PROCEEDINGS OF THE FOURTEENTH ANNUAL RUTGERS TURFGRASS SYMPOSIUM

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

January 13-14, 2005
Cook College

Symposium Organizing Committee

Stacy A. Bonos, Chair
Bruce B. Clarke
Barbara Fitzgerald
Daniel Giménez
James A. Murphy

Proceedings of the Fourteenth Annual Rutgers Turfgrass Symposium

Daniel Giménez and Barbara Fitzgerald, Editors

Director's Opening Remarks:

Welcome to the Fourteenth Annual Rutgers Turfgrass Symposium at Cook College/NJAES. The Symposium was established in 1991 to provide Rutgers faculty, students, and staff 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. I would like to thank Dr. Charles Taliaferro (Oklahoma State University) for giving this year's keynote address, as well as Dr. Daniel Peck (Cornell University), Dr. Roch Gaussoin (University of Nebraska), Dr. Scott Warnke (USDA/ARS), and the Center faculty who have agreed to present their research at this year's meeting. I would also like to recognize the Symposium Planning Committee comprised of Dr. Stacy Bonos (Chair), Dr. James Murphy, and Dr. Daniel Giménez and Ms. Barbara Fitzgerald (co-editors of the Symposium Proceedings), for their hard work in the preparation of this year's program. Without their efforts, this year's Symposium would not have been possible.

This is indeed an exciting time for the Rutgers Turfgrass Program. The Turf Center faculty continue to be recognized for excellence in turfgrass breeding, management, biotechnology, physiology, soil science, and pest management. In 2004, Dr. Randy Gaugler received the prestigious Recognition Award from the Entomology Society of America, Drs. Bingru Huang and Bruce Clarke were selected as Fellows of the Crop Science and Agronomy Societies of America, respectively, and Dr. C. Reed Funk received the Distinguished Leadership Award from the New Jersey Agricultural Experiment Station. We have also expanded our efforts to provide excellent undergraduate, graduate, continuing professional education, and service programs in support of students and turfgrass managers throughout the United States.

The Turfgrass Center and the Department of Plant Biology and Pathology continue to expand the undergraduate teaching program in turfgrass management at Cook College. With the help of Dr. Richard Hurley, who directs the undergraduate recruitment effort for the turfgrass program, both the quality and quantity of our students have significantly increased over the past few years. We look forward to building upon this success and continuing our recruitment efforts in 2005. During the past two decades, the Turfgrass Industry has donated over 4 million dollars in grants and gifts to our turfgrass program. This includes the Ralph Geiger Turfgrass Education Complex, the C. Reed Funk Equipment Storage Facility, and more than $70,000 in privately funded scholarships awarded each year to deserving students in turfgrass science. The Industry has also volunteered their time and effort to ensure the success of our research field days and educational conferences throughout the state. We are indeed fortunate to have such a close partnership with the Turfgrass Industry.

Thank you for coming to this year's symposium. I hope that you will find it an interesting and worthwhile experience.

Sincerely,

Bruce B. Clarke, Director
Center for Turfgrass Science

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FOURTEENTH ANNUAL RUTGERS TURFGRASS SYMPOSIUM

Cook College, Rutgers University
January 13-14, 2005
Foran Hall - Room 138

Thursday, January 13, 2005

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. Charles Taliaferro** (Department of Plant and Soil Sciences, Oklahoma State University) *Expanding the Horizons of Turf Bermudagrass Through Breeding*

8:30 - 10:00 PM Wine and Cheese Reception

Friday, January 14, 2005

8:30 - 9:00 AM Registration, Coffee and Donuts

9:00 - 10:00 AM SESSION I: Mapping the Bentgrass and Ryegrass Genome
(Moderator: Bradley Hillman)

9:00 – 9:20 **Dr. Scott Warnke** (USDA - ARS) *Genetic Map Development and QTL Analysis in a Ryegrass Mapping Population*

9:20 – 9:40 **Dr. Stacy Bonos** (Department of Plant Biology and Pathology, Rutgers University) *Development of a Genetic Linkage Map of Creeping Bentgrass Using SSR Markers*

9:40 – 10:00 **Dr. Faith Belanger** (Department of Plant Biology and Pathology, Rutgers University) *Differential Gene Expression Between Creeping and Colonial Bentgrass*

10:00 - 10:30 AM Discussion and Coffee Break

10:30 - 11:30 AM SESSION II: TURFGRASS PHYSIOLOGY AND STRESS MANAGEMENT
(Moderator: Daniel Giménez)

10:30 – 10:50 **Dr. Roch Gaussoin** (Department of Horticulture, University of Nebraska - Lincoln) *Physical Properties of Sand Based Root Zones Over Time*

10:50 – 11:10 **Dr. Barbara Zilinskas** (Department of Plant Biology and Pathology, Rutgers University) *Advances in Agrobacterium-mediated Transformation of Turfgrass*

11:10 – 11:30 **Dr. Thomas Gianfagna** (Department of Plant Biology and Pathology, Rutgers University) *Transgenic Bentgrasses with the ipt Gene for Increased Cytokinin Biosynthesis*

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: BIOLOGY, ECOLOGY, AND CONTROL OF WEED AND INSECT PESTS
(Moderator: James Murphy)

1:30 – 1:50 **Dr. Albrecht Koppenhöfer** (Department of Entomology, Rutgers Cooperative Extension, Rutgers University) *New Developments in Oriental Beetle Management: Sustainable White Grub Management with Steinernema scarabaei*

1:50 – 2:10 **Dr. Daniel Peck** (Department of Entomology, Cornell University) *Challenges and Perspectives for Managing the Annual Bluegrass Weevil*

2:10 – 2:30 **Dr. Stephen Hart** (Department of Plant Biology and Pathology, Rutgers Cooperative Extension, Rutgers University) *Poa annua and Poa trivialis Control with Byspyribac-Sodium in Cool-Season Turfgrass: Research and Real World Results*

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

3:00 – 4:00 PM SESSION IV: TURFGRASS MANAGEMENT AND PHYSIOLOGY
(Moderator: Steve Hart)

3:00 – 3:20 **Mr. John Inguagiato** (Department of Plant Biology and Pathology, Rutgers University) *Anthracnose on Annual Bluegrass Affected by Nitrogen, Plant Growth Regulators, and Verticutting*

3:20 – 3:40 **Dr. William Meyer** (Department of Plant Biology and Pathology, Rutgers University) *Update on Breeding Programs to Improve Gray Leaf Spot Resistance in Perennial Ryegrass and Brown Patch Resistance in Tall Fescue*

3:40 – 4:00 **Ms. JoAnne Crouch** (Department of Plant Biology and Pathology, Rutgers University) *Evidence for a Change in the Species Designation for Colletotrichum graminicola Causing Anthracnose in Turf*

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

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Plenary Presentations

Expanding the Horizons of Turf Bermudagrass through Breeding

Charles M. Taliaferro

Department of Plant and Soil Sciences, Oklahoma State University

Bermudagrass, *Cynodon* sp., is widely used as turf in the southern USA and in other warm climatic regions of the world. These warm-season, perennial, sod-forming grasses provide attractive turf and are generally tolerant of stresses common to tropical and subtropical climates. The turf bermudagrass breeding program of G. W. Burton at Tifton, GA was initiated in the mid-1900's and focused on developing clonally propagated F_1 hybrid varieties for the south. This program produced the interspecific (*C. dactylon* var. *dactylon* x *C. transvaalensis*) F_1 hybrid varieties 'Tifgreen', 'Tifway', and 'Tifdwarf' that became industry standards. Until recently, seed-propagated bermudagrass for turf use was restricted to that produced in Arizona and California from naturalized "common" bermudagrass. Major turf bermudagrass improvements needed for the transition zone included combining into varieties enhanced adaptation (freeze tolerance) and turf quality.

Turf bermudagrass breeding at Oklahoma State University was initiated in the mid-1980's with the objectives of providing improved seed- and vegetatively-propagated varieties for the transition zone. Phenotypic recurrent selection was used to improve turf quality and seed yield in breeding populations synthesized from cold hardy germplasm. The development of 'Riviera' exemplifies the effectiveness of the breeding effort. Riviera has transition zone adaptation, economic seed yield potential, and turf quality on par with that of industry standard varieties. Interspecific (*C. dactylon* var. *dactylon* x *C. transvaalensis*) hybridization has been used to breed improved clonal varieties combining enhanced transition zone adaptation, turf quality, and sod tensile strength.

Research supporting the breeding effort includes *Cynodon* germplasm acquisition and evaluation, laboratory assessment of freeze tolerance, and study of genetic mechanisms of freeze tolerance.

Genetic Map Development and QTL Analysis in a Ryegrass Mapping Population

Scott E. Warnke[1], Reed E. Barker[2], and Geunhwa Jung[3]

[1]*National Arboretum, Floral and Nursery Plants Research Unit, Washington D.C 20002.*
[2]*National Forage Seed Production Research Center, Corvallis, OR 97330*
[3]*Department of Plant Pathology, University of Wisconsin, Madison WI, 53706*

Male and female molecular marker linkage maps of an interspecific annual x perennial ryegrass mapping population were developed using AFLP, RFLP, SSR and isozyme markers. RFLP markers from Oat and Barley and SSR markers from Tall Fescue allowed the establishment of chromosome numbering relative to the *Triticeae*. Map construction was carried out using JoinMap and indicated that *Lolium* chromosomes share large regions of synteny with those of other members of the *Triticeae*. Two major QTLs influencing photoperiodic control of flowering time were identified and they map in regions known to contain major photoperiod genes in wheat and barley. Three QTLs influencing vernalization control of flowering were identified and they map in regions known to contain vernalization genes in wheat and barley. The isozyme loci *Pgi-2* and *Sod-1* mapped close to regions that influence flowering control, further establishing their utility for species separation in the ryegrasses. In some cases synteny can be traced to rice and candidate genes for flowering control can be identified.

Development of a Genetic Linkage Map of Creeping Bentgrass Using SSR Markers

Stacy A. Bonos, Christine Kubik and Joshua A. Honig

Department of Plant Biology and Pathology, Rutgers University

Genetic linkage maps and Quantitative Trait Loci (QTLs) associated with disease resistance have been developed for over 18 important crop species including corn, rice and wheat. Genetic linkage maps can be used for comparative mapping, evolution, inheritance and functional genomics studies. Until recently, very few research projects on creeping bentgrass genomics were conducted.

