PROCEEDINGS OF THE SIXTEENTH ANNUAL RUTGERS TURFGRASS SYMPOSIUM

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

January 11-12, 2007
School of Environmental and Biological Sciences / NJAES

Symposium Organizing Committee

Bradley Park, Chair
Bruce B. Clarke
Barbara Fitzgerald
Daniel Giménez
Joseph R. Heckman

Proceedings of the Sixteenth Annual Rutgers Turfgrass Symposium

Joseph Heckman, Mary Provance-Bowley, and Barbara Fitzgerald, Editors

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Director's Opening Remarks:

Welcome to the sixteenth Annual Rutgers Turfgrass Symposium at the School of Environmental and Biological Sciences/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 has been expanded to include presentations by colleagues at other institutions. I would like to thank Dr. Bill Meyer for giving this year's keynote address, as well as Dr. Geunhwa Jung (University of Massachusetts), Dr. Brian Horgan (University of Minnesota) 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 Mr. Brad Park (Chair), Dr. Daniel Giménez, and Dr. Joseph Heckman 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.

The faculty and students in the Turf Center continue to be recognized for excellence in research, teaching, and outreach. In 2006, Dr. Randy Gaugler received the prestigious Albert Einstein Visiting Professorship from the Chinese Academy of Sciences, Dr. Bingru Huang was honored as a Chang Jiang Scholar by the Chinese Ministry of Education, Drs. Jim White and Bruce Clarke were selected as Fellows of the American Association for the Advancement of Science and the Crop Science Society of America, respectively, and Dr. Bill Meyer will receive the Distinguished Service Award from the Golf Course Superintendents Association of America in 2007. Our graduate students also were recognized for significant accomplishments in 2006. At the International ASA-CSSA-SSSA meeting in Indianapolis, Indiana, Ms. Yan Xu placed second in the C-5 Graduate Student Oral Presentation Competition, Mr. Steven McCann received first place recognition in the C-5 Graduate Student Poster Industry Award Competition, and Mr. Jon Bokmeyer received the Tom Salt Award from the Turfgrass Breeders Association for the best oral presentation in the C-5 Division.

Turf Center faculty and staff continue to provide excellent undergraduate, graduate, continuing professional education and service programs in support of students and turfgrass managers throughout the United States. A recent study conducted by the Turf Center revealed that in New Jersey alone, the turfgrass industry has grown significantly over the past 20 years and now contributes 3.2 billion dollars annually to the State's economy. During this time, the turfgrass industry has donated over 4.2 million dollars in grants and gifts to our turfgrass program. This includes more than $85,000 in privately funded scholarships awarded each year to deserving students in turfgrass science. We are indeed fortunate to have such a close partnership with the Turfgrass Industry and look forward to working with them in the future.

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

Sincerely,

Bruce B. Clarke, Director
Center for Turfgrass Science

Table of Contents

SIXTEENTH ANNUAL RUTGERS TURFGRASS SYMPOSIUM

School of Environmental and Biological Sciences, Rutgers University
January 11-12, 2007
Foran Hall - Room 138

Thursday, January 11, 2007

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. William Meyer** (Department of Plant Biology and Pathology, Rutgers University) *Breeding Advances for Disease Resistance in the Major Cool-Season Turfgrasses*

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

Friday, January 12, 2007

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

9:00 - 10:00 AM SESSION I: TURFGRASS PHYSIOLOGY AND MOLECULAR BIOLOGY
(Moderator: Dr. Chee-kok Chin)

9:00 – 9:20 **Dr. Faith Belanger** (Department of Plant Biology and Pathology, Rutgers University) *Colonial Bentgrass Mapping Using Dideoxy Polymorphism Scanning: A New Approach to Mapping Genes*

9:20 – 9:40 **Steve McCann** (Department of Plant Biology and Pathology, Rutgers University) *Water Conservation in Cool-Season Turfgrasses: The Impact of Irrigation Scheduling and PGR Application*

9:40 – 10:00 **Dr. Thomas Gianfagna** (Department of Plant Biology and Pathology, Rutgers University) *Studies on Environmental Stress Tolerance in Transgenic Creeping Bentgrass with the ipt Gene for Cytokinin Biosynthesis*

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

10:30 - 11:30 AM SESSION II: SOIL SCIENCE AND TURFGRASS BREEDING
(Moderator: Dr. Joseph Heckman)

10:30 – 10:50 **Dr. Brian Horgan** (Department of Horticultural Science, University of Minnesota) *True or False: N Fertilizers Applied to Turf Do Not Impact the Environment*

10:50 – 11:10 **Mr. James Devaney** *(Department of Plant Biology and Pathology, Rutgers University)* Maturation of Amended Sand Root Zones

11:10 – 11:30 **Dr. Stacy Bonos** (Department of Plant Biology and Pathology, Rutgers University) *Breeding for Salt Tolerance in Cool-Season Turfgrasses*

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: TURFGRASS PATHOLOGY
(Moderator: Dr. James Murphy)

1:30 – 1:50 **Dr. Geunhwa Jung** (Department of Plant, Soil, and Insect Sciences, University of Massachusetts) *A Comparative Analysis of Pathogen-Specific Quantitative Disease Resistance Genes in Ryegrass with Cereal Crops*

1:50 – 2:10 **John Inguagiato** (Department of Plant Biology and Pathology, Rutgers University) *Developing Best Management Practices for Anthracnose Control on Annual Bluegrass Putting Greens: Summarizing Four Years of Field Research*

2:10 – 2:30 **Dr. Bradley Hillman** (Department of Plant Biology and Pathology, Rutgers University) *Lysobacter Enzymogenes, a Broad-Spectrum Biocontrol Bacterium that Infects Lower Eukaryotic Hosts Intracellularly*

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

3:00 – 4:00 PM SESSION IV: PEST MANAGEMENT
(Moderator: Dr. Albrecht Koppenhöfer)

3:00 – 3:20 **Dr. James White** (Department of Plant Biology and Pathology, Rutgers University) *Turf Endophytes: Current Research on Biology and Applications*

3:20 – 3:40 **Mr. Benjamin McGraw** (Department of Entomology, Rutgers University) *Biological Control of the Annual Bluegrass Weevil Using Entomopathogenic Nematodes*

3:40 – 4:00 **Dr. Stephen Hart** (Department of Plant Biology and Pathology, Rutgers University) *Use of Mesotrione Herbicide for Weed Control at Cool-Season Turfgrass Establishment*

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

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PLENARY PRESENTATIONS

Breeding Advances for Disease Resistance in the Major Cool-Season Turfgrasses

William A. Meyer and Stacy Bonos

Department of Plant Biology and Pathology, Rutgers University

Turfgrasses are grown and maintained throughout the world to enhance the environment and increase property values. Turf also prevents erosion, reduces air and noise pollution, and moderates temperatures.

Over the past 50 years, dramatic progress in genetic improvement has occurred in a number of cool-season species. These new cultivars are more persistent with improved pest and stress tolerance and reduced maintenance requirements.

There are two breeding behaviors in cool-season turfgrass species. Kentucky bluegrass (*Poa pratensis*.) reproduces primarily through an asexual process called apomixis. In this process, seed is produced without sexual recombination. Fortunately some Kentucky bluegrasses exhibit facultative apomixis having varying levels of sexual recombination. Both intra-specific and inter-specific (with Texas bluegrass, *Poa arucinifera*) can be made in the greenhouse.

Advances in resistance to leaf spot (caused by *Drechslera poae*), stem rust (caused by *Puccinia graminis*) and stripe smut (caused by *Ustilago striiformis*) have been made in Kentucky bluegrass cultivars. Stable resistance has been maintained to leaf spot and stripe smut in many cultivars for over 25 years. The situation with stem rust has changed since 2002 when a new race began to attack formerly resistant cultivars.

The other breeding behavior occurring in the remaining important cool-season species is cross-pollination. Breeding approaches such as phenotypic and genotypic recurrent selection can be used on these cool-season turfgrass species. The turfgrass species of tall fescue (*Festuca arundinacea*) perennial ryegrass (*Lolium perenne*), creeping bentgrass (*Agrostis stolonifera*), and fine fescue (*Festuca* spp.) are cross-pollinating and self-incompatible. Recurrent selection involves the selection of superior genotypes and their inter-mating to create combinations with superior characteristics and disease resistance. Most of the starting germplasm used is selected from old turf areas in the United States and Europe.

In tall fescue, great improvements have occurred in turf density, texture, color and lower growth habit. Brown patch (caused by *Rhizoctonia solani*) is the most serious disease of tall fescue. Great progress is being made with improved brown patch resistance and a concurrent increase in turf density. Stem rust is a serious seed production disease in tall fescue in the Pacific Northwest. Great progress has been made in the development of resistant cultivars to stem rust disease.

Since the 1990's, gray leaf spot (caused by *Pyricularia grisea*) has become a serious turf disease of perennial ryegrass in the United States. Very little resistance has been found in commercial cultivars. In 2000, 34 new sources of resistance were identified at Rutgers University in New Jersey. Half of these resistant sources trace to collections from Eastern Europe and the other half to NJAES germplasm originally collected in the United States since 1961. Stem rust is a very serious seed production disease of perennial ryegrass. Resistance to this disease has been developed from collections of perennial ryegrass from Washington, DC and St. Lewis, MO. Crown rust (caused by *Puccinia coronata*) is another serious disease of perennial ryegrass turf. Both qualitative and quantitative resistances have been developed for this disease.

Creeping bentgrass is the primary cool-season turfgrass species used for closely cut golf course fairways and putting greens. Dollar spot (caused by *Sclerotinia homeocarpa*) is the most important disease of this species. Resistance to dollar spot has been reported as being quantitatively inherited. Many resistant cultivars are now available.

Colonial bentgrass (*Agrostis tenuis*) is a promising species for golf course fairways. It produces rhizomes in turf and has less of a propensity to produce thatch than creeping bentgrass. The major disease of colonial bentgrass is brown patch. Attempts are being made to identify sources of resistance to this disease.

Fine fescues comprise several important species used for turf. The beneficial role of endophytes has been shown to control feeding by above ground insects. An additional benefit of endophytes is their beneficial role in improving resistance to dollar spot and red thread (caused by *Latesaria fuciformis*).

Colonial Bentgrass Mapping Using Dideoxy Polymorphism Scanning: A New Approach to Mapping Genes

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

[1]*Department of Plant Biology and Pathology, Rutgers University*
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While working for several years on approaches to improve dollar spot resistance of creeping bentgrass, some interspecific hybrids between colonial bentgrass and creeping bentgrass have exhibited excellent dollar spot resistance (Belanger et al., 2004). A backcross of a hybrid plant to a creeping bentgrass plant also had progeny exhibiting good resistance. As one approach to identifying the colonial bentgrass contribution to dollar spot resistance, we are developing a genetic linkage map of colonial bentgrass. Our segregating backcross population is being used as the mapping population.

