RUTGERS
New Jersey Agricultural
Experiment Station

Proceedings of the Seventeenth Annual Rutgers Turfgrass Symposium

January 10 - 11, 2008

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William A. Meyer, Associate Director

The Center for Turfgrass Science

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Proceedings of the Seventeenth Annual Rutgers Turfgrass Symposium

James F. White, Jr. and Barbara Fitzgerald, Editors

Associate Director's Remarks:

Welcome to the Seventeenth Annual Rutgers Turfgrass Symposium. This Symposium was started in 1991 to provide Rutgers faculty, students and staff and their collaborators with a forum to exchange ideas on a wide range of topics in turfgrass science. This year we are pleased to have Dr. Tom Voigt from the University of Illinois Urbana-Champaign present a keynote address on the role of crop production in Illinois on biofuels. We also have the following guest speakers: Dr. Frank Rossi (Cornell University), Dr. Eric Lyons (University of Guelph), and Jeff Carlson, who is a golf course superintendent from Martha's Vineyard. We greatly appreciate the Symposium Committee's efforts in organizing this meeting. The committee includes Dr. Joseph Heckman (Chair), Mr. Bradley Park, Dr. Bruce Clarke, along with Dr. Jim White and Ms. Barbara Fitzgerald who edited the Proceedings.

This past year has been an exciting time for the Rutgers Center for Turfgrass Science. Our faculty has continued to excel in turfgrass breeding, management, biotechnology, physiology, pest science, and many other areas. In 2007, I was fortunate to be recognized by the Golf Course Superintendents Association of America with a Distinguished Service Award. Dr. Bruce Clarke will soon receive the Distinguished Graduate Alumni Award from the Rutgers Graduate School. Dr. Barbara Zilinskas became a Fellow of the American Association for Advancement of Sciences. Dr. Jim Murphy received a recognition award from the New Jersey Turfgrass Association for his work in preparing the Monmouth Park turf course for the world renowned Breeder's Cup. Dr. Bingru Huang received the Research Excellence and Impact Award presented by the School of Environmental and Biological Sciences and the New Jersey Agricultural Experiment Station. The Turfgrass Team won the Team Research Award from Rutgers Cooperative Extension and NJAES for their work on controlling gray leaf spot disease of perennial ryegrass. Three of our graduate students (John Inguagiato, Patrick McCullough, and Yan Xu) received national recognition at the 2007 Crop Science Society of America annual meeting in New Orleans for their oral and poster research presentations.

I hope you enjoy this year's Symposium and that you take full advantage of the opportunity to exchange ideas. Thanks for your participation.

Sincerely,

William A. Meyer
Associate Director
Center for Turfgrass Science

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SEVENTEENTH ANNUAL RUTGERS TURFGRASS SYMPOSIUM

School of Environmental and Biological Sciences, Rutgers University
January 10-11, 2008

Thursday, January 10, 2008
Alampi Room, IMCS

4:00 - 4:30 PM	Registration
4:30 - 4:40 PM	Welcome and Introduction: **Dr. Bruce Clarke, Director - Center for Turfgrass Science**
4:40 - 5:30 PM	Keynote Address: **Dr. Tom Voigt** (Department of Natural Resources and Environmental Science, University of Illinois – Urbana Champaign) *Energy from the Heartland – Illinois' Role in Biofuel Crop Production*
5:30 - 7:00 PM	Wine and Cheese Reception

Friday, January 11, 2008
Foran Hall, Room 138A

8:30 - 9:00 AM	**Registration, Coffee and Donuts**
9:00 - 10:00 AM	**SESSION I: SOILS AND PEST MANAGEMENT** (Moderator: Brad Park)
9:00 – 9:20	**Dr. James Murphy** (Department of Plant Biology and Pathology, Rutgers University) *Evaluation of N Fertilization on Anthracnose Disease on Annual Bluegrass*
9:20 – 9:40	**Dr. Stephen Hart** (Department of Plant Biology and Pathology, Rutgers University) *What's New in Turfgrass Weed Control. A Lot!*
9:40 – 10:00	**Dr. Daniel Giménez** (Department of Environmental Science, Rutgers University) *Saturated Hydraulic Conductivity of Sand-Based Root Zones*
10:00 - 10:30 AM	**Discussion and Coffee Break**
10:30 - 11:30 AM	**SESSION II: SUSTAINABLE TURFGRASS MANAGEMENT** (Moderator: Mary Provance Bowley)
10:30 – 10:50	**Dr. Frank Rossi** (Department of Horticulture, Cornell University) *The Bethpage Project – Reducing the Risks of Golf Course Management*
10:50 – 11:10	**Dr. Eric Lyons** *(Department of Plant Agriculture, University of Guelph)* The Effect of Perennial Ryegrass Overseeding on Weed Suppression and Sward Composition