The objectives of this project were to create a genetic linkage map of allotetraploid creeping bentgrass (*Agrostis stolonifera* L.) using genomic SSR markers (microsatellites) and subsequently identify DNA markers linked to dollar spot disease (caused by *Sclerotinia homoeocarpa* F.T. Bennett) resistance.

To do this, an intra-specific pseudo F_2 mapping population of creeping bentgrass was generated from a cross between a dollar spot resistant (L93-10) and a susceptible (7418-3) genotype. Additionally, a second-generation full sib [pseudo F_3] population containing 250 individuals was created from a cross between two F_2 individuals differing in dollar spot disease resistance and two backcross populations (100 individuals each), one to each original parent (L93-10 and 7418-3) were also created. A field trial containing replicated plants of the 180 F_2 progeny and 450 F_3 and backcross progeny was planted in the fall of 2002 and inoculated with the dollar spot pathogen in the spring of 2003. These were evaluated for dollar spot disease in both 2003 and 2004. The phenotype data from both 2003 and 2004 is currently being compared to molecular marker data to identify QTLs associated with dollar spot resistance.

Approximately 100 microsatellite markers have been identified and characterized in the mapping population from approximately 2,300 sequences tested. Approximately 25% of the markers amplified two alleles, 45% amplified three alleles, 25% amplified four alleles and 10% amplified five alleles with an average of 3.2 alleles per locus. Initial analysis of the SSR loci indicates some complex inheritance patterns at several loci. The SSR data for 100 SSR markers was transformed into a Single Dose Allele (SDA) format for each parent and analyzed using JoinMap 3.0 to develop a linkage map of creeping bentgrass. We will be conducting more in depth analysis of the SSR loci to determine the extent of complex inheritance that is occurring how that affects the specific mode and type of inheritance present in this species.

Phenotypic dollar spot data from the mapping populations indicate a range in disease resistance among the progeny. The pseudo F_2 cross was normally distributed with individuals ranging from a 3 to an 8 (on a 1-9 scale). No progeny were completely resistant to dollar spot disease. In both backcrosses, the population is skewed toward the original parent. Susceptible transgressive segregants were observed in the backcross to the resistant parent and resistant transgressive segregants were observed in the backcross to the susceptible parent. These data support the idea that dollar spot resistance is quantitatively inherited. These data will help us further identify the inheritance of dollar spot resistance in creeping bentgrass. We are hopeful that all of this information will help provide the framework for a genetic linkage map in creeping bentgrass and subsequent QTL analysis for dollar spot disease resistance.

Differential Gene Expression Between Creeping and Colonial Bentgrass

Faith C. Belanger, Huaijun Michael Li, David Rotter, Stacy Bonos, William Meyer

Department of Plant Biology and Pathology, Rutgers University

Creeping and colonial bentgrasses, *Agrostis stolonifera* and *A. capillaris*, respectively, are commercially important turfgrass species. Creeping bentgrass is highly susceptible to the fungal disease dollar spot, whereas colonial has good resistance. We have generated an interspecific hybrid that exhibits excellent resistance. We are investigating the molecular basis for the resistance by using suppression subtractive hybridization to detect transcripts that are unique or over-expressed in either the resistant hybrid or its creeping parent following fungal inoculation. RNA for the libraries was isolated from field samples when the creeping plant was exhibiting symptoms of the disease. Numerous genes were identified that are differentially expressed between the two plants.

A surprising result from this study was the identification of a gene, designated CRS-1, that is in the process of being lost from the bentgrass genome. A few similar genes have been reported from other grass species, but the functions of the encoded proteins have not been resolved. The CRS-1 gene was not detectable in most of the creeping bentgrass plants we examined. Some plants were hemizygous for two closely linked genes of CRS-1. In a screen of 8 creeping bentgrass cultivars, CRS-1 was detectable in 3, Cobra, L93, and Procup. In Cobra and L93 less than 50% of the individuals screened contained the CRS-1 gene. Presence of the gene was not detected in several related *Agrostis* species, indicating it is being lost from the genus. Gene loss is considered one of the processes contributing to speciation and genome diversity. The creeping bentgrass CRS-1 gene is a unique example of a gene that is in the process of being lost from a species and also the genus.

We have also identified several genes that are over-expressed in the dollar spot resistant interspecific hybrid relative to its creeping bentgrass parent. These genes are of particular interest since some may be relevant to the disease resistant phenotype. We will be following transmission of these genes in a backcross population to see if any are correlated with resistance.

We are also participating in a multi-institutional effort, including Rutgers, University of Wisconsin, and the USDA to sequence bentgrass cDNAs. Currently we are focused on sequencing 10,000 creeping cDNA clones and 10,000 colonial cDNA clones. These clones and sequences will then be used by the participants to construct genetic linkage maps of creeping and colonial bentgrass. In our lab we will be mapping colonial bentgrass using a population generated by crossing a dollar spot resistant colonial x creeping interspecific hybrid with a creeping bentgrass plant. We are developing PCR-based markers based on indels in the 3' regions of the cDNA sequences to generate colonial specific markers.

Physical Properties of Sand-Based Root Zones Over Time

R.E. Gaussoin, PhD

Department of Agronomy and Horticulture, University of Nebraska - Lincoln

An eight-year study of USGA specification putting greens was conducted at the UNL Turfgrass Research Facility near Mead, NE. USGA specification putting greens were built and established each year for four years (1997-2000). Greens were established with Providence creeping bentgrass (*Agrostis palustris* Huds.). Root-zone-mix treatments were 80% sand and 20% sphagnum peat (80:20 by volume) and 80% sand, 15% sphagnum peat and 5% soil (80:15:5 by volume). Establishment treatments included an accelerated and a controlled fertilizer program. The accelerated treatment application rates were: 544 kg N ha^{-1}, 530 kg P ha^{-1}, and 383 K kg ha^{-1}, and the controlled treatment rates were: 212 kg N ha^{-1}, 170 kg P ha^{-1}, and 146 kg K ha^{-1}. The accelerated treatment applied twice the nutrient amount during preplant and four times the monthly amount following preplant when compared to the controlled treatment. Following the establishment year, all greens received the same annual fertilizer treatment (foliar) of 292 kg N ha^{-1}, 195 kg P ha^{-1}, and 292 kg K ha^{-1}. Greens are maintained according to regional recommendations. Sand topdressing program was light, frequent every 10-14 days (based on growth rate) and heavy sand topdressing combined with hollow-tine aerification twice annually. Experimental design was a 2 x 2 factorial (grow-in procedure x root-zone mix) replicated three times per year and repeated over time 4 years (1997-2000). Emphasis is being placed on characterization of the long-term effects of root-zone mix and grow-in procedures on soil physical and chemical parameters. Results indicate significant changes over time for numerous soil physical, chemical and organic matter measurements. A summary of these results follows:

- As a green matures, soil infiltration is not affected in the first two years after grow-in but decreases significantly in the third year and this trend continues for up to eight years post construction.
- Bulk density increased over time.
- Total porosity decreased minimally over time while air-filled porosity decreased at a greater rate with a corresponding increase in capillary porosity.
- Following establishment, CEC, soluble salts, organic matter, and all nutrients investigated generally decreased with depth while pH increased with depth for all greens.
- Root-zone composition generally had no effect beyond establishment year for all chemical properties.
- Excluding phosphorous, grow-in procedure did not have a significant effect beyond the first year of establishment. Phosphorous remained significantly higher in greens receiving accelerated fertilizer grow-in treatments.
- Consistent topdressing program has resulted in no visible layering, only an overall color transition between developing mat layer and underlying original root-zone.

- Given the current topdressing program, mat development is accumulating at approximately 6.5 mm (0.25 in.) annually. The eight-year USGA green has a mat layer 7 cm (2.75 in.) thick; the 5-yr green was 5 cm (2 in.).
- Results from our field study suggest that peat degradation in USGA-specification root-zones is much less than previous laboratory studies have shown and, regardless of original amount added during green construction, appears to stabilize at 0.8% (by weight) of original root-zone composition five years following establishment.
- In both root-zones the existing soil was significantly lower than the original root-zone pre construction.
- The loss in infiltration in the original root-zone from preconstruction to greens up to eight years old is attributable primarily to the fine sand portion of sand used migrating from topdressing in combination with verticutting and/or core aeration.

Advances in *Agrobacterium*-mediated Transformation of Turfgrass

Matthew Kinkade, William Meyer, Cynthia Nezames, Lynne H. Pitcher, Aurea C. Vasconcelos, Gengyun Zhang and Barbara A. Zilinskas

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Traditionally, turfgrass improvement has relied on conventional breeding by which many warm-season and cool-season cultivars have been produced over the last sixty years. However, inaccessibility of genetic material owing to barriers to sexual reproduction, as well as the relatively long time required in breeding programs, has led to the application of various biotechnological tools in turfgrass improvement. Genetic transformation of turfgrass was first achieved with direct gene transfer, including protoplast transformation and particle bombardment. Our laboratory later demonstrated that *Agrobacterium tumefaciens* could be used to mediate gene transfer to creeping bentgrass and subsequently to several other turfgrass species, including velvet bentgrass, tall fescue and Kentucky bluegrass. The advantages of gene transfer mediated by *Agrobacterium* over direct DNA transfer are several; these include stable transgene integration without rearrangement of either host or transgene DNA, preferential integration of the transgene into transcriptionally active regions of the chromosome, ability to transfer large segments of DNA, and integration of a low number of gene copies into plant nuclear DNA.

We now present recent improvements in genetic transformation of several cool-season turfgrass species using *Agrobacterium tumefaciens.* Modifications of culture media and methodology for production of embryogenic callus that are highly suitable for transformation; tight selection of transgenic calli; and subsequent regeneration of healthy plants have resulted in an efficient and reliable transformation system. This system is currently being used to introduce into creeping bentgrass and tall fescue genes for improved tolerance to salt, drought, temperature extreme and disease. Research is also currently underway to produce glyphosate-resistant Kentucky bluegrass with enhanced turf quality/dwarfing.