In order to take advantage of genomic resources already developed for the cereal grasses, it is essential to have a gene-based linkage map. We are therefore focused on developing gene-based markers for mapping. During the past year we developed a new approach to marker development, termed dideoxy polymorphism scanning (ddPS) (Rotter et al., 2006). This method has several advantages:

1) It is PCR based.
2) No prior knowledge of a particular sequence polymorphism is needed.
3) It can be effective even with heterogeneous PCR products, such as are common in heterozygous species.
4) It does not require specialized equipment.

We anticipate that this method will be broadly applicable for marker development for mapping of many species. The ddPS method has proved to be efficient in identification of gene-based polymorphisms for mapping colonial bentgrass. We now have a total of 61 gene-based markers.

Numerous investigations into the genome organization of some of the cereal grasses have revealed that there are regions of map colinearity among the various species and several grass synteny maps have been developed (Devos, 2005). The genus Agrostis is evolutionally related to rice and wheat. This close relationship can facilitate the transfer of research from these model grass genomes to that of colonial bentgrass. Detailed comparisons of rice and wheat chromosomes have been reported (Sorrels et al., 2003; LaRota and Sorrells, 2004). Although there are numerous exceptions, wheat chromosomes are largely derived from specific rice chromosome regions. Examination of the genes mapped on the colonial bentgrass linkage groups indicates that they are generally following the rice/wheat relationship. This is of practical significance since we can use this relationship to guide our future mapping to target regions needing more markers. Also, this relationship can be used in the future for identification of candidate genes that are responsible for observed QTLs.

Our mapping population was field tested for dollar spot resistance. At the end of the rating period about 15% exhibited good resistance. The software program MapQTL was used to search for possible QTL regions from our current map data. Two possible QTL regions were identified.

References

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Rotter D, Warnke SE, Belanger FC (2006) Dideoxy polymorphism scanning, a gene-based method for marker development for genetic linkage mapping. Mol. Breed. DOI 10.1007/s11032-006-9061-y

Sorrells ME et al. (2003) Comparative DNA sequence analysis of wheat and rice genomes. Genome Res. 13:1818-1827

Water Conservation in Cool-Season Turfgrasses: The Impact of Irrigation Scheduling and PGR Application

Steve McCann and Bingru Huang

Department of Plant Biology and Pathology, Rutgers University

'L-93'creeping bentgrass was examined at a fairway mowing height (9.5 mm) to compare variation in irrigation frequency requirements and to develop Crop Water Stress Index (CWSI) values. The CWSI is a technique that uses the measurement of canopy surface temperature and air temperature to infer water stress status and predict if irrigation is necessary. 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 (10.7 m x 18.3 m) at Rutgers University Horticultural Farm II, allowing for strict control of irrigation frequency and amount. CWSI values were calculated as the ratio of actual canopy and air temperature difference to the maximum canopy and air temperature difference of a plant. According to our data, CWSI values below 0.40 will result in acceptable turf quality. Additionally, irrigating at 100% ET, three times a week may not be necessary to sustain plant growth and physiological processes, as this can be dependent on time of year. Generally, irrigating once or twice a week and replacing 100% of ET is adequate to maintain acceptable turf quality during summer months. Additional research has suggested that a PGR, trinexapac-ethyl, can improve drought tolerance of cool-season grasses.

Studies on Environmental Stress Tolerance in Transgenic Creeping Bentgrass With the ipt Gene for Cytokinin Biosynthesis

Jinpeng Xing, Yan Xu, Jiang Tian, Thomas Gianfagna and Bingru Huang

Department of Plant Biology and Pathology, Rutgers University

Creeping bentgrass (*Agrostis palustris*) is widely used on greens throughout the eastern United States because it makes an almost ideal putting surface. Unfortunately, creeping bentgrass is not very heat tolerant. Heat stress results in a decline in plant health, leaf yellowing and reduced plant density, a syndrome known as summer bentgrass decline (SBD). Cytokinins may be the key to controlling SBD. Cytokinins prevent leaf senescence and control tillering and root formation, but high soil temperatures quickly and significantly reduce the production of this hormone. To increase cytokinin synthesis when plants experience heat stress, we created two types of transgenic bentgrass with a bacterial cytokinin synthesis gene (*ipt*) in which expression is controlled by either a promoter that is activated at the start of leaf senescence (*pSAG12-ipt*), or by a heat shock promoter (*pHSP18-ipt*) that is activated by exposure to temperatures >35 C. Over 40 *pSAG12-ipt* and *pHSP18-ipt* plants were selected and propagated that exhibited superior chlorophyll retention after heat stress treatment bioassays.

Northern analysis for *ipt* gene expression was conducted on selected genetic lines of *pSAG12-ipt* after transferring plants from 20 C to 35 C for two weeks. For lines 25, 41, 43, 32, 16 and 37, heat stress activated the *ipt* gene. Placing plants in darkness for 30 days at 20 C had similar effects. Although *SAG12* was originally described as a senescence-activated promoter, other treatments such as heat stress or darkness that induce senescence also lead to activation.

Results with whole plants were similar to those obtained with excised leaves. Shoot growth, root growth and chlorophyll content of *pSAG12-ipt* plants were greater at 35 C than for plants containing the empty vector *pCAMBRIA1301*. An unexpected finding of considerable significance was the increase in chlorophyll content of these plants when grown at 20 C. Moreover, *pSAG12-ipt* plants had significantly increased tiller and root numbers when grown at 35 C after propagation from single tillers in sand culture. Line 41 produced more tillers and roots at 20 C as well. These results indicate that simply excising the tillers activates *ipt* and may speed the recovery of damaged turf by increasing the rate of new root and shoot production.

The cytokinin content of *pSAG12-ipt* plants was greater at 35 C than for plants containing the empty vector *pCAMBRIA1301*. Lines 25, 32, 37 and 41 had higher levels of IPA and lines 25, 32, and 41 higher levels of ZR than controls. Line 32 also had higher levels of ZR at 20 C.

Combined, the data suggests that *pSAG12-ipt* plants produce more cytokinins in response to heat stress, and that increased cytokinin maintains chlorophyll content, root and shoot growth, and increases tillering. Some of these effects, especially on chlorophyll content, were also evident at 20 C.

True or False: N Fertilizers Applied to Turf Do Not Impact the Environment

Brian Horgan

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Nitrogen fertilization of turfgrass continues to be scrutinized due to environmental concerns. The majority of research has indicated that turfgrass fertilization with nitrogen poses little risk to the environment. However, Frank et al., (2006) evaluated nitrogen and phosphorus fate and found leaching of ^{15}N-labeled urea from a 10 year old Kentucky bluegrass turf. On turf receiving 245 kg N ha^{-1} annually, $N0_3$ leaching exceeded EPA legal drinking water standards 10 years after establishment. In contrast, leachate levels from turf receiving 98 kg N ha^{-1} did not exceed levels of 10 ppm NO_3. This is the first long-term research project evaluating the environmental impact of turfgrass N fertilization. As Porter et al. (1980) also observed, storage of N in soils is finite. Over time, mineralization of organic N may exceed immobilization on fertilized turf, thus leading to nitrate leaching.

In addition to NO_3 leaching as an avenue for N loss from the turfgrass system, denitrification of N fertilizers has recently been evaluated. Readily available NO_3, wetting and drying cycles from irrigation, and a supply of organic carbon seems to make fertilized turfgrass an ideal system from which nitrogen can denitrify. Results suggest that anaerobic microsites are sufficient for denitrification and complete anaerobicity is not necessary for the production of N_2O and N_2 (Horgan et al., 2002). In a mass balance of applied fertilizer, as much as 22% N was denitrified.

Maturation of Amended Sand Root Zones

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Sand-based root zones are commonly used to construct golf course putting greens; however these are reputed to develop undesirable physical properties over time. Longer term evaluation of the physical characteristics of root zones is critical to ensure that recommendations generated from research will be applicable over many years of use as a putting green.

This field study investigated the potential changes in physical properties of sand-based root zones over a seven year period. Eight sand-based root zone mixtures varying in amendment (peat, inorganic and loam) were replicated four times in a randomized complete block design located in two microenvironments varying in air circulation. Plots were seeded to 'L-93' creeping bentgrass (*Agrostis stolonifera* L.) in May 1998. Intact core samples (76 mm diam.) of the root zone were removed from the 0- to 76-mm depth of each plot in 1999 and 2005. Additionally, a 76 mm diam. sample of the mat layer was collected in 2005. Bulk density, porosity and saturated hydraulic conductivity (K_{sat}) were measured for each core sample. Thickness of the mat layer was measured from three 25 mm diam. core samples as organic matter (OM) content by loss on ignition (360°C). Ratings of turf quality were monthly throughout each growing season of the study.

Bulk density of the 0- to 76-mm depth of the root zone indicated some compaction occurred from 1999 to 2005, with greater bulk density observed for root zones in the enclosed location. As expected, air-filled porosity (at -3 kPa) was the portion of total pore space that decreased the most over time, and by 2005 none of the root zones were able to maintain air-filled porosity above 10 m^3 m^{-3}. Contrary to expectations, K_{sat} indicated that the physical changes of the root zones did not restrict water flow; K_{sat} was relatively unchanged from 1999 to 2005 at both locations. Thus, current standards (bulk density and porosity) used to assess physical structure of root zones may not serve as adequate predictors of K_{sat}.

The thickness of the mat layer increased an average of 18 mm from 1999 to 2005; the amount of OM in this layer increased an average of 1.49 kg m^{-2}. Accumulation of OM was greatest in the open microenvironment, probably due to the better growing conditions. Capillary porosity of the mat layer was 60% greater than that of the root zones in 2005; additionally, K_{sat} of the mat layer was 59% lower than the root zone. Elevated capillary porosity combined with reduced K_{sat} in the mat layer explains the increased surface wetness that golf course superintendents observe as sand-based putting green root zones mature.

Turf quality was generally better on amended root zones compared to straight sand plots in 2005. Root zone treatment effects on turf quality were typically consistent across microenvironments except in June and August. Turf quality in the open microenvironment was consistently higher with few and subtle differences among root zones; whereas, turf quality in the enclosed microenvironment was more varied among root zone treatments. Most notable was the dramatic loss of turf quality in the 4:1 sphagnum plots in August, when turf quality of all plots declined in the enclosed site due to a period of warm hot weather. This dramatic decline in turf quality was related to excess water retention at the surface caused by greater capillary porosity in the mat layer of the 4:1 sphagnum plots.