11:10 – 11:40 **Jeff Carlson** (Vineyard Golf Club) *It's Not Easy Being Green: An Organic Approach to Golf Course Management at the Vineyard Golf Club*

11:40 - 12:00 PM **Discussion and Poster Session**

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

1:00 – 2:00 PM **SESSION III: TURF PATHOGEN AND PEST SYSTEMS**
(Moderator: Dr. James White)

1:00 – 1:20 **JoAnne Crouch** (Department of Plant Biology and Pathology, Rutgers University) *Ecological Specialization Drives the Evolution of the Turfgrass Anthracnose Fungus Colletotrichum cereale Across Diverse Grass Communities*

1:20 – 1:40 **Dr. Raymond Sullivan** (Department of Plant Biology and Pathology, Rutgers University) *Molecular Interactions Between Gray Leaf Spot (Magnaporthe grisea) and the Biocontrol Bacterium Lysobacter enzymogenes*

1:40 – 2:00 **Dr. Albrecht Koppenhöfer** (Department of Entomology, Rutgers University) *Development of Mating Disruption Technology for the Oriental Beetle*

2:00 – 2:30 PM **Discussion and Coffee Break**

2:30 – 3:30 PM **SESSION IV: IMPROVEMENTS IN ENVIRONMENTAL STRESS TOLERANCE**
(Moderator: Dr. Thomas Gianfagna)

2:30 – 2:50 **Dr. Stacy Bonos** (Department of Plant Biology and Pathology, Rutgers University) *Update on QTL Markers for Dollar Spot Resistance in Creeping Bentgrass*

2:50 – 3:10 **Emily Merewitz** (Department of Plant Biology and Pathology, Rutgers University) *Identification of QTL Associated with Drought Tolerance in Creeping Bentgrass*

3:10 – 3:30 **Dr. William Meyer** (Department of Plant Biology and Pathology, Rutgers University) *Breeding and Evaluation of Kentucky Bluegrasses, Perennial Ryegrasses, and Tall Fescues for Wear Tolerance*

3:30 - 4:00 PM **Discussion/Closing Remarks**

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PLENARY PRESENTATIONS

Energy from the Heartland – Illinois' Role in Biofuel Crop Production

Tom Voigt

Department of Natural Resources and Environmental Science,
University of Illinois at Urbana Champaign

While traditional energy sources in Illinois include fossil fuels and nuclear power, there is much interest in other energy sources such as wind, corn-based ethanol, and soybean-based biodiesel. In the future, local energy may come from perennial grasses that can be burned to produce heat and electricity or treated with enzymes to produce sugars that can then be used to produce cellulosic ethanol. Plants used in these ways may be termed biofuel crops, biomass crops, bioenergy crops, or feedstock.

Nationally, switchgrass (*Panicum virgatum*) has received a great deal of attention and will probably be used as a primary biofuel crop in many portions of the country east of the Rocky Mountains, particularly in the southeastern and Great Plains regions of the U.S. University of Illinois researchers, however, are studying another biomass grass, Giant Miscanthus (*Miscanthus* x *giganteus*), a perennial warm-season (C4) grass native to Asia. Giant Miscanthus has been widely studied and grown in Europe where its senescent stems are harvested and burned to produce heat and electricity.

Voigt's presentation will generally explore the potential for biomass production in the U.S. and the University of Illinois's biofuel research focusing on Giant Miscanthus.

Evaluation of N Fertilization Effects on Anthracnose Disease on Annual Bluegrass

James A. Murphy, Bruce B. Clarke, John C. Inguagiato, Joseph Roberts

Department of Plant Biology and Pathology, Rutgers University

Anthracnose is a destructive disease of weakened or senescent turf caused by the fungus *Colletotrichum cereale* (Crouch et al., 2006). The disease occurs throughout the United States, Canada, and Western Europe (Smiley et al., 2005; Smith et al., 1989) on almost all turfgrass species but is particularly severe on annual bluegrass (*Poa annua*). The frequency and severity of anthracnose epiphytotics on golf course putting greens has increased over the past decade (Dernoeden, 2002; Landschoot and Hoyland, 1995; Mann and Newell, 2005; Wong and Midland, 2004). It has been suggested that management practices commonly employed on golf courses may be enhancing abiotic stress and thus predisposing turf to anthracnose (Vermeulen, 2003; Zontek, 2004). And it is probable that more than one or combinations of management factors may be enhancing the severity of this disease, making it more difficult to control.