Transgenic Bentgrasses with the *ipt* Gene for Increased Cytokinin Biosynthesis

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Leaf senescence, and decline in tiller density and root growth are major problems associated with summer bentgrass decline. Our previous research indicated that root-produced cytokinins regulate leaf senescence and lateral shoot and root formation, especially at high soil temperatures. Cytokinin synthesis can be increased by incorporating the bacterial gene, isopentenyl transferase (*ipt*) into plants. The *ipt* gene encodes an enzyme that catalyzes the condensation of dimethylallylpyrophosphate and 5'-AMP to form isopentenyladenosine 5'-phosphate, a precursor for cytokinins. Research in non-turfgrass species has proven that expression of the *ipt* gene in plants increased the cytokinin content and successfully improved stress tolerance (heat and salinity) by increasing chlorophyll content, delaying leaf senescence, and stimulating lateral branching and root production. Our objective is to develop heat tolerant creeping bentgrass by introducing the *ipt* with a specific set of promoters so that growth and chlorophyll synthesis are maintained constitutively, or are triggered by high temperatures or the onset of leaf senescence.

We have chosen 3 different promoters to activate the *ipt* gene. The first is the ubiquitin-P promoter from corn. This promoter is active in all tissues of the plant throughout development. The second promoter is the SAG12 promoter from Arabidopsis. This promoter is active in the leaves, but only at the onset of leaf senescence. The third promoter is the HSP18 promoter also from Arabidopsis that is active only at the onset of heat stress. The SAG12 and HSP18 promoters will not affect normal plant growth under normal temperature conditions.

We will report on our progress to date on the production of the gene constructs and the transformation and regeneration of bentgrass.

New Developments in Oriental Beetle Management: Sustainable White Grub Management with *Steinernema scarabaei*

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The overall objective of our research is to develop sustainable and IPM compatible methods for the control of turfgrass insects, in particular the root-feeding white grubs. Entomopathogenic nematodes have been an integral part of our efforts. Our studies have shown that presently commercially available nematodes species cannot provide good control of most white grub species other than the Japanese beetle. Among the relatively resistant species is the oriental beetle, *Anomala* (=*Exomala*) *orientalis* larvae, the most common white grub species in New Jersey and surrounding areas. However, *Steinernema scarabaei*, isolated from epizootics in Japanese beetle and oriental beetle larvae in central New Jersey, has shown exceptional potential for curative control of most white grub species in turfgrass including the oriental beetle.

Because of its high pathogenicity to white grubs and its close adaptation to this insect group as hosts, *S. scarabaei* also holds promise as an excellent candidate for long term white grub suppression following inoculative and/or augmentative releases. We have started one field experiment in September of each of the last 3 years (2002 - 2004) to test how long S. scarabaei can persist under field conditions and what level of white grub suppression it can provide over extended periods of time, i.e., ideally for several years after application. Our field studies show that *S. scarabaei* reproduces very well in oriental beetle larvae and that the progeny emerging from S. scarabaei-infected white grubs provides additional control. One month after application, *S. scarabaei* provided 50 to 77% control at rates of $0.1 – 0.2 \times 10^9$ /ha and 86 to 100% control at rates of $0.4 – 0.6 \times 10^9$ *S. scarabaei* /ha (standard nematode field rates $2.5 – 5.0 \times 10^9$ /ha). *S. scarabaei* provided additional control in the following spring with 96 – 100% control at rates as low as 0.1×10^9 *S. scarabaei* /ha. *S. scarabaei* also persisted into the following grub generation when it provided 62 to 91% control at rates of $0.12 – 2.5 \times 10^9$ /ha. In our first experiment started in 2002 *S. scarabaei* also persisted into the third year after the application but control more than 2 years after application was variable (31 to 94%).

Observations in these experiments will continue until we have at least 2 years of data from each experiment. However, it is already obvious that *S. scarabaei* can provide effective white grub control at extremely low rates for at least 2 years after applications. Over longer periods control is likely to become too variable as nematode recycling depends on the presence of white grubs. However, we can expect a positive feedback mechanism (i.e., the higher the reinfestation rate from surrounding areas, the higher and less variable the S. scarabaei populations and white grub suppression levels.

We are also studying the effects of soil conditions, in particular soil type and soil moisture, on the efficacy and persistence of *S. scarabaei*. Overall *S. scarabaei* has shown high efficacy and excellent persistence over a wide range of soil types and soil moisture conditions. For more detail on this aspect of our studies see the poster abstract by Fuzy and Koppenhöfer in these proceedings.

Challenges and Perspectives for Managing the Annual Bluegrass Weevil

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The Problem. The annual bluegrass weevil (*Listronotus maculicollis*, ABW) is a burgeoning pest of high maintenance turf in the Northeast and Mid-Atlantic. Every spring, golf course superintendents contend with adult movement from off-course overwintering sites to the greens, resulting in heavy damage to *Poa annua* in the collars and surrounding areas as the insect completes 2-3 generations. Females insert eggs between the leaf sheaths, early instars feed within the stem, and later instars drop down to feed on the crown, killing up to 20 stems over the course of development. Adults feed on grass blades but cause little severe damage. Feeding injury due to larvae is expressed as growing areas of yellow and brown spots, usually first noticed around the collar and perimeter of the greens, tees or fairways. High populations will cause substantial areas of dead turf that severely impact the visual and functional quality of golf course turf.

The Challenge. ABW is a problem of growing concern because its principal host, *P. annua*, is increasingly promoted as a desirable grass variety and because there are no real control options other than pyrethroid insecticides, which may be applied 2-5 times a season. Under this scenario, there is an urgent need to develop other control alternatives; insecticide options will undoubtedly be more limited in the future due to FQPA restrictions and the likelihood of pesticide resistance development. We also need to better understand the association between ABW and the golf course landscape; in addition to better targeting control applications, a stronger basic foundation will uncover entirely new ways to intercept and suppress populations.

The Perspectives. Promoting reduced insecticide alternatives to more effectively control ABW will depend on three activity areas. First, we need to fill critical knowledge gaps in our basic understanding of ABW biology, behavior and ecology. Despite recent advances, certain critical gaps remain, especially in the face of our changing control environment. Some priorities are to (i) establish current geographical distribution in Northeastern and Mid-Atlantic States to monitor spread, (ii) describe the overwintering biology, (iii) establish patterns of adult dispersal, population fluctuation and phenology, (iv) describe and quantify reproductive biology, and (v) determine adult oviposition and larval feeding preferences.

Second, we need to identify and develop new cultural, biological, chemical and genetic control options including determining the effect and role of (i) cultural practices such as mowing height, fertility and barrier strips of non-preferred grasses (ii) biologicals such as entomopathogenic nematodes, spinosad and Bt, (iii) new chemical control products, and (iv) host plant resistance.

Third, we need to develop improved IPM decision tools including (i) refining and validating a degree-day model for predicting ABW phenology, (ii) refining action thresholds, and (iii) developing more efficient techniques for laboratory rearing and field sampling. Finally, we need to promote the most effective and least pesticide-intensive control tactics in the context of our best understanding of *Poa annua* management.

Our Approach. As far as we are aware, no field studies have addressed this pest in Upstate NY. Studies based in the metropolitan areas of NY and CT suggest specific phenological windows for targeting adults as they recolonize in the spring. Nevertheless, we have no measure of how applicable these generalizations are across other areas of the ABW's range. Moreover, the resolution of previous population studies has not afforded a detailed look at when the life stages occur and how the generations develop over the course of the season. To really interpret the association between ABW and the golf course, we need to conduct highly detailed studies on how adults move between overwintering and feeding sites, and how populations of the different life stages and generations develop in space and time.

In response, we have launched a series of studies designed to interpret the association between ABW and the golf course landscape. Our main objective is to describe directional movement in adults and how this understanding can be exploited to improve IPM. Our specific objectives are to (i) describe patterns of variation in seasonal fluctuations and phenology, (ii) determine the factors that affect overwintering site selection and success, and (iii) document the relationship between overwintering sites and feeding sites.

Most Recent Results. ABW life stages were surveyed at two golf courses in central NY from April to October 2004. Three transects were laid out across one fairway at each golf course and insects were monitored weekly at thirteen sampling points that fell on the rough, intermediate rough and the fairway. Adults were counted with soap flushes and larvae were extracted from soil cores. All adults were identified as male or female, and as callow or mature; all larvae were identified to instar by measuring the width of the head capsule.

Population fluctuation curves of the different life stages revealed one generation at both sites with some evidence for a second smaller generation. First instars of the initial generation were detected in the second week of May for both golf courses. Peak abundance of immature stages was observed in late May followed by the emergence of callow adults in late June. Analyses based on cumulative insect-days will permit us to measure variation in certain aspects of population ecology across the three transects of the fairway, between the two geographic sites and from one year to the next. Temperature data will be used to calculate degree-days and develop a model to describe and predict when adults start moving from the overwintering sites and when other life stages appear in the field.

Overall, we expect this research to provide new understanding of where the insect overwinters, how and when it recolonizes the golf course, and how population development proceeds over the course of the season. This specifically includes factors that influence in the selection of overwintering sites, number of generations a year, timing of the life stages, and fluctuations in abundance. These results will strengthen our understanding of the association between *L. maculicollis* and the turfgrass habitat and lead to new insights for management programs. We hope to confirm directional movement in this insect, which will reveal ways that control tactics might be targeted to "intercept" the insect as it moves in from overwintering sites, or as it leaves to overwintering sites. New options like this will help reduce pesticide use and contribute to our overall understanding of how landscapes might be interpreted and manipulated in managed ecosystems to improve pest management strategies.

***Poa annua* and *Poa trivialis* Control with Bispyribac-Sodium in Cool-Season Turfgrass: Research and Real World Results**

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Research has been conducted since 2001 to evaluate the use of bispyribac-sodium for selective control of *Poa annua* and *Poa trivialis* in cool-season turfgrasses. Seasonal timing studies conducted at Riverton Country Club in 2002 and 2003 have determined that late spring or early summer applications of bispyribac provide the highest levels of *Poa annua* control with the least amount of creeping bentgrass injury, compared with early spring or fall applications. Growth chamber studies have also confirmed that bispyribac provides higher levels of *Poa annua* control at 30 C, compared with 10 or 20 C.