Accumulation of OM above the surface of these amended-sand root zones (that is, development of the mat layer) had greater influence on water retention and flow than the underlying root zone mixtures. Deleterious physical properties in the mat layer were more a function of pore size distribution than compaction. Thus, observed changes in the physical performance and quality of putting greens over time will most likely be due to mat layer development and management rather than deleterious changes in the root zone profile.

Breeding for Salt Tolerance in Cool-Season Turfgrasses

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Turfgrass areas are potential sites for utilizing non-potable water sources however; these water sources can be high in dissolved salts which can cause salt stress injury and poor turf quality. The objectives of this study were to: 1) develop greenhouse and field screening techniques for evaluating salt tolerance and 2) evaluate salinity stress of cool-season turfgrasses and identify tolerant germplasm.

A greenhouse salt chamber system was developed to screen cool-season turfgrasses for salt tolerance. This method was to simulate actual field conditions by using overhead irrigation to apply the salt water treatments. The saltwater was applied in an enclosed chamber and collected into a reservoir tank containing a circulating pump for re-application. Eight clones of each of five perennial ryegrass cultivars (Palmer III, Paragon GLR, Applaud, Brightstar SLT and Nui) were established in plastic trays containing 100% sand. The plants were evaluated at four different salt water concentrations (Control [0-1], 5, 10 and 15 ds/m) and arranged in a randomized complete block design with three replications. Plants were exposed to salt treatments for 10 weeks. Clipping weights, plant heights, and percent green ratings were taken weekly. Root lengths, root weights, and shoot weights were taken after 10 weeks of salt stress. Significant differences were observed between salt treatments. The highest salt treatment (15 ds/m) caused the most stress on the perennial ryegrass plants. Significant differences between perennial ryegrass clones were also observed. Based on initial results, clones of Palmer III and Applaud exhibited the most salt tolerance when all measurements were included. Clones of Brightstar SLT and Nui exhibited the most injury from salt stress and the most decrease in growth compared to the control plants.

A field screening technique for salt tolerance evaluation in turfgrasses was also developed. Approximately 5,000 perennial ryegrass plants and 29 Kentucky bluegrass cultivars and selections were evaluated between 2005 and 2006. The plants were placed in a randomized complete block design with four replications and irrigated three times a week with a salt solution made from 50% NaCl and 50% CaCl. The electrical conductivity (EC) of the irrigation water was kept consistent at 10 ds/m. In 2006, a total of 29 saltwater applications were made throughout the growing season. Each plant received exactly 0.125 gallons of the salt solution, using a handheld flow meter. Soil EC concentrations were recorded weekly and percent-green ratings were taken when salt stress was evident. One hundred and fifty perennial ryegrass plants were identified with improved salt tolerance using this technique. These plants were moved into a spaced-plant nursery and four experimental selections were developed. For the Kentucky bluegrasses evaluated, the experimental selection, A00-1400, had the highest percent green leaf tissue under salt stress while A02-949 (an experimental Texas x Kentucky bluegrass selection) had the least. Of the ten released cultivars ‘Diva’ had the highest percent green under salt stress while 'Sonic' exhibited the most salt injury (least percent green) under these conditions.

The results indicate that both field and greenhouse techniques can be developed to screen cool-season turfgrass germplasm for salt tolerance. Both of these methods were also effective at identifying salt tolerant germplasm. Research is currently underway to validate both the greenhouse and field screening techniques by testing common cultivars and experimental selections in both the greenhouse and the field and to test tolerant germplasm in areas where salt stress is a common problem. This research will hopefully result in cultivars with improved salt tolerance that can be used by turfgrass managers to successfully incorporate alternative water sources in irrigation regimes.

A Comparative Analysis of Pathogen-Specific Quantitative Disease Resistance Genes in Ryegrass with Cereal Crops

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Perennial ryegrass (*Lolium perenne* L.) is one of the important forage and turf grass species in temperate climate zones worldwide. In Europe and Australia, along with annual ryegrass (syn = Italian ryegrass; *L. multiflorum* Lam.), perennial ryegrass is extensively grown for feeding ruminant livestock. In the northern United States, perennial ryegrass is one of the most popular turfgrasses due to its fast establishment, fine texture and dark green color, providing excellent aesthetic quality for golf courses and residential areas.

Gray leaf spot (GLS) caused by the fungal ascomycete *Pyricularia oryzae* Cavara [teleomorph *Magnaporthe oryzae* B. Couch, formerly known as *M. grisea* (Hebert) Barr] has become a serious problem on perennial ryegrass fairways and roughs since it was first reported on golf course fairways in Pennsylvania in 1992. The causal agent, *M. grisea*, also causes blast disease on rice, as well as foliar diseases on many grasses, such as blast on wheat and barley, and gray leaf spot on other turf and forage grasses such as tall fescue (*Festuca arundinacea* Schreb.), St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze], and Italian ryegrass. Under warm, humid conditions GLS can completely destroy mature ryegrass plants in a matter of days. In addition, rust diseases caused by *Puccinia* spp. are particularly important for forage-type perennial ryegrass and seed production, directly affecting quality and yield. Foliar, crown and root diseases caused by *Bipolaris*, *Drechslera* and *Exserohilum* species that were once referred to as the same genus, *Helminthosporium*, due to the similar epidemiology and symptoms, are common and widespread on graminaceous plants. These fungi have a broad host range, infecting turfgrass as well as most cereal crops including barley (*Hordeum vulgare* L.), wheat (*Triticum aestivum* L.), oat (*Avena sativa* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.). Several qualitative and quantitative resistance genes to *Bipolaris* and *Drechslera* spp. have been identified in barley and wheat.

Breeding disease resistant cultivars is one of the best disease management strategies in cereal crops, although this may take considerable time and understanding of the genetics of host resistance. In rice, a monocot model plant, many quantitative (partial) and qualitative (complete) resistance genes have been identified. Important gene loci conferring broad-spectrum resistance have also been found and potentially can be used for managing multiple diseases in rice. Development of molecular markers tightly linked to disease resistance traits provides a means to pyramid disease resistant genes in elite cultivars. This gene-pyramiding strategy exploits genes conferring quantitative resistance as well as qualitative resistance, which is ideal for managing different races or multiple diseases and precluding rapid breakdown of resistance by pathogens, which would be more likely from a few complete race-specific genes.

Recently, more molecular genetic markers have been developed for forage and turf grasses which enhance the effective marker-based selection for cultivar improvement, and allow comparative genomic analysis with model cereals. Conserved syntenic and collinear relationships among genomes of cereal crops and other grass species make it possible to transfer valuable genetic information to ryegrass from cereal crops of which more genetic information is available, and facilitate the finding of underlying genes of agronomic importance in syntenic ryegrass genome regions. Effective utilization of important genetic information available in cereal crops will also lead to a better understanding of the genetic architecture of disease resistance traits that are important targets for genetic manipulation and eventually crop improvement in ryegrass.

Quantitative trait loci (QTL) analysis based on a three-generation interspecific ryegrass population was conducted to determine partial resistance to four different fungal diseases: leaf spot (*B. sorokiniana*), stem rust (*P. graminis*), gray leaf spot (*M. grisea*), and crown rust (*P. coronata*). A total of 16 QTLs for resistance to these four pathogens were mapped on six of seven genetic linkage groups (LGs). Further, these QTLs were compared with 46 resistance loci for the same or related pathogens previously identified in cereal crops, using the rice physical map as a reference in order to challenge the hypothesis that pathogen-specific resistance loci and gene loci associated with resistance to multiple diseases are conserved between ryegrass and cereal crops. Results indicated that many pathogen-specific QTLs identified in ryegrass were conserved at corresponding genome positions in cereal crops. One genomic region associated with a QTL for multiple disease resistance was found on ryegrass LG4, which has a syntenic relationship with a genomic region of rice chromosome 3 where broad-spectrum resistance loci were found previously. This comparative QTL analysis via the integration of the ryegrass genetic map and rice physical map indicated conservation of pathogen-specific partial resistance and broad-spectrum resistance to multiple diseases between ryegrass and cereal crops.

In conclusion, the conserved synteny of disease resistance loci will facilitate transferring genetic resources of disease resistance between ryegrass and cereals to accommodate breeding needs for developing multiple disease resistance cultivars.

Developing Best Management Practices for Anthracnose Control on Annual Bluegrass Putting Greens: Summarizing Four Years of Field Research

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Anthracnose is a destructive disease of weakened or senescent turf caused by the fungus *Colletotrichum cereale*. The disease occurs throughout the world on almost all turfgrass species but is particularly severe on annual bluegrass (*Poa annua* L.). It has been suggested that management practices commonly employed on golf courses may enhance abiotic stress and thus predispose turf to anthracnose. It is probable that more than one, or various combinations of management factors, may enhance the severity of this disease and make it more difficult to control. The objective of this project is to determine the influence of management practices on the incidence and severity of anthracnose on annual bluegrass putting green turf. Our approach has been to develop comprehensive studies that assess commonly employed management practices in factorial arrangements. This provides an assessment of not only individual factors (main effects), but also the potential for management practices to interact. Two field studies have been completed and four projects were initiated in 2006. All studies were conducted on annual bluegrass turf maintained as putting greens at the Rutgers Turf Research Farm in North Brunswick, NJ. Ultimately, results from this work will be used to formulate a comprehensive set of best management practices for the control of anthracnose on golf courses.

Nitrogen Fertility, Plant Growth Regulators and Verticutting

Our initial study was established in 2003 to evaluate the impact of recent trends in putting green management including decreased nitrogen fertilization (i.e., < 73 kg ha^{-1} yr^{-1}), increased use of plant growth regulators (PGRs) to suppress seedheads (i.e., mefluidide) and vegetative growth (i.e., trinexapac-ethyl), and routine verticutting on anthracnose. After three years of observation, it was evident that maintaining adequate nitrogen fertilization (~ 145 kg N ha^{-1} yr^{-1}) is critical to reducing anthracnose severity on annual bluegrass putting greens. Weekly N applications of 4.9 kg ha^{-1} during summer months reduced disease 25–73% compared to the same rate applied monthly. Mefluidide (ME) initially increased anthracnose incidence when symptoms first appeared in June 2003 and 2004; but had little effect later in the summer. Repeat applications of trinexapac-ethyl (TE) typically had either no effect or slightly reduced the severity of anthracnose during this study. The sequential use of ME and TE had the greatest impact on anthracnose in 2004 and 2005, reducing the disease more than 27% compared to ME and TE alone in 2004, and 43-54% compared to TE alone in 2005. Wounding associated with verticutting had little effect on anthracnose severity.