The overall goal of our project is to develop a set of best management practices (BMPs) for the control of anthracnose disease on annual bluegrass putting green turf. Although we have improved our understanding of how some cultural practices affect this disease (Inguagiato, et al. 2006a; Inguagiato, et al., 2006b; Inguagiato, et al. 2007), there remain critical questions regarding nitrogen (N) fertilization effects on anthracnose. Our previous research demonstrated the importance of N fertilization in minimizing anthracnose; however further evaluation is needed to determine the optimal frequency of summer soluble-N applications as well as the impact of late- and early-season granular-N fertilization programming on the severity of this disease.

Mid-season N Fertilization and Growth Regulation Effects on Anthracnose

Our first trial evaluated the impact of N fertilization (4.9 kg ha^{-1} every 7 or 28 days), mefluidide (ME; 0 and 0.106 kg a.i. ha^{-1} yr^{-1}), trinexapac-ethyl (TE; 0 and 0.050 kg a.i. ha^{-1} every 14 days), verticutting (VC; 0- and 3-mm depth every 14 days) and interactions of these factors on anthracnose of annual bluegrass mowed at 3.2 mm. This was a 3-year field trial initiated in 2003 on annual bluegrass turf grown on a Nixon sandy loam with a pH of 5.9 in North Brunswick, NJ. Phosphorous and potassium were applied based on soil test results. Turf was mown 10 to 14 times wk^{-1} with a triplex mower at a bench setting of 3.2 mm. Silica sand was topdressed over the entire trial at 88.7 cm^3 m^{-2} and incorporated with a cocoa mat drag every 14 days after VC treatment. Turf was irrigated as needed to prevent wilt stress. Dollar spot (*Sclerotina homoeocarpa*) disease was preventatively controlled with vinclozolin or boscalid. Flutolanil was used to suppress brown patch (*Rhizoctonia solani*) every 14 days from June through August each year. These fungicides were previously found to provide no suppression of anthracnose on annual bluegrass greens in New Jersey (Towers et al., 2002). Annual bluegrass weevils (*Listronotus maculicollis*) were controlled with applications of chlorpyrifos, bendiocarb or bifenthrin.

Treatments were structured using a 2 x 2 x 2 x 2 factorial arrangement in a randomized complete block design with four replications; treatments were repeated in the same locations each year. Factors included N fertilization, ME, TE, and VC. N treatments were 4.9 kg ha^{-1} of

N sprayed as an NH_4NO_3 solution every 7 or 28 days from May to September 2003, October 2004, and August 2005. The entire experimental area was lightly irrigated immediately after N applications. Total N applied during the 7 and 28 days fertilization treatments was 107.5 and 29.3 kg ha^{-1} in 2003, 117.3 and 24.4 kg ha^{-1} in 2004, and 58.6 and 14.7 kg ha^{-1} in 2005, respectively. ME levels were either none or a split application of ME at 0.053 kg a.i. ha^{-1} on 14 and 28 April 2003, 7 and 21 April 2004, and 6 and 20 April 2005. TE levels were either none or TE applied at 0.050 kg a.i. ha^{-1} every 14 days. TE applications on non-ME treated plots were made from 14 April to 16 September 2003, 7 April to 22 September 2004, and 6 April to 10 August 2005. VC levels were either none or VC to a 3 mm depth (actual) with 1 mm wide blades spaced 13 mm apart every 14 days from 30 May to 7 August 2003, 11 May to 25 August 2004, and 28 May to 5 August 2005.

The trial was inoculated with *C. cereale* (isolate ValP-04) at the initiation of the trial to ensure uniform disease development across the site; disease outbreaks occurred naturally in subsequent years. Anthracnose severity was assessed from June through August each year as the percent turf area infested with *C. cereale* using a line-intercept grid count method similar to that of Gaussoin and Branham (1989) that produced 546 observations over 3.6 m^2 $plot^{-1}$. The number of observations of symptomatic leaf tissue was then transformed to a percent turf area infested using the formula: (n / 546) x 100; where n was the number of intersections observed over symptomatic leaf tissue.

N fertilization frequency had the greatest influence on disease throughout the trial; N applied at 4.9 kg ha^{-1} every 7 days reduced damage 5 to 24% compared to a 28 days interval. N has been associated with reduced anthracnose severity on turfgrass (Vargas et al., 1977; Backman et al., 2002; Crouch et al., 2004; Inguagiato et al., 2005; Uddin, 2006), but pending review this is expected to be the first peer reviewed report of increased N minimizing the severity of this disease (Inguagiato et al., 2008). Similarly, stalk rot of maize (*Zea mays* L.), caused by *C. graminicola*, has been reported to be reduced by increased N fertility throughout the season (White et al., 1978). Plant growth and maintenance requires relatively large amounts of N and N deficiency can inhibit growth, decrease photosynthesis (Beard, 1973) and reduce tolerance to environmental stress (Orcutt and Nilsen, 2000), potentially increasing susceptibility to stress related diseases such as anthracnose (Smiley et al., 2005). Specific mechanisms associated with reduced anthracnose severity in plants with greater N fertility are currently unknown, although increased plant vigor has been proposed (White et al., 1978; Huber et al., 2007; Krupinsky and Tanaka, 2001).