Research conducted at New Jersey National Country Club in 2003 and 2004 demonstrated that sequential applications of bispyribac at 30 to 60 g ai/A provided high levels of *Poa trivialis* control, compared to single applications at the same rates. In 2004, sequential applications of bispyribac at 30 g ai/A provided approximately 80% control of *Poa trivialis* and nearly complete *Poa annua* control on five fairways treated under a 24C label. The ability of bispyribac to provide high levels of *Poa annua* and *Poa trivialis* control when applied in late spring / early summer, combined with previous observations that creeping bentgrass can be safely overseeded in treated areas within two weeks, shows the potential of this product for converting fairways to higher populations of creeping bentgrass. Research will be initiated in the summer of 2005 to further explore this potential.

Anthracnose on Annual Bluegrass Affected by Nitrogen, Plant Growth Regulators, and Verticutting

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The effect of nitrogen, the growth regulators Embark 0.2L (mefluidide) and Primo MAXX 1MC (trinexapac-ethyl), and verticutting on the severity of anthracnose was assessed on a *Poa annua* (annual bluegrass) putting green turf at Rutgers University from April to October in 2003 and 2004. The study was arranged as a 2 x 2 x 2 x 2 factorial design with four replications and turf was mown at a minimum of ten times per week at 3.2 mm (0.125 in). Nitrogen was applied at 4.9 kg ha^{-1} (0.1 lb. N/1000 ft^2) every 7 days (~3.0 lbs/yr) or 4.9 kg ha^{-1} (0.1 lb. N/1000 ft^2) every 28 days (~1.5 lbs/yr). Embark treatments were applied twice at 2.2 L ha^{-1} (0.7 fl. oz./1000 ft^2) on 14 and 28 April. Primo MAXX was applied every two weeks throughout the season at 0.4 L ha^{-1} (0.125 fl. oz./1000 ft^2) beginning 14 April and continuing through September. Verticutting was conducted on plots at a 3 mm (0.12 in.) depth and 13 mm (0.5 in.) spacing every two weeks from May to September. Curalan 50EG 3.1 kg ha^{-1} (1.0 oz/1000 ft^2) and ProStar 70WP 6.4 L ha^{-1} (2.0 oz/1000 ft^2) were applied for the control of dollar spot and brown patch respectively. Previous studies conducted on this site had confirmed that neither product affected the development of anthracnose on *P. annua* greens.

In 2003, anthracnose developed from a natural infection in June and became well established on half of the trial by early July. The other half of the study was artificially inoculated with *Colletotrichum graminicola* (Ces.) G.W. Wils., the causal agent of anthracnose, on 6 July with 5 x 10^4 conidia/mL to ensure uniform disease development. In 2004, anthracnose developed throughout the study from a natural infection in June. Turf receiving the high rate of nitrogen had 25 to 65% less disease than turf maintained with the low rate of nitrogen over both years of the study. Embark enhanced disease severity in June (six to eight weeks post-treatment), and had no effect on anthracnose from July through October 2003 and 2004, compared to turf not treated with this plant growth regulator. Embark did, however, reduce the number of seedheads per unit area and increased turf quality before the onset of disease. Repeat applications of Primo improved turf quality, increased turf density, and reduced anthracnose severity, compared to non-Primo treated turf in both years. In 2004, an interaction involving Embark and Primo was apparent by 7 July and continued through the remainder of the season. Plots receiving Embark and sequential applications of Primo had 36-37% and 27-41% less anthracnose compared to Embark or Primo applied alone, respectively. The combined effect of these growth regulators on anthracnose may be due to an increase in carbohydrate reserves resulting from the suppression of seedheads with Embark and reduced mowing stress associated with the use of Primo. Since treatments were not re-randomized in 2004, the appearance of the Embark*Primo interaction in the second year may be an indication that the beneficial effect of these products is gradual, resulting from a cumulative effect over two years. An additional year of study will be conducted to determine if this effect is observed again in 2005 and whether it becomes more pronounced.

In 2003, the influence of verticutting on anthracnose was variable and dependent on the presence or absence of plant growth regulators and the nitrogen rate. In the presence of Embark, Primo, or the sequential application of Embark and Primo, anthracnose was enhanced by verticutting at low nitrogen, but was unaffected at the high nitrogen rate. In 2004, no effect of verticutting on anthracnose was observed. The importance of verticutting on the development of anthracnose still remains unclear. Observation over a third year should help elucidate the significance of this management practice on anthracnose development.

Update on Breeding Programs to Improve Gray Leaf Spot Resistance in Perennial Ryegrass and Brown Patch Resistance in Tall Fescue

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Since the early 1960's Rutgers University has been conducting cycles of population improvement each year on perennial ryegrass and tall fescue. This update will cover the progress that has been made on improvements in gray leaf spot resistance in perennial ryegrass and brown patch resistance in tall fescue.

Perennial Ryegrass

Starting in 1996, over 900 collections of perennial ryegrasses and their associated endophytes from central and eastern Europe have been evaluated at Rutgers University. Each year the most promising lines were topcrossed with the best Rutgers' germplasm available being used as the recurrent parent. The Rutgers' germplasm plants selected out of old turfs in northeastern US between 1962 and 1977. This material combined with new germplasm added from other US and European collections over the years has been cycled each year as part of a population improvement program for perennial ryegrass. Continued improvements in turf quality, overall disease resistance and persistence have been made in the populations of perennial ryegrass released by Rutgers.

Gray leaf spot (caused by *Pyricularia grisea* [Cooke] Sacc) has become a devastating new disease of perennial ryegrass since the early 1990's in the northeastern US and other humid parts of the USA. This disease was never observed on the Rutgers Adelphia Research Station in Freehold, NJ before the fall of 2000, making it impossible to breed for resistance. Individual progenies of perennial ryegrass with improved resistance to gray leaf spot were identified in the fall of 2000. Eighteen of the 36 new sources were from the original Rutgers' germplasm sources. The other sources were from new European collections. Most of the commercial varieties in this trial were devastated (up to 90%) by gray leaf spot while the most attractive gray leaf spot resistant progenies were damaged less than 5%.

In the spring of 2001, the maternal clonal parents of the most resistant progenies in the 2000 test were placed in isolated crossing blocks according to their plant type and maturity. The individual progenies and composites of the different crossing blocks were seeded on August 17, 2001 at the Adelphia farm. The three most recent populations had gray leaf spot ratings of over 7.7 out of 9 = no disease, while most of the commercial varieties rated from a 5.0 down to 1.5. The 2001 results were similar to the 2000 results for the commercial cultivars but the progeny plots exhibited better resistance as a result of the selection for resistance in 2000. The realized heritability = 0.98 indicates that selection for gray leaf spot resistance should be very effective in improving resistance in subsequent generations (Bonos et al., 2004).

Each fall (by mid October) from 2001, 2002 and 2003, selections were made from mowed single plot progeny tests of those plots having the least damage from gray leaf spot.

These were then placed in spaced plant nurseries and used to develop populations having the desirable turf characteristics combined improved gray leaf spot resistance. These new populations were increased in the fall of 2003 either at the Rutgers Adelphia Research Center or by collaborators in the Pacific Northwest.

In the fall of 2004, a new National Turfgrass Evaluation Program (NTEP) was started for perennial ryegrass throughout the US. One trial was seeded at Hort Farm II and one at the Adelphia Research Center. A severe epidemic of gray leaf spot occurred at both Rutgers locations. The results for both locations showed at least 17 of the new varieties selected for gray leaf spot resistance rated an average gray leaf spot rating of 8 or better out of 9 with 9 = most resistance. The top varieties in these tests included LTP-611-GLR, D04-UP, DP1, Pick-RB1, Pick-F4, GL-1, Protege, IS-PR-274, AZ-B104, SRX-4SP and Paragon-GLR. Many of the present commercial varieties in these NTEP's rated a 3 or less for gray leaf spot.

Tall Fescue

The major disease of tall fescue is brown patch caused by *Rhizoctonia solani* Kühn. This is a disease that occurs throughout the US on tall fescue with slow continual progress for improved resistance being developed. With increased density and a more compact of growth habit in new tall fescues, there must be a concurrent improvement in brown patch resistance to maintain turf quality.

Many new improved varieties of tall fescue have been released collaboratively by Rutgers turfgrass breeders. These new tall fescues were part of a population improvement program originating from plants selected from old turfs of the United States in a germplasm collection program initiated in 1962 to plants selected from or related to Rebel tall fescue (Funk et al., 1981). Attractive clones were selected from old turfs in Birmingham, AL; Athens, Atlanta, and Millegeville, GA; Preston, ID; Baltimore, MD; Bayonne, Jersey City, Elizabeth, Princeton, and Cape May, NJ; eastern North Carolina; Philadelphia, PA; Nashville, TN; Lexington, KY; Cincinnati, OH; Dallas, TX; and northern Mississippi. The tall fescue plans selected from old turfs were of unknown origin. All were large patches of turf surviving in stressful environments indicating that they had persisted and developed over a period of many years.

A few hundred attractive, turf-type plants were collected and established in spaced-plant nurseries and/or frequently mowed clonal evaluation trials at Rutgers University. All but a few dozen of the most promising plants were quickly discarded. The best selections were very different from any tall fescue variety in existence at the time of collection. They produced lower-growing turfs with finer leaves, greater density, darker color, and greater tolerance of close mowing.

The most promising plans were identified by their persistence and appearance in old turfs and their performance in spaced-plant nurseries, mowed clonal evaluation tests, a single-plant progeny trials under turf maintenance. Intercrosses of the best performing plants were subjected to varying cycles of phenotypic and genotypic selection depending on their date of collection. New sources of germplasm were added to the breeding program as it became available form the continuing collection program. Each cycle of selection showed continued progress in producing lower-growing, darker green, attractive plants with improved turf performance scores. Selection was also effective in maintaining high seed yields, and good stress tolerance. Substantial progress was made in developing tall fescues with finer leaves, a lower growth profile, increased persistence under close mowing, and increased density.

Large numbers of single-plant progenies were seeded in turf evaluation trials at the Plant Science Research Farm at Adelphia, NJ each year. The plants selected for progeny evaluation were selected from spaced-plant nurseries at Adelphia following varying cycles of phenotypic and genotypic selection of germplasm.