Mowing and Rolling Practices

Prior to our research, ultra-low mowing (<3.2 mm), increased mowing frequency, and lightweight rolling were thought to increase anthracnose severity. We examined the effect of these practices on anthracnose and ball roll distance (an important measure of putting green quality) in 2004 and 2005. A 0.4-mm increase in mowing height (2.8- to 3.2-mm or 3.2- to 3.6-mm) resulted in a meaningful reduction in anthracnose. Contrary to expectations, increased mowing frequency did not increase anthracnose severity. However, changing mowing frequency from a single- to double-cut was as effective at increasing ball roll distance as lowering the mowing height from 3.6 to 2.8 millimeters. Lightweight vibratory rolling every other day slightly reduced anthracnose under moderate disease pressure. Double-cutting and lightweight rolling slightly increased soil bulk density and surface hardness, but the increases measured were ameliorated by aerification and freezing and thawing. Acceptable ball roll distance (2.9 to 3.2 meters) was obtained at a 3.2- to 3.6-mm mowing height when combined with either double-cutting everyday and/or vibratory rolling every other day without increasing (and in many cases reducing) anthracnose severity.

Seedhead Suppression and Vegetative Growth Regulation Strategies

Further examination of seedhead suppression and vegetative growth regulation with PGRs began in 2005. This ongoing study is examining a range of TE rates (0.32 - 0.64L ha^{-1}), decreased TE application intervals (7- vs. 14-d), and combinations of TE with and without ME or ethephon (ET), both commonly used seed head regulators. TE did not affect anthracnose in 2005, but reduced the disease 29-60% in 2006 compared to untreated turf. Anthracnose severity declined linearly with increasing rate of TE in 2006. More frequent applications of TE were more effective in reducing disease in July 2006 at both 0.40- and 0.64-L ha^{-1}. However, TE at higher rates and shorter intervals of application reduced turf quality from April to July 2006. The combination of ME and TE regulation programs decreased disease by as much as 71% and 42% relative to ME- or TE-alone, respectively, over both years. The average ET treatment effect reduced anthracnose 24–77% relative to untreated turf in both years of this study. The combination of ET and TE regulation programs reduced disease in July of 2005 and 2006 more than either growth regulator applied alone. The average ET treatment had less disease than turf treated with ME in 2006.

Topdressing Practices

Despite documented agronomic advantages of sand topdressing, the abrasive nature of this practice has raised concerns that it may contribute to anthracnose epidemics. A study was initiated in May 2006 to determine if rate and frequency of sand topdressing influenced disease development. Light topdressing (i.e., 0.3 L ha^{-1}) initially enhanced anthracnose. However by early August, topdressing every 7- or 14-d at 0.3- or 0.6-L ha^{-1} reduced disease compared to non-topdressed plots. Infrequent sand topdressing every 21- or 42-d at a higher rate (1.2 L ha^{-1}) also reduced disease by August. During the disease recovery phase (late August), anthracnose damage had decreased most rapidly in turf topdressed with sand regardless of rate or frequency of application. Contrary to the initial hypothesis, this first year of data indicated that sand topdressing had a cumulative beneficial effect and that light-frequent applications provided the most rapid and substantial reduction of anthracnose

A companion study was also initiated in 2006 to ascertain whether different methods of sand incorporation and sand particle shape (i.e., round *vs* sub-angular) affect the disease. The incorporation methods evaluated in this study (i.e., stiff-, soft-bristled brush, vibratory rolling or none) had no effect on anthracnose. Both sand types, at first, enhanced disease in July, but continued topdressing reduced disease severity in August and September compared to non-topdressed turf. Results from this study corroborate the findings of the previous study; sand topdressing reduced anthracnose severity and brushing did not enhance disease.

Irrigation Management

Proper irrigation management is critical to maintaining plant health and the playability of putting green turf. Over-watering increases the potential for traffic stress such as mower scalping and may increase susceptibility to anthracnose, whereas maintaining putting greens at extremely low soil water availability can weaken and possibly predispose plants to this disease. In 2006, a study was established to determine whether irrigation regime (i.e., 100, 80, 60, and 40% evapotranspiration replacement) influences this disease. Anthracnose severity was greater in plots maintained with 40% or 60% evapotranspiration (ET) than turf receiving 80 or 100% ET replacement on 28-July. By 25-August, turf watered at 100% ET had as much anthracnose as turf receiving 40% ET replacement; moderate irrigation levels of 60 and 80% had the least disease on this date. This data illustrates that both over- and under-watering of turf can increase anthracnose.

Lightweight Rollers and Equipment Traffic Stress

Traffic stress from maneuvering mowing and rolling equipment on the edge of putting greens has been suggested as a potential cause of enhanced anthracnose on putting greens. A study was initiated in 2006 to determine if routine mowing and rolling operations can affect anthracnose, depending on the location of the equipment traffic on a putting green, that is, perimeter (edge) or center. Only three observation dates of disease incidence were obtained in 2006. Anthracnose was greater in plots treated as the center of a putting green on 18-August. However, disease was greater in perimeter plots than center plots on the last two rating dates. Both forms of rolling increased disease on 11-September compared to non-rolled turf. More data is required before any definitive conclusions can be drawn from this study.

Working Outline of Best Management Practices for Anthracnose Control

Our current findings indicate that nitrogen fertilization and mowing height are the most influential cultural practices affecting anthracnose severity on annual bluegrass putting green turf. Other practices that we have studied such as the application of plant growth regulators, irrigation, and topdressing can also affect this disease.

Nitrogen

- Nitrogen should be applied to maintain vigor of the putting green turf without over fertilization. An annual nitrogen program of approximately 150 kg ha^{-1} that includes frequent (two or more per month) low rate applications during summer months will reduce anthracnose incidence and severity.

Mowing and Rolling

- Mowing below 3.2-mm should be avoided. If feasible, raise the cutting height as high as 3.6-mm for greater suppression of anthracnose. Slight increases in mowing height (0.4 mm) can significantly reduce the severity of this disease.
- Roll and/or increase mowing frequency to maintain ball roll distances at higher mowing heights. Rolling and double-cutting increase ball roll, but typically will not enhance the disease. However, management of the additional equipment traffic particularly at the perimeter of putting greens will need to be considered.

Plant Growth Regulators

- Routine trinexapac-ethyl use even at high rates and short intervals reduces anthracnose severity by improving turf tolerance to low mowing and enhancing plant health.
- Mefluidide and ethephon can be used to suppress seedhead formation in annual bluegrass turfs without increasing anthracnose.
- Mefluidide or ethephon applied in March or April at label rates with subsequent applications of trinexapac-ethyl throughout the growing season will provide the best turf quality and will reduce anthracnose.

Irrigation

- Limited data; not feasible at this time to describe a BMP.

Topdressing

- Preliminary data suggests that frequent, light sand topdressing reduces anthracnose, although a slight stimulation of the disease may occur initially. Moreover, sand topdressing dramatically improves the recovery of annual bluegrass turf from anthracnose damage.

Lysobacter Enzymogenes, a Broad-Spectrum Biocontrol Bacterium that Infects Lower Eukaryotic Hosts Intracellularly

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Classical biological control of fungal pathogens by bacteria generally relies on mechanisms providing preferential niche colonization, antibiosis, or direct antagonism. *Lysobacter enzymogenes* is a common, soil-inhabiting bacterium which produces copious amounts of antibiotics and lytic enzymes and has been shown to suppress summer patch disease of cool season turfgrasses caused by the root-infecting, fungal ascomycete, *Magnaporthe poae*. Growth of fungal colonies is inhibited when cultures are directly challenged with the bacterium *in vitro*. While it is clear that antibiotic and enzyme production are key components of fungal antagonism displayed by *L. enzymogenes*, early microscopic examination of the bacterial/fungal interface suggests an interaction between *M. poae* by *L. enzymogenes* more intimate than that resulting from simple antagonism.

In setting out to elucidate the factors involved in successful host colonization and determination of its extensiveness as a possible biocontrol agent, we first looked to determine the host range of the bacterium. *L. enzymogenes* is not known to attack vascular plants or animals, and our infectivity studies confirm that plants react to it as they do with other non-pathogens. To begin to determine whether *L. enzymogenes* is universally pathogenic to fungi and whether there are measurable differences in virulence to different fungal species or strains, we performed limited host range studies on different fungi in culture. Results of these experiments showed that the bacterium was pathogenic to *Magnaporthe oryzae*, the gray leaf spot pathogen; *Colletotrichum cereale*, the anthracnose pathogen; and *Rhizoctonia solani*, the brown patch pathogen. Levels of virulence appeared to differ among fungal host strains, as determined by size of clearing zone, resulting from inoculations of bacterial suspensions directly onto fungal colonies. Host range studies have been expanded to include other lower eukaryotes: *L. enzymogenes* is pathogenic to stramenopiles such as *Phytophthora* and *Pythium*, lower plants such as the moss *Physcomitrella patens*, and nematodes such as *Caenorhabditis elegans*. In each of the hosts in which the bacterial/host interaction has been examined carefully, the bacterium has been shown to internalize within host cells, a very unusual property for pathogenic bacteria and one that has implications for gene expression of both the bacterium and host during colonization. Of significance, complete genome sequences are available for *M. oryzae*, *P. patens*, *C. elegans*, and *Phytophthora infestans*, and we have begun to sequence the genome of *L. enzymogenes*.

Studies are now underway to determine which bacterial genes are important for host colonization and which host genes are involved in defense responses to *L. enzymogenes* attack. Of bacterial factors identified in previous studies, two were of particular importance: one is the bacterial type III secretion system, which has been shown in both animal and higher plant-infecting bacteria to deliver various effector molecules that facilitate colonization and pathogenesis; the other is a *clp* regulator gene that globally controls expression of a variety of traits associated with antifungal activity, including extracellular enzymes and secondary metabolites. Each of these factors was shown to be important for *L. enzymogenes* colonization of the lower eukaryotic hosts, and differences in degree of their importance in the various host types were identified**.** Further studies are being pursued through more detailed analysis of these gene clusters on differential hosts.

Turf Endophytes: Current Research on Biology and Applications

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Endophytic fungi are commonly found in species of tall fescue, ryegrass, and fine and hard fescues and are an important means to improve performance of many turf species. They are In surveys of cultivars in the National Turfgrass Evaluation Program (NTEP) some 94% of ryegrass cultivars and accessions contain some level of endophyte; for fine and hard fescues 77%, and tall fescue 78%. The widespread presence of endophytes in turf cultivars provides the opportunity to develop their bioprotective potentials. This requires an understanding of their biology and the various mechanisms by which they improve turfgrass performance.