Interactions involving N and ME indicate that more frequent (7 days) N fertilization reduced anthracnose severity and negated any effect of ME on disease. The plant growth regulators, ME and TE, frequently interacted during the last 2 years of the trial; sequential application of ME and TE reduced disease 6 to 14% compared to plots that only received one of these plant growth regulators. At advanced stages of disease, the combination of 7 days N fertilization and ME and TE application had the greatest disease reduction.

Danneberger et al. (1983) reported that over-stimulating annual bluegrass fairway turf with N can enhance disease development; N applied at 292 kg ha^{-1} yr^{-1} increased anthracnose foliar blight compared to 146 kg ha^{-1} yr^{-1}. When evaluating the effect of annual N fertility programs on anthracnose severity, Danneberger et al. (1983) observed greater disease when most N was applied during April and May rather than November regardless of total annual N applied. Rapid foliar growth induced by excessive spring N fertilization can deplete carbohydrate reserves (Beard, 1973), which would be exacerbated by low net photosynthesis during summer stress (Liu and Huang, 2001). Thus, our trial indicates that frequent low rate soluble-N fertilization during the middle of the growing season can dramatically reduce anthracnose severity on putting greens. And the work of Danneberger et al. (1983) on anthracnose foliar blight suggests that the annual N fertilization rate should be moderate (146 kg ha^{-1} yr^{-1}) and a greater proportion of the annual N fertilizer should be applied in autumn versus spring to reduce disease severity on fairways; however, this approach needs to be evaluated for anthracnose basal rot under putting green conditions.

Nitrogen Fertilization Programming Effects on Anthracnose Disease of Annual Bluegrass Putting Green Turf

Our initial trial involving N fertilization indicated that frequent low rate soluble-N fertilization during the middle of the growing season can dramatically reduce anthracnose disease (Inguagiato et al., 2008). However, this previous trial was not designed to determine an optimum frequency for soluble low rate N fertilization relative to the severity of anthracnose. Moreover, previous research has not clearly defined the possible role of late- or early-season higher N rate granular fertilization on anthracnose of annual bluegrass putting green turf (Danneberger et al., 1983; Inguagiato, 2007). Nor has the influence of the timing of granular-N fertilization on the frequency of low rate soluble-N fertilization during the growing season been defined.

Superintendents have frequently asked about the potential role, if any, of late- and early-season granular-N fertilization in turfgrass management and are seeking guidance on the importance of this practice in suppressing anthracnose of annual bluegrass turf. Note that recent marketing of foliar (liquid) fertilization has been encouraging superintendents to reduce and possibly eliminate higher rate granular-N fertilization. This research should provide insight into the feasibility of this approach to N fertilizer programming with respect to disease management.

Therefore, our objectives in upcoming trials include:

1. identifying an optimum frequency for low rate soluble-N fertilization for suppressing anthracnose disease,

2. evaluating the N rate effect of late- or early-season granular fertilization on anthracnose disease severity, and

3. determining whether late- or early-season granular-N fertilization alters (interacts with) the effect of frequent low rate soluble-N fertilization during mid-season on anthracnose.

Objective 1. A water soluble-N fertilizer (NH_4NO_3) will be sprayed at 4.9 kg ha^{-1} of N at frequencies of every 1, 2, 3, 4, 5 and 6 weeks or applied at 9.8 kg ha^{-1} at frequencies of every 2 and 4 weeks. The latter two treatments are included to determine if it is feasible to increase the interval between sprays (thereby reducing costs) by increasing the N rate, yet maintaining the same degree of disease suppression as the respective more frequent lower-rate N application. The trial will use a randomized complete block design with four replications. Clippings will be collected at the same time that disease severity is assessed to determine the relationship of leaf tissue N content to disease severity. Results will confirm the range of treatment levels to be used in the soluble-N fertilization factor of the trials described below.

Objectives 2 and 3. Another annual bluegrass field trial area was established autumn 2007 to conduct a trial that will be repeated twice in space (Trials A and B). These experiments will use a randomized complete block design and treatments will be initiated in autumn of 2008. Treatments in both trials will be arranged as a 3 x 4 x 4 factorial with four replications. The first factor will be the season for granular fertilization: spring, autumn and none. The second factor will be the N rate of granular fertilization: 67.5, 135, 202.5, and 270 kg ha^{-1}. The third factor will be the frequency of low rate soluble-N fertilization during the growing season; for example, every week, every two weeks, every four weeks, and none, based on results from the trial addressing objective 1 above.