In the fall of 1999, 75,000 tillers were removed from single-plant progeny turf plots that had displayed higher levels of resistance to brown patch during the past summer. These were grown in greenhouses during the winter at short days and $40-50^0$ F temperatures. In the spring of 2000, 27,000 clones selected from these were placed in mowed tiller plots spaced 1 foot apart. During the summer of 2000 and 2001, these plants mowed at 2 inches were inoculated with brown patch carried on previously sterilized Kentucky bluegrass seed (Meyer and Watkins, 2003). An additional 17,000 tall fescue clones to be put in mowed tiller plots were selected for planting in the winter of 2001.

Selections were made from the 27,000 in the summer of 2001. Less than 1% of the population was selected for improved brown patch resistance and attractive appearance. This was again done in 2002 at a similar level. This process was also done on the 2002 tiller plot planting for 2003 and 2004.

The individual clones selected in the summer of 2001 were put into spaced plant nurseries in the fall of 2001. Four crossing blocks were established in early spring of 2002 from the tiller selected plants. They were designated as ATE (early maturing), ATM (medium maturing), ATN (medium-late maturing), and ATL (late maturing). These new synthetic's were compared with new cultivars in a large replicated trial in the fall of 2002 at Adelphia. These new synthetics have improved density and a bright appearance and improved levels of brown patch resistance compared to top performing varieties in the 2001 NTEP tall fescue trial such as Falcon IV, Avenger, Cayenne, 2nd Millennium, Da Vinci and Justice. This was shown from data from the summers of 2003 and 2004.

Another cycle of selection from these tiller plots was conducted in 2002 with new crossing blocks labeled ATO. These new varieties had the highest level of brown patch resistance and turf quality compared to all previously developed varieties in the summer of 2004.

Summary

Tremendous progress has been made in the past 4 years on breeding for improved resistance to gray leaf spot in perennial ryegrass. We will continue to work on further improvements in resistance on this disease along with improvements in dollar spot, red thread and crown rust.

The progress on improvements in tall fescue for brown patch and turf quality has occurred at a slower steady pace. The rise of single clone mowed tiller plots has improved the efficiency of this process as shown from the 2003 and 2004 results.

References

Funk, C.R., R.E. Engel, W.K. Dickson, and R.H. Hurley. 1981. Registration of 'Rebel' tall fescue. Crop Science 21:632.

Bonos, S.A, C. Kubik, B.B. Clarke, and W.A. Meyer. 2004. Breeding for gray leaf spot resistance in perennial ryegrass. Crop Science 44:575-580.

Meyer, W.A., and E. Watkins. 2003. Tall fescue (*Festuca arundinacea)*. In: Turfgrass Biology, Genetics and Breeding. M.D. Casler and R.R. Duncan (Eds.). John Wiley and Sons Inc., pgs. 107-127.

Evidence for a Change in the Species Designation for *Colletotrichum graminicola* Causing Anthracnose in Turf

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Intensively managed golf course turfgrass is continually threatened by a wide array of plant diseases, with one of the most formidable challenges presented by anthracnose, a destructive disease caused by the filamentous fungus *Colletotrichum graminicola*. Control of the disease is often unpredictable, possibly due to an imperfect understanding of population structure and pathogen variability.

Prior to the start of this project, three species of *Colletotrichum* were recognized as inhabiting graminaceous plants: *C. sublineolum* found on species of sorghum (Sutton, 1966), *C. falcatum* from sugarcane (Sutton, 1968), and *C. graminicola* (Wilson, 1914), which was considered to have a broad host range including corn and most of the remaining grass species. As disease severity in turfgrasses attributed to *C. graminicola* increased throughout the 1990s, several research groups (Backman et al., 1999; Browning et al., 1999; Chen et al., 2002; Horvath and Vargas, 2004; Hsiang and Goodwin, 2001) conducted small-scale molecular analyses aimed at characterizing variability in the species. Each study contributed important information, but overall the results were conflicted, the datasets small, and no general hypothesis of descent was apparent.

Our investigation of *C. graminicola* populations using multi-locus nucleotide sequence analysis and transposon RFLP fingerprint patterns revealed two strongly supported distinct lineages among isolates from turfgrass host plants. Phylogenetic analysis of these data also provided compelling evidence of species-level divergence between *C. graminicola* pathogenic t corn and *Colletotrichum* specimens causing disease in turfgrass host plants. Positive adaptive selection at the fungal mating-type gene, as estimated from non-synonymous nucleotide substitutions, suggests that reproductive isolation may have played a role in separating these two unique sibling species as they emerged in host-range restricted ecological niches. These data strongly support the taxonomic division of *C. graminicola*, requiring the establishment of an additional species to properly represent these evolutionarily distinct lineages of *Colletotrichum*.

References

Backman, P. A., P. J. Landerschoot, and D. R. Huff. 1999. Variation in pathogenicity, morphology, and RAPD marker profiles in *Colletotrichum graminicola* from turfgrasses. Crop Science 39:1129-1135.

Browning, M., L. V. Rowley, P. Zeng, J. M. Chandlee, and N. Jackson. 1999. Morphological, pathogenic, and genetic comparisons of *Colletotrichum graminicola* isolates from *Poaceae*. Plant Disease 83:286-292.

Chen, F., P. H. Goodwin, A. Khan, and T. Hsiang. 2002. Population structure and mating-type genes of *Colleotrichum graminicola* from *Agrostis palustris*. Canadian Journal of Microbiology 48:427-436.

Horvath, B. J., and J. M. Vargas. 2004. Genetic variation among *Colletotrichum graminicola* isolates from four hosts using isozyme analysis. Plant Disease 88:402-406.

Hsiang, T., and P. H. Goodwin. 2001. Ribosomal DNA sequence comparisons of Colletotrichum *graminicola* from turfgrasses and other hosts. European Journal of Plant Pathology 107:593-599.

Sutton, B. C. 1966. Development of fructifications in *Colletotrichum graminicola* (Ces.) Wils. and related species. Canadian Journal of Botany 44:887-897.

Sutton, B. C. 1968. The appressoria of *Colletotrichum graminicola* and *C. falcatum*. Canadian Journal of Botany 46:873-876.

Wilson, G. W. 1914. The identity of the anthracnose of grasses in the United States. Phytopathology 4:106-112.

Poster Presentations

Development of Predaceous Nematodes for Biocontrol of Phytoparasitic Turfgrass Nematodes

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A new diplogasterid species, *Mononchoides* sp., was isolated from soil at the Turfgrass Farm. The predatory potential of *Mononchoides* sp. was assessed in terms of predation, feeding, predator strike rate and prey preference, and prey resistance and susceptibility to predation. Experiments to date suggest that this nematode possesses attributes useful for biocontrol.

Prey preference and feeding behavior of *Mononchoides* sp. was studied using 11 phytoparasitic nematode species as prey. *Mononchoides* sp. showed preference for different species of prey when tested in a no choice and choice experiments. *Meloidogyne incognita* and *Helicotylenchus. mothi* were highly susceptible (PS = 91.5-93.5%) to predation as they were most attacked (SR = 92-94%) and preferred by predators (78.0-84.0% preference). Predators showed low preference *for Helicotylenchus indicus* (*Hel. indicus*) (28.0%) and 0% *for Hoplolaimus indicus* (*Hop. indicus*) and *Hemicriconemoides mangifeare* when tested with single prey species. All prey, except *Xiphinema americanum* and *Pratrichodorus trichodorus*, were accepted more than they were rejected in ten combinations. Preference for *M. incognita* (mean prey accepted = 39.6%) over others ranged between 04 to 88% with 0% rejection. Coefficient of preference was highest for *M. incognita* (1.0), minimal for *Hel. indicus* (-0.57) and zero for *Hop. indicus* and H. *mangiferae*. Degree of prey susceptibility determined predator feeding after prey wounding, highest being for *M. incognita* and *H. mothi* (PF = 100%), moderate for *Tylenchorhynchus mashoodi, Longidorus attenuatus, X. americanum* and *P. Christie* (PF = 60-87.5) and minimal for *Hel. indicus* (PF = 13.3%). Longest feeding duration was recorded on *L. attenuatus* (108.8 m; range: 90-121m) and shortest on M. incognita (33.5 m; range: 28-38m). Temperature and prey density governed predator's feeding activities e.g., search duration was shortest with 150-225 prey at 20-30ºC. Predators killed highest and fewer prey under similar conditions. Temperature and prey density extremes inhibited predator activities including aggregation duration at the feeding sites.

The Evaluation of Brown Patch Resistance in Tall Fescue

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Brown patch, caused by the fungus *Rhizoctonia solani* (Kühns), is one of the most important diseases affecting tall fescue (*Festuca arundinacea* Schreb) turfs. The identification and utilization of tall fescue cultivars with improved resistance to brown patch would improve quality and reduce the need for fungicide applications. Variation in brown patch resistance exists among tall fescue cultivars. However, there are no published reports on the inheritance of resistance in tall fescue. The heritability of brown patch resistance in tall fescue will be important for tall fescue breeding programs to determine selection efficiency and to understand the inheritance of disease resistance in tall fescue. The objectives of this study were to: 1) determine broad- sense heritability estimates for brown patch resistance in tall fescue populations, and 2) evaluate cultivars and experimental selections of tall fescue for resistance to brown patch disease.