Endophytic fungi in turfgrasses are in the genus *Neotyphodium* or *Epichloë* depending on the stage exhibited on plants. These species are largely non-pathogenic endosymbionts of grasses that concentrate in leaf sheaths and culms of the host. Endophytes have been documented to make turfgrasses more resistant to insect feeding, suppress fungal diseases and make grasses more tolerant to drought.

The research we have engaged in recently has been targeted toward understanding the biology and mechanisms of fungal disease resistance and the evolution of antiherbivore compounds. Grasses that show antifungal effects also develop a layer of epiphyllous mycelium on the surface of leaves. We propose that fungal disease resistance in turfgrasses is the result of a niche exclusion process whereby the endophytes occupy sites on leaf surfaces that effectively exclude colonization of leaves by pathogenic fungi. Further, the external mycelium on plants provides a means whereby endophytes may spread to uninfected neighboring plants.

To better understand how antiherbivore defense evolved we examined the distribution of major classes of secondary metabolites produced by endophytes- ergot alkaloids and lolines. Ergot alkaloids and lolines were encountered in several epibiotic ancestors of the grass endophytes. We suggest that grass endophytes were pre-adapted to develop defensive mutualisms by the presence of defensive compounds in ancestral species.

For future research we intend to develop studies on epiphyllous interactions of pathogens and endophytes to try to better understand the mycelial actions and reactions. We are also attempting to evaluate how conidia of endophytes spread from infected to uninfected grasses. Because of the importance of loline alkaloids in insect resistance we are planning to develop more efficient ways to assess the potential for loline alkloid production in grass endophytes as a way to select turf endophytes with maximum insect defensive properties.

Biological Control of the Annual Bluegrass Weevil Using Entomopathogenic Nematodes

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The annual bluegrass weevil (ABW) is currently the most destructive insect pest of golf courses in New Jersey. In April, overwintering adults migrate through the rough onto tees, fairways and greens with high percentages of annual bluegrass, *Poa annua*. The weevils deposit their eggs directly into the stem of the grass plant. The young larvae feed internally, exiting only to attack neighboring plants to complete their development. Older larvae cause the greatest damage as they tunnel through the crown, exiting in the soil to feed externally upon the roots. It is believed that there are two to three generations of ABW in New Jersey; however, it is the spring generation that is of utmost concern to turfgrass managers and usually the generation that causes the most extensive damage.

The fear of visible damage has lead superintendents to rely heavily on the use of preventive chemicals for suppressing egg laying by adults. The overuse of preventive chemical pesticides is largely due to a poor understanding of the behavior and ecology of the weevil and a lack of alternative controls. Consequently, pyrethroid-resistant populations are becoming a reality in some parts of the Northeast. In anticipation of resistant population development in New Jersey, we look toward biological controls as a less toxic and sustainable alternative to control ABWs. Our research seeks to address what role, if any, natural enemies play in the population dynamics of the weevil. In addition, we seek to broaden our understanding of ABW population dynamics on both a spatial and temporal scale, so that biological and chemical controls may be better integrated into ABW management programs on New Jersey golf courses.

Entomopathogenic Nematodes (EPNs)

EPNs are microscopic, non segmented roundworms that are obligate parasites of a diverse array of insects. They are common in most soils worldwide, and have been used successfully in agricultural pest management. EPNs have been successfully used in insect management on golf courses, and in some instances, applications have even resulted in area-wide suppression of a turfgrass pest. We hypothesized that ABWs were not only susceptible to EPNs, but that EPNs were likely to naturally infect ABW, since much of the weevil's life is spent at or near the soil surface. In June of 2005, we detected EPNs infecting a population of ABWs in Monmouth County, New Jersey. Since that time we have found several populations of ABWs infected with EPNs, and are beginning to document the impact that these natural enemies have on weevil populations.

Laboratory and Field Trials

We have assayed several commercial and two endemic strains of EPNs against ABW in the laboratory and field with varying levels of success. Early laboratory data suggests that the adult stage is not very susceptible to EPNs, even under ideal conditions for nematode infection. Lab bioassays with field collected larvae, though limited, show that EPNs can be effective in reducing the number of larvae to below damaging levels. Our field trials show the same promise; however, significant reductions have only been obtained for first generation larvae. EPNs applied at the end of May against late instar larvae demonstrated control comparable to chemical pesticides (68 to 94%). Applications against the summer generation of larvae (end of July to early August) were not effective, likely due to the lethally high temperatures and dry conditions experienced after application.

Use of Mesotrione Herbicide for Weed Control at Cool-Season Turfgrass Establishment

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Mesotrione is in the triketone herbicide family and controls weeds by inhibiting p-hydroxyphenyl pyruvate dioxygenase (HPPD), a key enzyme in plastoquinone biosynthesis responsible for bleaching herbicide injury symptoms on new growth. Mesotrione has both preemergence and postemergence herbicide activity and is currently registered for use in field and sweet corn.

Numerous research studies have demonstrated that established cool-season turfgrasses are tolerant to mesotrione including Kentucky bluegrass (*Poa pratensis* L.), perennial ryegrass (*Lolium perenne* L.), and tall fescue (*Festuca arundinacea* L.). Mesotrione has been reported to control a broad array of weed species including large crabgrass (*Digitaria sanguinalis* L.), smooth crabgrass [*Digitaria ischaemum* (Schreb.) Schreb ex. Muhl.], henbit (*Lamium amplexicaule* L.), broadleaf plantain (*Plantago major* L.), and yellow woodsorrell (*Oxalis stricta* L.). However, it is not well understood if mesotrione can be safely used on newly seeded or seedling cool-season turfgrass species.

Field studies were conducted in the spring and fall of 2006 and 2007 to evaluate the response of newly seeded and seedling Kentucky bluegrass, perennial ryegrass, and tall fescue to mesotrione applied at planting (PRE), and at two (2 WAE) and four (4 WAE) weeks after emergence. Spring and fall studies were conducted at the Rutgers Plant Science Research Center in Adelphia, NJ on a Holmdel sandy loam with a pH of 6.4 and organic matter content of 2.3%. An additional study was conducted in the fall of 2007 at Horticultural Research Farm II, in North Brunswick, NJ, on a Nixon sandy loam with a pH of 6.3 and 3.0% organic matter content.

Mesotrione was applied at rates ranging from 0.14 to 0.56 kg ai/ha using a single nozzle CO_2 pressured sprayer calibrated to deliver a total 375 L ha^{-1}. Nozzles used were 9504E and CO_2 regulators were set for 220 kPa. In the spring experiments, siduron, dithiopyr and quinclorac treatments were included as standard comparisons. Experimental design was a split-block with four replications at Adelphia and three at Horticultural Research Farm II. Treatments were the factorial combination of four seedings (main plots, 1.8 x 68-m) with seventeen mesotrione applications (sub-plots, 1 x 7.2-m). A non-seeded check strip was also included as a main plot for weed control evaluations. Turfgrass chlorosis was rated on a percent scale where 0 equaled no chlorosis and 100 equaled complete chlorosis. Turfgrass density and weed cover were rated visually on a percent scale.

Detailed data analysis is still being conducted, but overall, mesotrione caused minimal turfgrass density reductions when applied PRE. However, 2 WAE, and 4 WAE applications at high mesotrione rates tended to cause chlorosis on both tall fescue and perennial ryegrass and in some experiments, significant stand reductions, especially on

Kentucky bluegrass and tall fescue. Therefore, mesotrione was safest when used as a PRE application rather than a postemergence application on seedling turfgrasses.

In the spring, studies of crabgrass control using PRE mesotrione at 0.28 to 0.56 kg/ha treatment levels were equivalent to siduron. However, season long crabgrass control was not obtained. Postemergence treatments 2 WAE also provided good crabgrass control, but crabgrass control using 4 WAE treatments was significantly lower, suggesting that larger crabgrass will be more difficult to control. Control of summer annual broadleaf weeds such as common lambsquarters (*Chenopodium album* L.) and carpetweed (*Mollugo verticillata* L.) were excellent with all mesotrione treatments.

In fall studies control of winter annual broadleaf weeds such as chickweed (*Stellari media* L.) and henbit were nearly complete with all mesotrione treatments. Annual bluegrass was present at both fall studies at Adelphia. Mesotrione exhibited a potential to selectively control annual bluegrass (*Poa annua* L.) applied PRE especially at the 0.28 and 0.56 kg/ha application rate. However, significant annual bluegrass control was not observed with postemergence applications except when applied at 0.56 kg/ha. The most complete annual bluegrass control was observed with PRE applications followed by sequential applications 4 WAE at 0.28 and 0.56 kg/ha.

POSTER PRESENTATIONS

Morphological and Molecular Analysis of Fourteen Switchgrass Populations Grown in New Jersey

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Although a significant amount of genetic diversity exists within switchgrass (*Panicum virgatum*), little research has been conducted on the level of genetic diversity and local adaptation among different populations/ecotypes currently recommended for habitat restoration and biofuel production in the northeastern US. Switchgrasses are divided into upland and lowland ecotypes. Upland ecotypes are shorter, finer stemmed and more adapted to drier habitats, while lowland ecotypes are coarse-stemmed, tall growing and more robust (Lewandowski *et al*., 2003). The objectives of this study were to determine molecular and morphological differences within and between 14 different switchgrass populations.

Switchgrass seed from 14 populations was obtained from various sources. ‘Carthage’, ‘Timber’, ‘Contract’, ‘Shelter’ and ‘High Tide’ germplasm was obtained from the Natural Resources Conservation Service – United States Department of Agriculture Plant Materials Center in Cape May, NJ, and represented northeastern populations. All additional germplasm (‘Caddo’, ‘Shawnee’, 196, Pav12, Turkey, ‘Sunburst’, ‘Kanlow’, ‘Pathfinder’, and ‘Blackwell’) was obtained from the Plant Introduction (PI) collection curated by the Germplasm Resources Information Network (GRIN) and included standard cultivars developed in the Midwest, and germplasm sources from other countries. Carthage, Contract, Shelter, High Tide, Caddo, Shawnee, Sunburst, Pathfinder and Blackwell are considered upland ecotypes, while, Timber, and Kanlow are lowland ecotypes.