Trial A will be allowed to develop disease in 2009 while trial B will have disease suppressed with fungicides in 2009; disease will be allowed to progress on trial B in 2010. Trial B will provide a second year of data from plots that have received two years of cumulative N fertilization, which may result in some treatments having a buildup of soil N that could impact findings related to Objective 3. Trial A (disease allowed to develop in 2009) will include an additional year of treatments and data collection if turf can recover sufficiently from disease damage in the autumn of 2009.

Acknowledgments

This work was supported by the New Jersey Agricultural Experiment Station, State, and Hatch Act funds, Rutgers Center for Turfgrass Science, other grants, and gifts. Additional support was received from the Tri-State Turf Research Foundation, United States Golf Association, Golf Course Superintendents Association of America, and Golf Course Superintendents Association of New Jersey.

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What's New in Turfgrass Weed Control – A Lot!

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A number of new herbicides have recently or are about to be registered for weed control in turfgrass have been extensively tested at Rutgers over the past few years. These include mesotrione, fluroxypyr, sulfentrazone and sulfosulfuron.

Mesotrione: Field studies were conducted in the 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), four weeks after turfgrass emergence (4 WAE) and a sequential treatment at both timings. 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. Experimental design was a split-block with four replications. Treatments were a factorial combination of four seedings (main plots, 1.8 x 68-m) with 12 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 and weed cover were rated visually on a percent scale. Overall, mesotrione caused minimal turfgrass cover reductions applied PRE. However, 4 WAE applications at the higher 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. Control of winter annual broadleaf weeds such as chickweed and henbit were nearly complete with all mesotrione treatments. Mesotrione exhibited potential to selectively control annual bluegrass applied PRE especially at the 0.28 and 0.56 kg/ha application rate. Annual bluegrass control was lower with 4 WAE applications than PRE applications. 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. In the fall 2005 and 2006 experiments these treatments provided 94 to 99 and 73 to 91% annual bluegrass control the following spring.

Fluroxypyr: Field experiments have been conducted from 2004 to 2007 to evaluate fluroxypyr, applied alone or in combination with other herbicides for broadleaf weed control in cool-season turfgrass. Treatments were applied to 0.9 by 3 m plots with a single-nozzle CO_2 backpack sprayer system utilizing a 9504EVS nozzle tip which delivered 374 L/ha of spray solution at 221 kPa. Experimental design was a randomized complete block with 4 replications per treatment in all experiments. In 2004, fluroxypyr applied alone at 0.26 kg ai/h provided complete control of white clover 6 weeks after treatment (WAT) but only controlled dandelion and buckhorn plantain 70 and 67%, respectively. The addition of 2,4-D at 1.1 kg ai/h was required to obtain complete control of these two weeds. In a 2005 timing study an experimental ester combination of fluroxypyr + 2,4-D + dicamba provided nearly complete control of dandelion, white clover, buckhorn plantain and mouseear chickweed when applied on April 14, April 28, or May 27. In 2006 and 2007 experiments, the combination of fluroxypry + 2,4-D + dicamba applied in May continued to provide nearly complete control of dandelion, buckhorn plantain and white clover 8 WAT. In some cases white clover control was superior to control obtained with a combination of 2,4-D +MCPP + dicamba and a combination of 2,4-D and triclopyr. In additional studies in 2007 the combination of fluroxypyr + 2,4-D + dicamba provided 98% oxalis control 4 WAT while all other herbicide combinations tested only provided 65% or less control with the exception of a combination of 2,4-D +MCPP + dicamba + carfentrazone which provided 86% control. One weed that the combination of fluroxypry + 2,4-D + dicamba was not completely effective on was prostrate knotweed were only 70% control was obtained 8 WAT. The results of these studies over the last four years suggest that fluroxypry can provide very high and consistent levels of white clover control. Fluroxypyr was also effective at providing nearly complete oxalis control.

