeding program. These visits also provided Rutgers with the opportunity to develop potentially new turfgrass programs in Uzbekistan and Kyrgyzstan.

Acknowledgements: We wish to express our appreciation to both the Rutgers Center for Turfgrass Science and the New Jersey Agricultural Experiment Station for their support.

Somaclonal Variation in Salinity Tolerance for Creeping Bentgrass

Eddie Zhang, Jinpeng Xing, Thomas Gianfagna, and Bingru Huang
Department of Plant Biology and Pathology, Rutgers University

Turfgrasses are subject to rising amounts of salinity stress due to increased salinization of agricultural areas and the use of non-potable water sources as a method of turfgrass irrigation. Improving salt tolerance of turfgrasses is also important for conservation of fresh water. Plant tissue culture techniques have recently been employed to improve the genetic variability of plant tolerance to environmental stresses. The objective of this study was to determine whether *in vitro* selection of somaclonal variation could be used for improving salt tolerance of creeping bentgrass (*Agrostis palustris*), a cool-season turfgrass used widely on golf courses. This information is important for determining the feasibility of irrigating turfgrasses with non-potable water in a high salt environment. This study will also select salt tolerant plants that could be used as breeding materials.