Individual plants from each population were transplanted to a spaced-plant nursery in the spring of 2005 at the Rutgers University Plant Biology Research and Extension Farm at Adelphia, NJ. Morphological measurements were taken on 12 individuals from each of the 14 different switchgrass populations in 2005 and 2006. Measurements included plant and panicle height, and flag leaf height, length and width. Leaf tissue was collected from the same 12 individuals for molecular marker analysis. DNA was isolated from leaf tissue using the Sigma® GenElute™ Plant Genomic DNA Miniprep kit (Sigma-Aldrich Co., St. Louis, MO). Publicly available microsatellite (SSR) markers specific for switchgrass were utilized for molecular marker analysis (Tobias et al, 2006). Thirty-two SSR primer pairs were tested for polymorphism on the 12 individuals totaling 180 individual samples. SSR markers were genotyped on an ABI 3130 genetic analyzer. Morphological and marker data was analyzed using the program *structure* (Pritchard *et al*., 2000) which identifies clusters of related individuals from multilocus genotypes. The full data set was analyzed for all models from K=1 through 14.

Significant morphological and molecular differences between switchgrass populations were observed. *Structure* analysis of morphological and molecular data separated the individuals into groups with the best distinction occurring for K=3. Based on morphological data from 2005 'Kanlow' and 'Timber' formed a unique group. These populations, both lowland ecotypes, looked phenotypically similar and were very tall stiff plants when compared to other populations evaluated. *Structure* also placed individuals from 'Pathfinder', 'Contract', and 'Blackwell' in a cluster. In addition, 'Caddo', 'Shawnee', 196, Pav12, Turkey, 'Sunburst' and 'Shelter' shared some similarities and were placed in a third class. *Structure* analysis of the 2006 morphological data produced similar results, as both 'Kanlow' and 'Timber' were assigned to one grouping. In contrast to the 2005 morphological data, 'Carthage' and 'High Tide', both northeastern ecotypes, were clustered together in 2006. The morphological analyses provided distinction between upland and lowland ecotypes, but did not completely separate northeastern from midwestern populations. Evaluation of molecular marker data using s*tructure* yielded different results than the morphological data analysis. Molecular marker data did not differentiate between upland or lowland ecotypes or between midwestern or northeastern populations, and was not sufficient to distinguish one population from another. One assigned group included 'Kanlow', 'Timber', and 'Contract'. In addition, 'Shawnee', 196, and 'Turkey' were clustered together, while 'Shelter and 'High Tide' were assigned to a third grouping. As such, continued work with molecular markers is needed to further differentiate between switchgrass populations. Results were similar to findings of Casler *et al.* (2006), who reported high levels of within-population variability and a lack of genetic differentiation between bred switchgrass cultivars, prairie-remnant populations, and prairie-remnant seed increase cultivars.

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The Identification of Brown Patch Resistance in Colonial Bentgrass

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Brown patch, caused by the fungus *Rhizoctonia solani*, is one of the greatest factors limiting the wide-spread use of colonial bentgrass (*Agrostis capillaris*) on golf course fairways in temperate regions of the US. The objectives of this study were to 1) determine the narrow-sense heritability of brown patch resistance in colonial bentgrass from half-sib families and controlled crosses between tolerant and susceptible bentgrass clones and 2) identify colonial bentgrass germplasm with brown patch resistance. Parental clones and progenies from half-sib families or crosses were established in field trials using a randomized complete block design with four replications and inoculated with one isolate of *R. solani* applied at a rate of 0.25 g m^{-2} of prepared inoculum. Brown patch disease severity of parents and progeny was evaluated on a 1-9 scale for two years. Narrow-sense heritability was calculated from one-parent regression analysis for the half-sib families or mid-parent progeny regression for the controlled crosses. Colonial bentgrass clones exhibiting less brown patch disease from these spaced-plant trials were identified and used to develop experimental selections of colonial bentgrass. These were compared to standard cultivars in a replicated field trial established in 2004.

Narrow-sense heritability ranged from 0.70-0.75 for one half-sib family and 0.84 for the controlled crosses. However, brown patch resistance was not heritable in the other half-sib family evaluated. Additionally, susceptible parents were not significantly more susceptible than resistant parents when evaluated in a replicated field trial and resistant x resistant crosses were not more resistant than resistant x susceptible crosses. These results are contrary to previous results reported for dollar spot resistance in creeping bentgrass. However, similar to dollar spot resistance in creeping bentgrass, experimental selections of colonial bentgrasses exhibited significantly less brown patch disease compared to standard cultivars. This research indicates that breeding for improved resistance to brown patch in colonial bentgrass should be possible, at least in some populations, although, future research is needed to further discern the genetic mechanism of brown patch resistance in colonial bentgrass. This information is useful for future breeding efforts and could result in increased utilization of this species for turfgrass.

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Evolution of Host Specialization in *Colletotrichum cereale* Associated with Grasses from Golf Course Greens, Cereal Crops and Native Prairies

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In populations of the turfgrass anthracnose fungus *Colletotrichum cereale*, the prevailing mode of reproduction is thought to occur clonally, as inferred primarily through the lack of a teleomorph. Coupled with the visual absence of a sexual state, previous reports of clonal genotypes from RAPD and isozyme analysis contribute to the notion that *C. cereale* has endured throughout history as an asexual organism. Because a pathogen's mode of reproduction strongly influences the course of its evolution and the alternative hypothesis has never been adequately tested, we are evaluating patterns of variation in this species. In the present study, we used an extensive nucleotide sequence dataset (4 genes, 3,400 nucleotides) to examine a large, worldwide sampling of pathogenic isolates of *C. cereale* from turfgrass and their counterparts isolated from cereal crops (wheat, oats, barley) and prairie grasses. This dataset illustrated that *C. cereale* is subdivided into several lineages, each composed of primarily (but not exclusively) either turfgrass or non-turfgrass derived isolates. Next, RFLP analysis of three transposon species provided evidence for recombination by *C. cereale*, even in relatively small populations. Furthermore, 21 of 35 unique transposon loci, when evaluated for dinucleotide compositional bias, displayed the signature pattern of repeat-induced point mutation (RIP), a genome defense mechanism that functions only during meiosis. Taken together, our data rejects the presumption of clonality for *C. cereale* and, given the severe losses sustained in turfgrass systems due to this pathogen, strongly emphasizes the need for additional inquiry into the biology, mating and dispersal mechanisms of *C. cereale*.

Predicting Need for Phosphorus by Soil Testing During Seeding of Cool-Season Grasses

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Recent changes in soil testing methodology, the important role of P fertilization in early establishment and soil coverage, and new restrictions on P applications to turf suggest a need for soil test calibration research on Kentucky bluegrass (*Poa pratensis* L.), tall fescue (*Festuca arundinacea* Schreb), and perennial ryegrass (*Lolium perenne* L.). Greenhouse and field studies were conducted for 42 days to examine the relationship between soil test P levels and P needs for rapid grass establishment using 23 New Jersey soils with Mehlich-3 extractable P levels ranging from 6 to 1238 mg kg^{-1}. Soil tests (Mehlich-1, Mehlich-3, and Bray-1) for extractable P were performed by inductively coupled plasma-atomic emission spectroscopy (ICP) (only Mehlich-3 data is shown). Mehlich-3 extractable P and Al were measured to evaluate the ratio of P to Al as a predictor of need for P fertilizer. Kentucky bluegrass establishment was more sensitive to low soil P availability than tall fescue or perennial ryegrass. Soil test extractants chlich-1, Bray-1 or Mehlich-3 were each effective predictors of the need for P fertilization (only Mehlich-3 data is shown). The ratio of P to Al (Mehlich-3 P/Al %) was a better predictor of tall fescue and perennial ryegrass establishment response to P fertilization than soil test P alone. The Mehlich-1, Bray-1, and Mehlich-3 soil test P critical levels for clipping yield response were in the range of 170 to 280 mg kg^{-1}, depending on the soil test extractant, for tall fescue and perennial ryegrass (only Mehlich-3 data is shown). The Mehlich-3 P/Al (%) critical level was 42% for tall fescue and 33% for perennial ryegrass. Soil test critical levels, based on estimates from clipping yield data, could not be determined for Kentucky bluegrass using the soils in this study. Soil testing for P has the potential to aid in protection of water quality by helping to identify sites where P fertilization can accelerate grass establishment and thereby prevent soil erosion, and by identifying sites that do not need P fertilization, thereby preventing further P enrichment of soil and runoff. Since different grass species have varying critical P levels for establishment, both soil test P and the species should be incorporated into the decision-making process regarding P fertilization.

Effect of Chemical Growth Regulation Strategies on Anthracnose Severity of Annual Bluegrass Putting Green Turf

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Chemical growth regulation on golf putting greens has become commonplace in recent years. Turf managers are currently using these materials at increased rates and decreased intervals; and the effects on anthracnose, caused by *Colletotrichum cereale*, are unknown. Nineteen treatments were arranged in a randomized complete block design with four replications. Trinexapac-ethyl (TE) was applied at various rates (0.3-, 0.4-, and 0.6-L ha^{-1}) and intervals (7-, 14-d) April to September 2005 and 2006. Mefluidide (2.2-L ha^{-1}) or ethephon (15.9-L ha^{-1}) was applied 6 and 20 April 2005 or 31 March and 12 April 2006 both without and with trinexapac-ethyl (0.4-L ha^{-1}) applied at two intervals (7- or 14-d) throughout the season. Anthracnose incidence declined linearly with increased TE rate in 2006, but not in 2005. Anthracnose damage was reduced 18-30% on 3 and 21 July 2006 by TE applied every 7-d compared to 14-d (mean of two rates). Interval of TE did not significantly affect disease in 2005. Mefluidide (ME), without and with TE, reduced disease 51% on 2 July 2005, and 14-39% in 2006. However, ME alone had 38-67% and 19-61% greater disease than the combinations of ME + TE in 2005 and 2006, respectively. No difference was observed between TE and ME + TE in either year. Ethephon (ET), with and without TE, had 30-51% and 24-78% less disease than untreated turf in 2005 and 2006, respectively. Ethephon alone was not different from combinations of ET + TE over both years. Trinexapac-ethyl was 45% less effective than ET + TE at reducing anthracnose on 15 July 2005, and 52% less effective on 3 July 2006. Ethephon, without and with TE, had 15-73% less disease in 2006 than ME without and with TE. There was no difference between ET and ME in 2005.

Role of Turfgrasses and Other Landscape Plants in Reducing Global Warming and Our Addiction to Fossil Fuels

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Turfgrasses and other perennial landscaping plants contribute immensely in enhancing our environment and improving the enjoyment, health and lifestyles of all people. They harvest and utilize CO_2, increase soil organic matter and fertility, improve physical properties of soils, and prevent erosion. Perennial ground cover aids infiltration of water into the soil. This is our best and most economical way of storing fresh water, reducing floods, replenishing soil moisture and recharging depleted aquifers. Perennial plants also help reduce global warming and our addiction to unsustainable supplies of fossil fuels. In addition, trees, shrubs, grasses and other perennial plants reduce leaching of fertilizers and pesticides. Deep-rooted perennial trees and grasses lose less then two percent of applied nitrogen. Whereas, nearly one-half of the nitrogen fertilizer applied to annual cultivated crops in the Mississippi River drainage area is lost to leaching. This contaminates wells and ground water and ultimately results in large dead zones in the Gulf of Mexico (De Haan et al., 2004).