Sulfosulfuron and Sulfrentrazone: Field experiments were conducted in 2006 and 2007 in Adelphia, NJ to evaluate postemergence applications of halosulfuron, sulfosulfuron, and sulfentrazone for yellow nutsedge control in perennial ryegrass Lolium perenne L. ‘Manhattan II’. All herbicide treatments were applied once or twice on an approximately 5-week interval. Halosulfuron was applied at 35 or 70 g ai/ha, sulfosulfuron was applied at 13, 26, and 39 g ai/ha and sulfentrazon was applied at 140, 280 or 420 g ai/ha. Halosulfuron and sulfosulfuron treatments included non-ionic surfactant at 0.25% v/v. Herbicide application dates were June 20 and July 24 in 2006 and July 2 and August 13 in 2007. Turfgrass injury and yellow nutsedge control were evaluated 3 weeks after initial treatment (WAIT), prior to sequential applications, and 9 and 12 WAIT. Treatments were applied to 0.9 by 3 m plots with a single-nozzle CO_2 backpack sprayer system utilizing a 9504EVS nozzle tip which delivered 374 L/ha of spray solution at 221 kPa. Experimental design was a randomized complete block with 4 replications per treatment. In 2006, prior to the sequential application yellow nutsedge control ranged from 89 to 95% for halosulfuron, 56 to 86% for sulfosulfuron, and 63 to 90% for sulfentrazone. There was no turfgrass injury detected from any of the herbicide treatments. At 9 WAIT, perennial ryegrass injury from sequential sulfosulfuron treatments ranged from 15 to 31%. Injury from these treatments increased substantially at 12 WAIT and ranged from 26 to 50%. Injury observed was in the form of chlorosis and stand thinning. At 12 WAIT halosulfuron provided 87 to 98% yellow nutsedge control. Sequential treatments of halosulfuron did not increase yellow nutsedge control relative to single applications. Single applications of sulfosulfuron provided 60 to 74% yellow nutsedge control but sequential applications increased yellow nutsedge control to 85 to 96%. Single applications of sulfentrazone provided 70 to 90% control but sequential applications at 240 and 420 g ai/ha improved control to 93 and 97%, respectively. In 2007, prior to the sequential application yellow nutsedge control ranged from 77 to 91% for halosulfuron, 44 to 85% for sulfosulfuron and 28 to 88% for sulfentrazone. There was no turfgrass injury detected from any of the herbicide treatments. At 9 WAIT, no turfgrass injury was detected from any of the sequential herbicide treatments. At 12 WAIT halosulfuron provided 76 to 84% yellow nutsedge control. Sequential treatments of halosulfuron increased control to 91 to 94%. Single applications of sulfosulfuron preformed much better in 2007 providing 84 to 90% and sequential applications at all three rates provided 96 to 97% control. Single applications of sulfentrazone provided 75 to 82% and similar to observations in 2006 sequential applications at 240 and 420 g ai/ha improved control to 91 and 93%, respectively. The results of these studies suggest that sulfosulfuron and sulfentrazone may provide a viable alternative to halosulfuron for yellow nutsedge control especially when applied sequentially.

Saturated Hydraulic Conductivity of Sand-Based Root Zones

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Hydraulic property criteria suggested by the U.S. Golf Association (USGA) Green Section are used to select construction materials for golf putting greens, but measurement of these hydraulic properties is difficult and results are highly variable. This is particularly true in the case of the saturated hydraulic conductivity, K_{sat}. An alternative to direct measurement of hydraulic properties is their prediction using other measured predictor variable(s) such as soil water retention properties and particle size distribution data. A power-law model of K_{sat} was modified to derive all needed parameters from the inflection point of a s-shaped soil water retention function. The proposed model has been successfully used to predict textural averages of K_{sat}, but it has not been tested on individual samples. The objective of this study was to apply the model to the prediction of K_{sat} values of root zone mixes. Four datasets containing laboratory measurements of K_{sat} and water retention curves covering a range of textural compositions and levels of compaction were analyzed. The model successfully predicted K_{sat} for the four data sets. The linear relationship between predicted and measured K_{sat} was significant at $P>0.95$. Furthermore, significant correlations were found between the water retention derived parameters of the K_{sat} model and parameters characterizing particle size distributions of the mixes. This result suggests that in the absence of water retention information, K_{sat} could be predicted from particle size data. The proposed model could be used to improve the design, construction and management of golf courses.

The Bethpage Project
Reducing the Risks of Golf Course Management

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Golf course superintendents, owners and staff are motivated to reduce pesticide use due to pending regulation, economic factors, and environmental consciousness. However, golf turf managers faced with operating facilities with fewer pesticides need the best information on course conditioning less reliant on chemical pesticides that also meets golf client expectations. At the same time, those advocating pesticide restrictions need to be aware of the costs of implementing the policies and the resulting impacts on revenues in the case of widespread turf loss. In an effort to address the environmental, economic and practical aspects of pesticide restriction we are exploring golf turf management with little to no chemical pesticides.

Our approach has been to compare traditional putting green management to a strict IPM approach and to biologically-based and reduced-risk management. The putting green is the most intensively managed area of a golf course, has the highest quality expectations, and will therefore be the most difficult to manage with chemical pesticides.

The foundation of our work focuses on reducing plant stress associated with putting green management that often leads to pest problems. Reduced stress management programs include alteration of mowing, watering and feeding strategies designed to meet playability standards that might reduce visual quality.