Several tall fescue field experiments consisting of commercial cultivars and experimental selections were evaluated for brown patch disease resistance. Experiment 1 compared brown patch disease resistance of 33 cultivars and selections planted in three replicated tall fescue field trials established in 1998 at Adelphia, North Brunswick and Pittstown, NJ. Experiment 2 compared brown patch disease resistance of 160 and 41 cultivars and selections planted in two replicated tall fescue field trials established in 2001 at North Brunswick and Adelphia, NJ and one replicated trial established in 2002 at Adelphia, NJ, respectively. Field plots were inoculated with *Rhizoctonia solani* mycelium grown on sterilized Kentucky bluegrass (*Poa pratensis* L.) seed at a rate of 0.25 g m^{-2}. Susceptibility of germplasm to brown patch was evaluated following disease development, which occurred two to three weeks after inoculation. Broad sense heritability estimates were determined from restricted maximum likelihood (REML) variance and covariance components using the random model of Proc MIXED (SAS Institute, Cary, NC). Most cultivars and selections evaluated in both experiments had moderate to high levels of brown patch disease. Moderate broad-sense heritability estimates for brown patch disease resistance in tall fescue were obtained (0.74 to 0.55) depending on the experiment and number of cultivars replicated in each experiment. These heritability estimates are lower than those reported for dollar spot (caused by *Sclerotinia homoeocara* F.T. Bennet) resistance in creeping bentgrass (*Agrostis stolonifera* L.) (H=0.90) (Bonos et al., 2003) and gray leaf spot (caused by *Pyricularia grisea* (Cooke) Sacc) resistance in perennial ryegrass (Lolium perenne L.) (H=0.92) (Bonos et al., 2004). These data indicate that brown patch disease development may be more affected by the environment than dollar spot or gray leaf spot diseases. These heritability estimates indicate that selection for resistance should be possible in the next generation, which will be important for the development of more disease resistant cultivars.

References

Bonos, S.A., C. Kubik, B.B. Clarke, and W.A. Meyer. 2004. Breeding for gray leaf spot resistance in perennial ryegrass. Crop Science 44:575-580.

Bonos, S.A., M.D. Casler, and W.A. Meyer. 2003. Inheritance of dollar spot resistance in creeping bentgrass. Crop Science. 43:2189-2196.

What Can the Tallgrass Prairie Tell Us About Anthracnose Disease on the Golf Course Green?

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The fungal genus *Colletotrichum* contains several species that infect monocot hosts in both cultivated and natural grass communities. In monocultured agroecosystems like those found on golf course greens, these fungi are often found as destructive pathogens, capable of inducing significant disease in the host plant. In contrast, our recent sampling of *Colletotrichum* in a natural tallgrass prairie ecosystem suggests that populations of this fungus living in diverse grass communities maintain a non-pathogenic lifestyle, with their presence never correlated with substantial disease. In turfgrass stands, either one of two distinct *Colletotrichum* lineages may be present, but in the natural grassland environment, our preliminary data reveals the presence of only a single lineage. Interestingly, based upon transposon distribution data and RFLP patterns, it appears that the prairie grasslands may actually represent a hybrid zone between the genotypes of distinct *Colletotrichum* phylogenetic species, while the corresponding turfgrass populations are generally of non-hybrid origin. We are currently developing a set of microsatellite markers to generate the hypervariable genetic data needed to explore how variation is distributed spatially within *Colletotrichum* populations inhabiting these different ecosystems. Importantly, this comparative approach will allow us to detect historical events of interest such as population fragmentations, range expansions, and colonization in the *Colletotrichum* species that inhabit Pooideae grasses. Investigating the differences between the *Colletotrichum* populations from natural prairie grasslands and the inhabitants of golf course greens may help us to identify the forces that have shaped the recent evolution of this fungus into an aggressive pathogen of cultivated amenity turfgrasses.

Morphological and Physiological Factors Associated with Bentgrass Survival and Recovery from Drought

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Many areas of turf may be left un-irrigated or under-irrigated due to widespread water-use restrictions. Rapid recovery of turfgrasses from drought stress following irrigation restrictions is an essential strategy of turfgrass survival of stressful environments. Various morphological and physiological characteristics are associated with survival and recovery from drought, including rapid recovery of existing tissues, regeneration of new tissues, and alteration in plant hormone status. Abscisic acid (ABA) and cytokinins (CK) are two groups of plant hormones that are reported to improve plant resistance to drought stress. Changes in hormonal balance in particular have been reported as important for relief from drought stress and facilitating plant recovery. The primary objective for this study was to examine strategies for survival and recovery from drought in three bentgrass (*Agrostis*) species. Sods of creeping (cv. L-93), colonial (cv. Tiger 2), and velvet (cv. Greenwich) bentgrasses were transplanted into polyvinyl chloride (PVC) tubes (40 cm long, 10 cm diameter) filled with a 3:1 (v/v) sterilized mixture of soil and sand. The experiment consisted of three treatments: (i) well-watered control; (ii) drought-irrigation completely withheld; and (iii) drought recovery. For recovery, a group of drought-stressed plants were re-watered at the end of the drought period to evaluate recovery potential for each species. Bentgrass species varied in strategies for recovery from drought stress. Colonial bentgrass exhibited faster recovery through regeneration of new leaf tissue, while velvet bentgrass exhibited more rapid recovery of existing compared to new growth. Creeping bentgrass utilized both strategies for rapid initial recovery of existing tissue, followed also by regeneration of new leaf tissue. The morphological characteristics associated with recovery of bentgrasses from drought included new tiller generation from basal tissue (potentially from crowns, stolons, and rhizomes) and re-hydration of existing leaf tissue. Hormone status was also an important physiological factor for plant recovery, and plants exhibiting a rapid increase in CK and decrease in ABA recovered more rapidly than plants with delayed changes in hormone balance.

A New Green Revolution - (Food, Energy, Environmental Enhancement, and Mitigation of Global Warming)

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Agricultural scientists and practitioners throughout human history and especially during the past 65 years have made dramatic contributions to our well-being and prosperity. Even greater contributions are urgently needed during future decades and centuries. We have the ability to dramatically improve our environment, lifestyles, health, and prosperity by doubling world biomass production to harvest excess carbon dioxide from the atmosphere. This would ensure adequate supplies of more nutritious and health promoting food, reduce our addiction to and dependence on fossil fuels, enhance our environment, and mitigate many of the causes of global warming and its disastrous effects. The greatest opportunity for increasing biomass production involves planting trillions of genetically improved trees along with harvesting and replacing dead, dying and mature trees with adapted, productive cultivars to obtain a high percentage of trees in their rapid growth phase. Perennial trees, shrubs, grasses, legumes, and forbs adapted to land not suitable for sustainable production of cultivated annual crops will produce much of the added food, timber, fuel, and fiber needed to feed, house, and supply energy to the current world's poor and hungry as well as projected population increases of the future. Perennial crops, trees, and turfgrasses will preserve our precious soil and water resources. Genetic improvements of our annual food and fiber crops have been responsible for much of the added food production and prosperity of the past 65 years. Most was due to conventional plant breeding aided by advances in supporting agricultural sciences including pathology, entomology, agronomy, genetics, horticulture, physiology, ecology, biometrics, soil science, etc. These sciences abetted by innovations of agricultural practitioners and advances in molecular sciences and techniques will be the foundation of plant improvement programs of the foreseeable future. Land grant colleges with their Agricultural Experiment Stations, teaching, and extension programs, the United States Department of Agriculture and similar research, service, and educational institutions throughout the world will have the opportunity and responsibility to implement these programs. They will require the participation and support of all nations and people. Continued advances in the production of annual food crops will be limited as biological limits to increased yield and feed utilization efficiency are reached and decreasing amounts of fertile soil and other resources become available for production. The greatest current and future opportunities exist in the genetic improvement and culture of hundreds of species of underutilized perennial plants capable of sustainable growth and production on the vast areas of lands unsuitable for cultivated annuals. This will take a gigantic effort and must be started immediately.

Genetically improved grasses, legumes and forbs for turf, erosion control, and soil improvement are and will become increasingly important. Many of the world's best soils were formed under grasslands. Properly managed turfs increase soil organic matter and soil structure. Clippings can be used for feed, mulches, biofuels or returned to add fertility. Many hills and mountains throughout the world have suffered repeated deforestation, overgrazing, and unwise tillage. In most instances, conservation plantings of grasses, forbs and legumes will be needed, along with possible soil amendments, to stabilize remaining soils, prevent further erosion, enhance fertility, and add soil organic matter prior to and in addition to the establishment of desirable trees. These extensive turfs will harvest considerable carbon dioxide and furnish biomass for forage and other uses. US exports of turfgrass seed to rapidly developing countries such as China are increasing at a rapid rate. Turf-type tall fescues and other grasses tracing to the Rutgers breeding program are an important part of these exports.

Effect of Soil Type and Soil Moisture on *Steinernema scarabaei* (Rhabditida: Steinernematidae) Efficacy Against White Grubs and Persistence

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The entomopathogenic nematode *Steinernema scarabaei* has shown exceptional efficacy for the management of white grub, the root-feeding larvae of scarab beetles. To improve predictability of *S. scarabaei* applications we studied the effect of 7 soil/substrate types and soil moisture levels on its efficacy and persistence. In laboratory and greenhouse experiments, *S. scarabaei* infectivity and efficacy was not strongly affected by substrate type but tended to be the highest in a loamy sand, did not differ significantly among sandy loam, loam, silt loam, and clay loam, and tended to be the lowest in a highly acidic blueberry sand (pH 3.9) and a typical potting mix (69% OM). *S. scarabaei* persistence was high over the same range of soil types with a clear decline only aft 140 d at room temperature and without a clear effect of soil type. Only in the finest textured soil, clay loam, did *S. scarabaei* show a clear decline with about 50% less recovery than after 0 d.

The effect of soil moisture levels ranging from saturated to very dry (-1 to -3,000 kPa water potential) on *S. scarabaei* infectivity was studied in the laboratory in 3 selected soils. In loamy sand, there was no strong effect of soil moisture. Even at –3,000 kPa 70% of the grubs were killed. In sandy loam and silt loam, the mortality and infectivity were highest at –10 and –100 kPa, lower at –1 and –1,000 kPa, and the lowest at –3,000 kPa. This effect was stronger in silt loam than in sandy loam. In the same soils moisture levels of -10 to -3,000 had no strong effect on *S. scarabaei* persistence.