Studies by Yaling Qian and Ronald Follett in Colorado using long-term soil test data, document that agricultural soils converted to perennial turfgrasses, and the conservation reserve, accumulate additional soil organic matter at rates averaging about one tonne of carbon per hectare each year, at least for the first few decades following establishment (2002). With about 20 million hectares in lawns and other turfgrasses and 15 million hectares in the conservation reserve program of the USA, this does much to preserve and improve our soils and to harvest and use CO_2.

Deforestation, erosion, overgrazing, excess tillage and other poor management practices have resulted in the loss of 4 ± 1 billion tonnes of organic carbon from the soils of the USA, and 78 ± 12 billion tonnes from the world's soils (Lal et al., 2004). Increasing perennial plant cover, dramatic increases in no-till agriculture, mulching, and crop rotation to decrease soil erosion would reduce net annual organic carbon emissions by about one billion tonnes from the world's soils. This would be a significant contribution to offset the seven billion tonnes of carbon emitted annually from burning of fossil fuels. Obviously, these methods would need to be combined with much improved conservation, efficiency, and the extensive development and use of alternative energy sources.

Scientists in the Plant Biology and Pathology Department of Rutgers University are proposing a program to harvest sufficient carbon dioxide using perennial plants to make a large contribution in solving the problem of global warming. This program, if fully implemented, along with a worldwide increase in energy conservation, should help in solving many of the most severe problems facing the world today, as well as those faced by future generations.

Harvesting Carbon Dioxide with Solar Energy: A Sustainable, Renewable, Environmentally Friendly, Economical Source of Abundant Food and Energy

A healthy, fast growing perennial plant is an ideal collector of solar energy. It produces bioenergy, food, feed, and timber in a manner that is at least carbon neutral. It also stores these products and manufactures itself while providing beauty, environmental enhancement, shade, windbreaks, wildlife habitats, improved soil fertility, and organic matter. It reduces erosion and flooding, and recharges moisture in the atmosphere to increase precipitation in dryer regions. This removal of excess CO_2 could be adequate to allow regulation of global greenhouse gases at an optimum level by dramatic increases in biomass production, when combined with increases in other renewable energy sources, conservation, and efficiency. It should be biologically possible to economically double world biomass productivity, if needed, using current or soon to become available technologies. They would include:

1. Genetic improvement and use of hundreds of perennial species that are able to grow on lands unsuited for sustainable production of cultivated annual crops. This would include 850 million hectares of destroyed or degraded tropical forests. Oil palm trees yielding 5 tonnes of vegetable oil per hectare per year on 100 million hectares would produce more oil than the current 440 million tonnes produced by Saudi Arabia and could do so indefinitely into the future. Each hectare of oil palm would also produce 20 to 30 tonnes of dry matter annually in stems, leaves, and spent fruit bunches. This could be used as mulch for soil conservation and improvement or converted to bioenergy during and at the end of each 25 year rotation. Many other exceptionally productive perennial species exist in tropical regions with their 12 month growing season. Rubber, hybrid eucalyptus, Acacia, Leucania, and Macadamia show up to a 4-fold increase in productivity after a century of plant breeding and cultural improvements. Much additional improvement can be made. Agricultural productivity has increased more during the past 65 years than during all previous recorded history. Corn yields in the USA have increased beyond 5-fold since the early 1940s. Feed utilization has doubled the production of eggs, milk, pork, and poultry. This has resulted in a 10-fold increase in food production per hectare. These genetic and cultural increases are not sustainable for our major annual food and forage crops including corn, wheat, rice, sorghum, pearl millet, and barley. Also, very limited amounts of fertile land are available, with much having been lost to erosion, salinization, development, desertification, etc. Fortunately, we have hundreds of underutilized trees, grasses, legumes and other perennial plant species that can be produced on hundreds of million of hectares of land unsuitable for the sustainable production of cultivated annuals. Yield improvement potential of many of these species could be developed and utilized. A well-endowed network of stations dedicated to the genetic improvement and use of underutilized perennial plants for food and bioenergy should be developed as soon as possible.

2. The production of most trees and other perennial plants during their rapid growth phase. Plants have a sigmoid or S-shaped growth pattern. Mature

trees and mature forests produce little if any added growth and generally harvest no additional net CO_2. Short rotation plantations, rotational grazing of pastures and rangelands, and similar management and utilization of the hundreds of millions of hectares of trees and other plants growing on suburban streets, small towns, farm woodlots, waterways, and degraded woodlands all planted to polycultures of the best adapted, genetically improved plants would harvest immense amounts of CO_2 and provide substantial amounts of bioenergy. Recent and projected advances in improved cellulase enzymes, biomass gasification, etc. make this a compelling opportunity.

3. Providing meaningful, profitable employment for hundreds of millions of the world's poor. Lifestyles, freedom, and democracy throughout the world would be greatly enhanced by a more equal distribution of the world's wealth and a wiser sustainable conservation and development of our resources. The wasteful exploitation of our soil, water, fossil fuel, and forest resources is enriching a few at the expense of the under-employed, low-income, middle classes, and future generations. Oil wealth increasingly goes to greedy governments and privileged classes with little going to the common people of Middle Eastern countries and Nigeria, etc. Sustainable energy production from biomass would be globally dispersed and labor intensive. Hundreds of millions of small land holders would be employed growing and harvesting oil palms, nuts, sugarcane, fuel wood, Miscanthus, sweet sorghum, hybrid poplars, and switchgrass. They would be aided by hundreds of thousands of the best plant breeders, scientists, teachers, health care professionals, businessmen, and extension workers. Biomass conversion plants would also rejuvenate the economics of small towns and rural areas. The productivity and culture of family farms and social benefits of stable neighborhoods, communities, and extended family structures would be enhanced. Nutrition and health would be improved. The production and use of ethanol for fuel in Brazil has created more than 700,000 rural jobs with modest investment costs. Brazil was growing 4.1 million hectares of sugarcane in 2000 with about two thirds going into the production of fuel alcohol. Assuming one person employed for each five hectares of sugarcane, 100 million hectares of sugarcane producing energy would provide useful direct employment for 20 million workers in low-income developing countries using current technologies. Conversion of much of the lignocellulosic material in the stems and leaves of the sugarcane plant to fuel alcohol and other bioproducts would substantially increase employment, income, and energy resources. Fuel alcohol produced from sugarcane juice has sold for prices as low as US \$0.21 per liter (\$0.79 per gallon) retail and US \$0.14 per liter at the mill (US \$0.53 per gallon). This would be a great benefit to the world economy by equalizing world income, placing a ceiling on crude oil prices, prolonging fossil fuel supplies, harvesting CO_2, and enhancing our environment.

Transition to an economy based on renewable energy, productive sustainable agriculture, and more equitable worldwide wealth distribution is urgently needed. This would lead to unprecedented, sustained economic growth in the USA and throughout the world, increasing food security, dramatically reducing our addiction to fossils fuels, lowering CO_2 and other greenhouse gases, reducing or eliminating global warming and preserving and enhancing our soil and water resources. Recent and projected advances in the development of improved cellulase and other enzymes, methane production, and biomass gasification will provide important tools. We must immediately expand programs to increase production of tree crops, grasses and other perennial biomass in an environmentally sustainable manner. Planting hundreds of millions of genetically improved trees in urban, suburban, and rural landscapes; along waterways; roadsides; farm woodlots; and degraded forests could provide immense amounts of biomass. This along with discarded wood from forests and landscape plantings can be converted to heating and cooking fuel or electricity and transportation fuels. Food producing trees should be more widely used in edible landscapes and organic agriculture. An initiative reported in American Forests (2004) is directed toward making the cities of upstate New York " Cleaner and Greener" as a cost effective way of improving air and water quality, reducing ozone pollution and the need for storm water facilities. They recommend 40 percent tree cover in cities. Existing totals range from 11.4 percent in Buffalo, 23.9 percent in Rochester, 24.0 percent in Poughkeepsie, 26.7 percent in Syracuse, and 37.0 percent in Binghamton. They also suggest that each American should plant 30 trees each year to offset the average American's "carbon debt" – the amount of carbon dioxide produced each year from homes and cars.

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Cultural Management of Velvet Bentgrass

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Velvet bentgrass (*Agrostis canina* L.) is a prostrate, stoloniferous grass that produces a turf with fine-leaf texture and very high shoot density. H.B. Sprague (1945) stated that velvet bentgrass "…has the widest range of usefulness of any species". However, others have indicated that the adaptation of velvet bentgrass is limited to mild temperate climates. Recent trials that included velvet bentgrasses in New Jersey suggest that further study of velvet bentgrass is warranted. Management techniques required to produce acceptable playing surface quality on velvet bentgrass putting green turf are not well understood. The objective of this field research was to evaluate the management practices of nitrogen fertilization, light-weight rolling, grooming, and growth regulation for their effects on the quality of a putting green playing surface.

'Greenwich' velvet bentgrass was seeded to a Nixon sandy loam in 2003 and grown-in during 2004 to produce a putting green management research area. Trial work was initiated in June 2005 using a 2 x 2 x 2 x 2 factorial arranged in a randomized complete block design with four replications. Treatment factors and levels consisted of:

i) N fertilization at 4.9 g m^{-2} wk^{-1} or 4.9 g m^{-2} $month^{-1}$
ii) rolling 3 times wk^{-1} or no rolling
iii) grooming (0.05 inch depth) 2 times wk^{-1} or no grooming
iv) growth regulation with trinexapac-ethyl (Primo) at 0.125 oz per 1000 ft^2 every two weeks or no growth regulation

Plots were evaluated for turf quality, density, incidence of disease and ball roll distance. Data analysis is underway; only representative data for treatment main effects will be reported.

Monthly N fertilization produced adequate turf quality throughout the trial, while weekly N fertilization created a dense dark green turf that developed a puffy surface by August 2006. Grooming decreased turf quality, but the lowered quality was within an acceptable level, except for August 2006. Rolling had no affect on turf quality until August 2006 when a reduction was observed. Trinexapac-ethyl produced a modest improvement in turf quality. Grooming produced the largest increase in ball roll distance 8 to 69 cm (3 to 27 inches). As expected, rolling increased ball roll distance 8 to 30 cm (3 to 12 inches). Weekly N fertilization frequently reduced ball roll distance 5 to 20 cm (2 to 8 inches). Growth regulation with trinexapac-ethyl did not affect ball roll (data not shown).