Our project is unique for many reasons. We look at the full suite of management practices performed on a golf course—not just one aspect, and our research site is an operational golf course. The Green Course at Bethpage State Park on Long Island is a high-use public course, getting 50,000 rounds of play each year.

The project is long term—we're just completing our seventh year. It's an experiment using full putting greens as experimental units as well as a demonstration to the many thousands of golfers who play the course each year.

Throughout the project, we have been able to apply fewer chemical pesticides on the IPM and reduced-risk (or non-chemical) greens as compared to traditionally managed greens. The IPM greens have consistently received 30-60% fewer applications, while maintaining equal quality. However, numbers of applications do not tell the full story. Numbers of pesticide applications are easily compared, but they reveal nothing about the qualitative effect of these pesticides. As traditional chemical pesticide applications have decreased, reduced-risk and biological product use has increased. So how can we tell which products are "better" to use, and when we are improving?

The Effect of Perennial Ryegrass Overseeding on Weed Suppression and Sward Composition

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Pesticide bans in Canada have resulted in a requirement for municipal turfgrass managers to use cultural methods of weed control to provide a safe playing surface for athletes. A field study was conducted to determine if overseeding provides enough competition to decrease weed populations in Kentucky bluegrass athletic turf typically used in municipal parks for recreation. Perennial ryegrass was overseeded in non-irrigated and irrigated trials at the Guelph Turfgrass Institute (GTI) field station in Guelph, and on in-use soccer fields at the University of Guelph campus and in the Town of Oakville, Ontario, Canada over two years. Weed populations were not affected by overseeding in 2005, a dry growing season. However, when weed populations were high and normal growing conditions existed in 2006, overseeding applications in May/July/September at 4 and 8 kg/100 m^2 decreased perennial weed cover, specifically white clover in the irrigated trial and dandelion in the non-irrigated trial at the GTI. An increase in perennial ryegrass was observed in all plots that received an overseeding treatment. Treatments applied on the in-use soccer fields in Oakville and Guelph, which included May/September and May only overseedings, had no effect on weed populations or perennial ryegrass populations compared to the weedy control. Over the short-term, high rate and frequent overseeding with perennial ryegrass appears to provide competition against perennial weeds when weed cover is high and should be considered an important part of a weed management program for municipal turfgrass managers.

It's Not Easy Being Green: An Organic Approach to Golf Course Management at the Vineyard Golf Club

Jeff Carlson CGCS

Golf Course Superintendent of the Vineyard Golf Club, Martha's Vineyard, MA

In November 1998, I joined a team of developers attempting to permit an 18-hole golf course on a 238 acre wooded site on the Island of Martha's Vineyard. A year and a half and a mountain of paperwork later, this abandoned 148 lot subdivision was approved for a private 18-hole golf course. One of the 36 conditions of approval was that the golf course be managed organically; with organic defined as eliminating the use of traditional synthetic pesticides and using only natural organic fertilizers.

With some serious concerns, I accepted the position as construction and grow-in superintendent for this new course; The Vineyard Golf Club. Because of an encouraging experiment in the late 90's with a practice green at the Widow's Walk Golf Course that was pesticide free for a year and a half (picture of green), a faith in some of the recent advances in turfgrass research, a concern about future of pesticide use in the US and a history of not always thinking through the long-term ramifications of my actions, I forged ahead.

Throughout the construction process, we utilized various strategies to give the course an advantage in combating disease "organically". We mixed our topsoil with the partially decomposed forest litter, selected only grasses that tested well against diseases common to our location, cleared away most of the trees on the site, lined all 19 greens with plastic, took great pains not to compromise the excellent drainage characteristic of a sandy site and installed perimeter wells prior to grow-in to monitor ground water quality

Before any evaluation of the organic management program can be made, qualifiers need to be acknowledged that give The Vineyard Golf Club a leg up:

- Less than 1% of the grass on the course is poa annua.
- This course is a walking course.
- We have very few trees and no plans for a tree planting program.
- The course has less than 10,000 rounds per year.
- Because it is surrounded with water (an Island), the weather is temperate; rarely in the 90's, prolonged stretches of high humidity are unusual even in August and the wind almost always blows.
- The membership is informed, supportive and wants a firm and fast golf course.

The organic management approach to fungus diseases is five-fold: feed and water the plant sparingly, manage the micro-environment where possible, apply a few bio-pesticides frequently, manage guttation water constantly and adhere to a repetitive system of cultural controls.

I will discuss strategies for disease management focusing on Dollar Spot, *Sclerotinia homoeocarpa,* as well as other patch diseases common commonly to our course. Disease management will consist of a discussion of products and cultural practices that have contributed to disease control in addition to thresholds of acceptability and the communication of these thresholds to our membership.

We will also discuss Nitrogen applications; their rates, role in disease management and evolution from exclusively natural organic to small per cent of synthetic based fertilizers based on the results of an on-site water quality monitoring program.