Biochemical Changes Associated with Leaf Senescence in Creeping Bentgrass

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The decline in turf quality and leaf senescence often occurs for creeping bentgrass under heat stress. This study was performed to investigate changes in turf quality, membrane lipid peroxidation, total protein content, amino acid content, and protease activity for creeping bentgrass (*Agrostis palustris* Huds.) in response to a gradual increase in temperature and to direct heat stress. Plants were subjected to different temperatures from 20 to 40^{o}C at 5^{o}C intervals for 7 d at each level of temperature (indirect heat stress) or directly exposed to 40 ^{o}C after 7 d of 20 ^{o}C and maintained for 28 d (direct heat stress) in growth chambers. During indirect heat stress, turf quality declined significantly when plants were exposed to 30 ^{o}C for 7 d; simultaneously, malondialdehyde (MDA) content increased and total protein content in shoots decreased significantly compared to that at 20 ^{o}C. Protease activity increased when plants were transferred from 20 to 25 ^{o}C and then decreased from 30 to 40 ^{o}C. Amino acid content decreased with increasing temperature, beginning at 25 ^{o}C up to 35 ^{o}C, and then increased when temperature rose to 40 ^{o}C. During direct heat stress, turf quality declined significantly and MDA content increased significantly with stress duration beginning at 14 d of treatment; total protein content decreased when plants were exposed to 40 ^{o}C for 7 d; protease activity and amino acid content increased to above the initial level at 7 d of direct heat stress, and declined with longer stress duration. The results indicated that protease activity, amino acid content and total protein content were more sensitive to heat stress compared to MDA content and turf quality. It is inferred that the turf quality decline and oxidative stress is related to net decrease of protein and amino of acid content in bent grass under heat stress.

Assessment of Mowing and Rolling Practices on Anthracnose Severity and Ball Roll Distance on an Annual Bluegrass Putting Green

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Currently, recommendations made to superintendents struggling with anthracnose (*Colletotrichum graminicola* (Ces.) G.W. Wils.) are derived from studies that have evaluated the effect of cultural practices on diseases other than anthracnose, or are based on general knowledge involving the influence of management practices on plant health. The objective of this study is to provide direct evidence about the effect of cultural practices on anthracnose severity, ball roll, and turf quality. Data generated over the next few years from this project will be used to provide superintendents with guidelines illustrating the relationship of management intensity (i.e., mowing height, and frequency, rolling, etc.), ball roll, and anthracnose severity. A comprehensive set of disease control recommendations will be developed for superintendents using results of this and other studies conducted at Rutgers University evaluating the impact of nitrogen, plant growth regulators, and verticutting on anthracnose basal rot.

The current study was initiated in April 2004 on a one-year old stand of annual bluegrass (*Poa annua*) maintained on a Nixon sandy-loam at the Horticultural Research Farm II in New Brunswick, NJ. Aerifier cores obtained from Plainfield Country Club, Plainfield, NJ, in addition to the indigenous weed seed, were used to establish the annual bluegrass field. The area was maintained during the 2004 growing season using standard golf course management practices for the Northeast region. Nitrogen was applied at 4.9 kg ha^{-1} (0.1 lb N/1000ft^2) every 7-14 days and Primo MAXX 1MC (trinexapac-ethyl) was applied at 0.4 L ha^{-1} (0.125 fl. oz./1000ft^2) every 14 days from 26 May to 13 Oct. Dollar spot and brown patch were controlled as needed with Curalan 50 EG 3.1 kg ha^{-1} (1 oz./1000ft^2) and ProStar 70WP 6.4 L ha^{-1} (2 oz./1000ft^2) since it has been previously determined that neither fungicide controls anthracnose. Every 14 days, the area was topdressed with 280.81 g sand/m^2 and brushed with a Coco mat. Turf was hand watered as needed to prevent wilt stress. 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; 0.110, 0.125, and 0.141 inch) was the main plot factor, mowing frequency (7 times/wk or 14 times/wk) was the split plot factor, and lightweight rolling (rolling vs no rolling) was the split-split plot factor.

Symptoms from a naturally occurring outbreak of anthracnose were apparent in the study by 29 July. To insure uniformity, the area was artificially inoculated with *C. graminicola* at 7 x 10^3 conidia/mL on 3 Aug. Disease severity was greatest at the 2.8 mm mowing height, while plots mowed at 3.6 mm incurred the lowest levels of disease. The severity of anthracnose at the intermediate mowing height (3.2 mm) was not significantly different than when turf was maintained at either 2.8 or 3.6 mm. Double cutting (14 times/wk) reduced anthracnose by 7.7 to 16.9% on 2 of 3 rating dates, compared to single cut turf. Lightweight vibratory rolling reduced disease by 6.8 to 7.7% over all rating dates. There were no interactions involving rolling, indicating that the influence of lightweight rolling on anthracnose was not dependent on mowing practices evaluated in this study. An interaction between mowing frequency and height was apparent by the end of the season, where double cutting at 2.8 mm enhanced anthracnose, but more research is necessary to confirm these results.

Ball roll distance was affected by the main effects in the first year of this study. Mowing height and mowing frequency significantly impacted ball roll 76% of the time, with rolling influencing 48% of the observations. As expected, ball roll distances were increased when turf was mowed at 2.8 mm, compared to higher cutting heights. Likewise, greater ball roll was associated with more frequent mowing and lightweight vibratory rolling. A number of treatment combinations met or exceeded the minimum acceptable ball roll distance established for this study (i.e., 2.9 to 3.2 m; 9.5 to 10.5 feet) between 4 June and 20 July. All combinations of mowing frequency and rolling at the low and intermediate mowing heights (2.8 and 3.2 mm) achieved the minimum acceptable distance. Interestingly, either double cutting or rolling at the high height of cut (3.6 mm) also produced acceptable ball rolls.

Irrigation Frequency Requirement for Three Bentgrass Species Under Golf Course Fairway Conditions

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‘L-93’creeping bentgrass, ‘AT5’ colonial bentgrass, and ‘EVN’ velvet bentgrass were examined at two different mowing heights (1/4” and 3/8”) to compare species variation in irrigation frequency requirements and Crop Water Stress Index (CWSI) values. 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. Our results demonstrate that irrigating at 100% ET, three times a week may not be necessary to sustain plant growth and physiological processes, and that this depended on species and time of year. Generally, irrigating twice a week and replacing 100% of ET was adequate to maintain acceptable turf quality during summer months for all species of grasses tested. The data also suggest that both early and late in the season, watering once a week is sufficient to maintain adequate quality in both colonial and velvet bentgrass. Maintaining turf at a lower cutting height produced higher water demands when irrigated 3 times a week. Lysimeter readings consistently show that creeping bentgrass watered three times a week and maintained at ¼” lost more water than turf cut at 3/8”. Both creeping and colonial bentgrass had significantly lower carbon fixation rates and lower Water Use Efficiency (WUE) when watered once a week or less. Velvet bentgrass was much better adapted to maintaining high levels of both parameters, even when irrigation was limited.

Plant Growth Regulator Regimens for *Poa annua* Control in Creeping Bentgrass

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Plant growth regulators (PGRs) are commonly applied for *Poa annua* suppression but various PGR regimens may be more applicable in creeping bentgrass management than exclusive applications. Two field experiments in Riverton, NJ investigated various regimens of paclobutrazol (PB) and trinexapac-ethyl (TE) for *Poa annua* control in creeping bentgrass golf course fairways. Over the four years, *Poa annua* coverage was greater in the spring compared to summer and fall. In the first experiment, *Poa annua* reductions were 22 and 30% in untreated turf and turf treated only with TE, respectively. Reductions in *Poa annua* were ≈ 55% for turf receiving PB with and without TE applications. In the second experiment, PB reduced *Poa annua* populations to approximately half of the untreated plots but combinations with TE did not enhance turf quality or *Poa annua* suppression. Routinely applying PB at 0.14 kg ha^{-1} 3 wk^{-1} provided similar *Poa annua* control to single applications of 0.56 kg ha^{-1} while both regimens gave better control than 0.28 kg ha^{-1} of PB applied in the spring and fall. Overall, PB will be an effective tool for suppressing *Poa annua* in creeping bentgrass fairways for northeastern golf courses; however, tank mixing TE with PB will likely not enhance these effects.

Field Infiltration and Saturated Conductivity of Creeping Bentgrass Root Zones

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Laboratory assessment of saturated hydraulic conductivity (K_{sat}) of sand root zones before construction of golf putting greens is often extrapolated to rather precise expectations of field water infiltration. This study compared pre-construction K_{sat} of mixes to water infiltration of 4-yr old creeping bentgrass putting greens in two microenvironments. Root zone mixes containing various sand size distributions were arranged in a randomized incomplete block design nested over two microenvironments. Double-ring infiltration through the 0- to 50-mm surface depth was measured. Pre-construction K_{sat} ranged from 407 to 937 mm h^{-1}, with root zones ranked greatest to lowest: coarse, coarse-medium, medium = medium-fine 2, and medium-fine 1. As expected, water infiltration was dramatically lower than K_{sat}. Greater infiltration in the enclosed microenvironment was only observed on coarse sand (37 mm h^{-1}) compared to other root zones that had infiltration of 9 to 23 mm h^{-1}. Infiltration rates of root zones in the open microenvironment ranged from 12 to 68 mm h^{-1} and were ranked greatest to lowest: coarse-medium, medium, medium-fine 1 = medium-fine 2. Thus, expectations that pre-construction root zone K_{sat} serves as a precise index for water infiltration of putting greens are unreliable.

Response of Kentucky Bluegrass Cultivars to Traffic

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Many cultivars of Kentucky bluegrass (*Poa pratensis* L.) have been developed since the release of the first turf-type selection 'Merion' in 1947. Kentucky bluegrass is often established on highly used sports fields and individual cultivars may differ greatly in their responses to traffic. Cultivars of Kentucky bluegrass were seeded in 2002 and a study was initiated in spring 2004 with the following objectives: 1) Identify the relative importance of specific traffic stresses (wear and/or compaction) to performance of Kentucky bluegrass cultivars; and 2) Determine seasonal wear tolerance and recovery differences among Kentucky bluegrass cultivars. The first objective will refine our understanding of damage caused by traffic, enable turf managers to prioritize cultural practices that target the most important stress, and assist breeders in developing screening procedures for germplasm selection. The second objective is important because many better performing Kentucky bluegrass cultivars tested under traffic during summer months have strong 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. To satisfy the first objective, simulated wear, compaction, and combined wear and compaction was applied to Kentucky bluegrass cultivars from March to November 2004. To fulfill the second objective, wear was applied to Kentucky bluegrass cultivars as part of separate spring (March-May), summer (July-August), and fall (October-November) treatments in 2004. All plots were visually rated for turfgrass performance and recovery throughout the test period. Turfgrass performance was assessed utilizing a 1-9 scale (9=best performance) and by visually determining fullness of turfgrass cover (0-100%; 0%=complete defoliation of turfgrass cover; 100%=full turfgrass canopy). Initial data from this study suggests that the combined stresses of wear and compaction contributed to lower turfgrass performance compared to either wear or compaction alone. Examining wear and compaction individually, Kentucky bluegrass cultivar performance was lower under wear alone compared to compaction applied alone. Data collected from individual seasonal applications of wear appears to indicate that the performance level of some cultivars when subjected to wear is affected by the season in which wear is applied. Continued data collection will identify specific traffic stresses which most affect turfgrass performance and allow for season-specific Kentucky bluegrass cultivar recommendations.