Thus, it is feasible to achieve ball roll distances suitable for championship play on Greenwich velvet bentgrass putting green turf. Ball roll distance was inversely related to turf quality (both within acceptable standards range); therefore, managing Greenwich for an attractive lush green appearance will probably reduce playability. Monthly N fertilization of velvet bentgrass is recommended since this fertilization schedule (at low N) provided adequate quality without puffiness and increased ball roll distance compared to weekly N. Rolling is recommended; this practice increased ball roll distance without reducing turf quality. Grooming of velvet bentgrass is also recommended as this practice was highly effective at increasing ball roll distance. However, frequency of grooming will depend on N fertility inputs (based on interactions not shown); that is, more frequent grooming will require more frequent N fertilization (greater than once per month). Growth regulation with trinexapac-ethyl provided a modest improvement in turf quality and had no effect on ball roll distance. Interactions (data not shown) suggest that trinexapac-ethyl may be useful for partially mitigating the detrimental effect of grooming on turf quality.

Recovery of Kentucky Bluegrass Subjected to Seasonal Applications of Simulated Wear

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Kentucky bluegrass (*Poa pratensis* L.) is often established on highly used sports fields and individual cultivars may differ greatly in response to traffic. Many better performing Kentucky bluegrass cultivars tested under traffic during summer months have long winter dormancy period. Thus, evaluation of cultivar performance under traffic during spring and fall is also needed since these are the seasons when the majority of traffic (i.e., soccer, football, and lacrosse) occurs on sports fields. Cultivars of Kentucky bluegrass were seeded in 2002 on a Nixon sandy loam and a study was initiated in the spring of 2004 with the objective of determining seasonal wear tolerance and recovery among Kentucky bluegrass cultivars. The experimental design was a split-plot with three replications. The whole (main) plots were the season of traffic (none, spring, summer, fall); subplots were the cultivars. Wear was applied to Kentucky bluegrass cultivars using a modified Sweepster in 2004 and 2005. Sixteen passes of a wear simulator were applied per week over a six-week period (96 total passes) for each season (spring [April-May], summer [July-August], and fall [October-November]). Fullness of turf cover was visually rated on a 0-100% scale (0% = complete defoliation of turfgrass cover; 100% = full turfgrass canopy) to assess wear tolerance and recovery throughout the test period.

Analysis of recovery data was performed for rating dates where the mean fullness of cover for 24 individual cultivars subjected to wear was approximately 33% and 66%. At the 33% mean recovery level, 'Julia' had the greatest fullness of cover compared to all other cultivars after spring 2004, summer 2004, and spring 2005 wear applications. Also, at the 33% mean recovery level, Julia was within the top statistical grouping of cultivars after wear in fall 2004 (including 'Moonshadow', 'Cabernet', and 'Lakeshore'), summer 2005 (including Cabernet), and fall 2005 (including 'Jefferson' and 'Limousine'). At the 66% mean recovery level, Julia had the greatest fullness of cover compared to all other cultivars after spring 2005 and was within the top statistical grouping of cultivars after wear in spring 2004, fall 2004, and summer 2005. Limousine had the greatest fullness of cover compared to all other cultivars at the 66% mean recovery level after wear in fall 2005.

Several cultivars had very slow recovery after spring-, summer-, and fall-applied wear. At the 33% mean recovery level, 'Bedazzled', 'Langara', and 'Touchdown' were in the lowest statistical grouping for fullness of cover after all wear applications in 2004 and 2005. Similarly, Langara, Touchdown, 'Moonlight' and PST-161 had the lowest fullness of cover after spring and fall wear in 2004 at the 66% mean recovery level. Moonlight and Bedazzled were within the lowest statistical group for fullness of cover after spring, summer, and fall wear in 2005.

Previously reported data from this research indicated Julia has excellent wear tolerance. Thus, it is probable that the excellent recovery of Julia was related to the reduced level of damage from wear. The excellent performance of Julia under wear stress indicates this cultivar should be evaluated for possible mechanisms associated with wear tolerance and recovery. Unfortunately, the relatively high susceptibility of Julia to disease prevents this cultivar from being recommended in Kentucky bluegrass blends for sports fields. The cultivar Limousine had moderate to good wear tolerance and recovery in this study.

Midnight II, Midnight, and Liberator had good recovery after summer wear but were among the slowest to recover after spring and fall wear. 'Brooklawn', 'Coventry', and A96-1201 had good recovery after spring wear but recovery was poor after summer and fall wear. Touchdown, Langara, and Bedazzled consistently had the poorest recovery in each season of both years. These seasonal differences among cultivars are important particularly for the Midnight type cultivars which are commonly used for sports field receiving use in fall and spring. The poor response of Touchdown to wear and subsequent recovery was notable since this cultivar has been commonly recommended for use on sports fields.

Thus, the data indicates cultivar performance under wear will vary based on the season during which the wear occurred. However, there was evidence that cultivars possessing good tolerance and recovery from wear regardless of the season can be developed.

Dideoxy Polymorphism Scanning, an Efficient Gene-Based Method for Marker Development

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Genetic linkage mapping and QTL analysis of important phenotypic traits is currently an active area of research in agronomically important plants and animals. Marker assisted breeding, based on linkage maps and QTLs, is likely to be one of the most important and broadly useful applications of biotechnology in agriculture. The ultimate goal of genetic linkage mapping is to identify the genes controlling important phenotypic traits. However, effective breeding strategies can be developed prior to gene identification based on closely linked markers. Current genetic linkage mapping uses molecular markers almost exclusively and is based on DNA sequence polymorphisms between parents whose segregation is followed in their progeny. Numerous types of molecular markers have been used to develop linkage maps, such as restriction fragment length polymorphisms (RFLPs), randomly amplified polymorphic DNAs (RAPDs), amplified fragment length polymorphisms (AFLPs), and simple sequence repeats (SSRs). To facilitate the association of phenotype with genes, and for comparative genomics, gene-based maps are highly desirable. With the rapidly increasing availability of expressed sequence tag (EST) sequences, numerous approaches to the development of markers based on these sequences have been reported. Single nucleotide polymorphisms (SNPs) and small indels are the most widespread types of polymorphisms in both plant and animal genomes, and SNPs are becoming the marker type of choice. Although SNPs and indels are relatively common, their use in the development of gene-based markers for mapping can be difficult. To improve the efficiency of marker generation, we have developed a simple and cost effective method of polymorphism detection. We refer to this method as dideoxy polymorphism scanning (ddPS) (Rotter et al, 2006).

We are currently using the ddPS method in developing a genetic linkage map of colonial bentgrass. Our current map covers 800 cM and consists of 15 linkage groups. Additional markers should resolve the linkage groups into the expected 14, 7 for the A1 genome and 7 for the A2 genome. We now have a total of 104 linked markers (43 gene based and 61 AFLP) and 37 unlinked markers (18 gene based and 19 AFLP).

References

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Effects of an Ethylene Inhibitor and Cytokinin on Heat-Induced Leaf Senescence in Creeping Bentgrass

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Cytokinins and ethylene are two major plant hormones that mediate signaling events involved in plant senescence. Our previous studies demonstrated a negative correlation between cytokinins and leaf senescence, and a positive correlation between ethylene and leaf senescence in creeping bentgrass. In this study, we hypothesized that exogenous application of cytokinin and an ethylene inhibitor may partially compensate for the change of cytokinin and ethylene during heat stress, resulting in delayed leaf senescence. Creeping bentgrass (Agrostis stolonifera) cv. Penncross was exposed to either heat stress **(**35°**C)** or control temperature **(**20°C**)** for 35 days in growth chambers. Chemical treatments applied on plants in each chamber included cytokinin [50 ml of 25 μM trans-zeatin riboside (tZR)], ethylene inhibitor [30 ml of 25 μM aminoethoxyvinylglycine (AVG)] and non-treated control (50 ml of distilled water). Turf quality and chlorophyll content were measured at weekly intervals to indicate heat-induced leaf senescence. Antioxidant enzyme activities and lipid peroxidation levels were also examined to determine whether the differences in leaf senescence and heat tolerance resulting from the applications were related to changes in antioxidant defense mechanisms.

Unique Central Asian Germplasm for Turfgrass Breeding

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A successful strategy for the genetic improvement of North American turfgrass species has been the introduction, evaluation, and incorporation of desirable traits from unique accessions from around the world. Until recently, turfgrass germplasm from Central Asia has not been well represented in U.S. collections. The 2003 - 2005 joint turfgrass project between Rutgers University and Tashkent State Agrarian University was the first official exchange approved by both the Uzbek Ministry of Agriculture and Water Resources and the USDA. Through this project, scientists from Rutgers and Uzbekistan have successfully obtained and collected potentially valuable turfgrass germplasm from Central Asia.

For several years Rutgers University has been increasing cooperative ties with the Republic of Uzbekistan and the Kyrgyz Republic. Rutgers University now has reciprocal germplasm exchange agreements with several prominent Uzbek research institutions and five scientific institutes of the Kyrgyz Agrarian Academy of Sciences. Turfgrass breeders from both the U.S. and Central Asia continue to focus on collecting heat, drought, disease and insect resistant germplasm, as well as shade tolerant grasses, and grasses that appear productive on marginal, overgrazed lands.

Through these efforts, Rutgers University currently possesses the largest and most diverse collection of Central Asian turfgrass germplasm in the U. S. To date, 3,511 accessions of turfgrass have been collected in Central Asia and evaluated by breeders at Rutgers University. In 2006, 54 accessions of turfgrass from Central Asia were collected and sent to Rutgers University for evaluation, (Table 1).

Table1. Turfgrass species collected from Central Asia, 2006.

Country	Species	Number of Accessions
Kyrgyzstan	*Festuca rubra*	18
Kyrgyzstan	*Festuca sulcata*	11
Kyrgyzstan	*Lolium perenne*	5
Kyrgyzstan	*Poa pratensis*	20
Total accessions:		54

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

The joint agreements have allowed Rutgers University to host delegations from both Uzbekistan and Kyrgyzstan for a special mini-training program. Tours of the Rutgers research facilities provided the visiting researchers with methods for the establishment of a turfgrass collection, nursery, and breeding program. This cooperative exchange has been a successful international collaboration and has provided Rutgers scientists with access to unique germplasm that has now been incorporated into the turf breeding collection.

Acknowledgments

All the participating scientists wish to express appreciation to both the Rutgers Center for Turfgrass Science and the New Jersey Agricultural Experiment Station for their support.