Root Respiratory Characteristics Associated with Plant Adaptation to High Soil Temperature for Geothermal and Turf-type Agrostis Species

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The mechanisms that control adaptation and acclimation of plants to high temperature soils are essential to our understanding of natural, agricultural and leisure environments. Respiration is a major avenue of carbohydrates loss. Shortage of assimilates due to high respiratory losses has long been proposed to be a primary factor responsible for root growth inhibition.

In the current study, responses of root vitality, growth, root maximal length, total respiration rate and its components (maintenance, growth and ion uptake) to high soil temperature were evaluated in two *Agrostis* species: *Agrostis scabra*, a heat tolerant grass collected from the Yellowstone National Park is adapted to high-temperature soils, and two creeping bentgrasses (*A. palustris*) cultivars, 'L-93' and 'Penncross' that differ in their heat sensitivity. The plants were studied following subjection of roots either to high temperature (37^{o}C) or to the optimum temperature (20^{o}C). All parameter were measured once a week for four weeks during the treatment.

Total root respiration increased under high temperatures in all species. The lowest increase (35%) was in the heat tolerant specie, *A. scabra,* and the highest increase (94%) was in the most sensitive creeping bentgrasses 'Penncross'. Total respiration increases were positively correlated to roots mortality and negatively correlated to root biomass and maximal root length. Respiration maintenance costs were lower under 20^{o}C: 1.19, 1.12 and 1.09 mmol CO_2 g^{-1} d^{-1} in *A. scabra*, 'L-93' and 'Penncross', respectively. Under 37^{o}C, the maintenance costs were: 1.7, 2.29, and 2.45 mmol CO_2 g^{-1} d^{-1} in *A. scabra*, 'L-93' and 'Penncross', respectively.

Our results indicate that carbon utilization in the geothermal grasses adapted to high-temperature soils was more efficient and that carbon utilization play an important role in slow root growth and high root mortality under high soil temperatures. Heat tolerance of roots was related to the ability to control respiratory costs and increase their respiratory efficiency by lowering their maintenance costs.

Identification of Genes Over-Expressed in a Colonial Bentgrass x Creeping Bentgrass Interspecific Hybrid

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Creeping bentgrass (*Agrostis stolonifera* L.) is highly susceptible to dollar spot disease caused by the fungus *Sclerotinia homoeocarpa*. Colonial bentgrass (*A. capillaris* L.) is a related species that has good dollar spot resistance. Interspecific hybrids between creeping and colonial bentgrass have been made and several hybrids exhibited resistance to dollar spot. The molecular basis for this resistance can be investigated by using suppression subtractive hybridization to detect low copy number transcripts that are unique or over-expressed in either the resistant hybrids or the creeping bentgrass parent following fungal inoculation. RNA was isolated from field samples when creeping lines exhibited dollar spot symptoms. Two subtraction libraries were created from creeping and colonial bentgrass cDNAs, one is enriched for genes in the hybrid relative to creeping parent, and the other is enriched for genes in the creeping parent relative to the hybrid. We are now carrying out RNA blot analysis on field samples to evaluate relative expression levels of the differentially expressed genes. A beta-glucosidase and a 14-3-3 protein were dramatically over-expressed in the hybrid relative to its creeping parent in greenhouse grown plants and both were upregulated in the field samples. The resistant hybrid was crossed to a creeping plant to generate a backcross population that was evaluated for dollar spot resistance in 2004. This population will be used for mapping the colonial bentgrass genome and to determine if any of the differentially expressed genes can be correlated with the resistance trait.

Kentucky Bluegrass Cultivar Response to Bispyribac-sodium Herbicide

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Bispyribac-sodium herbicide can selectively control both *Poa annua* and *P. trivialis* in some cool-season turfgrass species. Kentucky bluegrass (*P. pratensis* L.) has typically exhibited unacceptable injury from applications of bispyribac-sodium; however, these studies only evaluated a limited number of cultivars. Currently there is no effective control of *P. annua* and *P. trivialis* in Kentucky bluegrass. The objective of this study was to determine the effects of bispyribac-sodium herbicide on several diverse Kentucky bluegrass cultivars in both field and greenhouse experiments. A greenhouse study consisting of 14 cultivars (America, Avalance, Brooklawn, Baron, Cabernet, Gnome, Langara, Lakeshore, Livingston, Midnight, Moonshadow, P-105, Sonic, and Total Eclipse) was established in a randomized complete block design with 4 replications. Four bispyribac-sodium rates (0, 120, 240, and 480 g.a.i./A) were applied to 6wk old seedlings of Kentucky bluegrass grown in containers. Percent injury was evaluated at 21 and 28 days after treatment (DAT). Plants were harvested on day 28 and both fresh weights and dry weights were recorded. Bispyribac-sodium was also applied to a replicated mowed Kentucky bluegrass turf experiment established in the fall of 2001, consisting of 250 cultivars and selections. Two applications (60 and 90 g.a.i./A) were applied on June 9, 2004, and July 7, 2004, respectively. Percent injury was evaluated at 7, 14, 21, and 28 DAT. A wide range of injury levels to bispyribac-sodium treatments was observed among Kentucky bluegrass cultivars. Some cultivars, such as Lakeshore and Brooklawn, exhibited a high tolerance to bispyribac-sodium treatments, while other cultivars, such as Baron and P-105, were completely killed. Such a variable response among cultivars indicates that genetic resistance may be responsible for the observed reactions. This research indicates that it may be possible to develop bispyribac-sodium tolerant Kentucky bluegrass cultivars through selection and breeding. Tolerant cultivars would provide the turfgrass industry with a post-emergent, chemical control option for *P. annua* and *P. trivialis* in Kentucky bluegrass.

Turfgrass Germplasm Collection from Central Asia

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Rutgers University has had formal ties with the Republic of Uzbekistan and the Kyrgyz Republic for several years. Reciprocal germplasm exchange agreements have been formulated 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.

The genetic improvement of North American turfgrass species by the introduction, evaluation, and incorporation of desirable traits from unique accessions from around the world has proven to be a successful strategy. The focus of collection efforts continues to be on potentially shade tolerant grasses, grasses that appear productive on marginal, overgrazed lands, and grasses resistant to heat, drought, diseases and insects. With regard to germplasm acquisition in the region, the partnership between Rutgers University and the Central Asian institutes has been due to the efforts of Dr. David Zaurov. 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. (Table 1).

As part of a USDA grant, we also co-sponsored turfgrass field trials of North American cultivars in Uzbekistan. This is the first turfgrass breeding and evaluation program in Central Asia. U.S. scientists were able to provide to Uzbeki partners seeds of turfgrass cultivars for these trails and technical assistance in setting up the field plots. The preliminary results of this trial have been published in the International Agronomy Journal of Uzbekistan, and will be published in Turfgrass Proceedings.

Drs. W. A. Meyer, C. R. Funk, J. A. Murphy, and D. E. Zaurov have hosted delegations from both Uzbekistan and Kyrgyzstan yearly from 1999 to the 2004. During this period, a special mini-training program was developed and tours were set-up to show researchers how to establish a turfgrass collection, nursery, and breeding program. This visit also provided Rutgers with the opportunity to develop potentially new programs in Uzbekistan and Kyrgyzstan.

Table 1. Turfgrass species collected from Central Asia, 2004.

Country	Species	Number of Accessions
Kyrgyzstan	*Poa angustifolia*	4
Kyrgyzstan	*Festuca rubra*	39
Kyrgyzstan	*Festuca sulcata*	25
Kyrgyzstan	*Lolium perenne*	17
Kyrgyzstan	*Poa pratensis*	1
Kyrgyzstan	*Agrostis hissarica*	2
Uzbekistan	*Lolium perenne*	30
Uzbekistan	*Festuca arundinaceae*	5
Uzbekistan	*Poa Pratensis*	117
	Total accessions collected in 2004: 240	

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In Vitro Selection for Salt Tolerant Turfgrass Plants

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Turfgrasses are being subjected to rising amounts of salinity stress, resulting from increased salinization of agricultural areas and use of non-potable water sources as a method of turfgrass irrigation. The objective of this study was to determine the feasibility of an *in vitro* method for selecting salt tolerant turfgrasses. The information will provide a metric for determining the optimal salinity content in non-potable water sources, and the feasibility of irrigating turfgrasses in a high salt environment. Seeds of creeping bentgrass (cv. Penncross) were sterilized and calli were generated in MS medium containing varying solutions of NaCl (0%, 0.5%, 0.75%, 1.0%, 1.25%, 1.5%). The growth rates of calli were evaluated using surface area measurements taken with a digital image analysis program. After 28 days of culture, surface area of the control calli increased 47%. Similarly, the calli exposed to 0.5% NaCl concentration showed a surface area increase of 48%. However, calli in 0.75% and 1.0% NaCl increased only 35% and 42% in size, respectively. At a high level of salinity, surface area increases were only 20% at 1.25% NaCl and 13% for 1.5% NaCl. Despite showing a significant decrease in growth rate, a number of calli in the 1.25% - 1.5% salinity range still showed characteristics of growth after 28 days. Surviving calli from the 1.25% range were transferred to a 2.0% NaCl concentration medium, and subsequently regenerated into plants on 0% NaCl media for further tests of salinity tolerance**.** Calli cultured at 1.25% NaCl maintained higher survival rate when transferred to 2.0% NaCl, while those calli grown previously at 0% NaCl lost viability quickly when transferred to 2.0% NaCl medium. These results suggest that callus selected through increasing concentration of salt would likely generate turfgrass plants that have greater tolerance to high salinity.