Insect damage, primarily from Oriental Beetle, *Exomala orientalis,* will be examined. Organic strategies for grub control as well as predator control will be discussed and evaluated in terms of control.). While we have actively engaged the entamologists from our local universities to use the Club as a research site, we had to deal with the here and now. Along came Walter Walodyka , skunk and crow removal expert. Walter's aromatic pick-up can be found throughout the course in the spring and fall retrieving skunk and crow traps and removing them from the site (shot of crow in a have-a-heart cage). Organic insect management is much more " in your face" than the timely application of an insecticide…. just ask our members.

Finally weed control through products and cultural management will be discussed. This is a new frontier as far as organic products are concerned. I will discuss a product from New Zealand called *Waipuna* that can be best described as an organic (and non-systemic) "Roundup".

As I look back five years, I was not sure I would be here to talk organic management program at The Vineyard Golf Club. But by combining the latest products and research with an understanding and informed membership and throw in an extraordinarily dedicated staff, we have a golf course that is eminently playable; although as Kermit says "It's not easy being green".

Ecological Specialization Drives the Evolution of the Turfgrass Anthracnose Fungus *Colletotrichum cereale* Across Diverse Grass Communities

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Emerging infectious diseases represent one of the greatest threats to both cultivated and natural plant communities, threatening food production, wildlife habitats and biodiversity conservation. Over the past decade, the emergence of anthracnose disease has challenged the health of North American golf course turfgrasses, resulting in considerable economic loss. The fungus responsible for the outbreaks, *Colletotrichum cereale*, has also been isolated from numerous natural grasses and cereal crops, although disease symptoms are generally absent. Here we utilize phylogenetic and population genetic analyses to determine the role of ecosystem in the advancement of turfgrass anthracnose and assess whether natural grass and/or cereal inhabitants are implicated in the epidemics. We find that the graminicolous *Colletotrichum* diverged from an ancestral population into two lineages correlated with host physiology (C3 or C4). In the C4 lineage, which includes the important cereal pathogens *C. graminicola*, *C. sublineolum*, *C. falcatum*, *C. caudatum* and nine novel species, host specialization predominates. In contrast, although the C3 lineage -- *C. cereale* -- is comprised of just one species with a wide host-range , it is divided into ten highly specialized populations derived from a generalist founder population. Extreme differentiation between locally-adapted populations suggests that asymptomatic grasses are unlikely reservoirs of infectious disease propagules, but gene flow between the generalist founder population and specialized genotypes provides a mechanism for genetic exchange between otherwise isolated populations. These findings demonstrate that while disease occurrence and spread is currently localized to the turfgrass environment, introgression between *C. cereale* ecotypes can lead to the expansion of anthracnose disease into new ecosystems.

Molecular Interactions Between Gray Leaf Spot (*Magnaporthe grisea*) and the Biocontrol Bacterium *Lysobacter enzymogenes*

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Lysobacter enzymogenes is a gram negative, soil-inhabiting bacterium that produces a wide array of enzymes and antibiotics and is antagonistic to a broad range of deleterious microbes, including many plant pathogens. Recent studies indicate that *L. enzymogenes* is pathogenic towards lower eukaryotic hosts, but not higher plants or animals. Assays over the past year have revealed that the pathogenic host range of the bacterium is broad: it infects fungal pathogens of turfgrass, including the gray leafspot pathogen, *Magnaporthe oryzae* (=*M. grisea*), the anthracnose pathogen *Colletotrichum cereale*; and the brown patch pathogen, *Rhizoctonia solani*. It also infects stramenopiles such as *Pythium* and *Phytophthora* spp., nematodes and nonvascular plants such as mosses. Most significantly, research from this project has shown that *Lysobacter* internalizes in all of the eukaryotic hosts in which it has been examined in detail, a property that has not been described for bacterial pathogens of lower eukaryotes.

We have initiated proteomic and transcriptomic studies to characterize proteins/genes involved in virulence and defense response between the bacterium and the gray leaf spot pathogen of turf. Forty one proteins differentially expressed in the first stage of *L. enzymogenes* pathogenesis (attachment to the fungal host) were recognizable by 2D gel electrophoresis and, of these, three *Magnaporthe oryzae* and 8 *L. enzymogenes* proteins were identified by MALDI-TOF analysis. Microarray analysis revealed over twice as many *Magnaporthe* genes are up and down regulated when first infected with a non-pathogenic *L. enzymogenes* mutant than when infected with the wild type bacterium. Interestingly, the mutant infected group contains many more times the number of genes involved in signal transduction compared to the wild type infected group. Taken together, these preliminary transcript comparisons indicate that *M. oryzae* is most likely recognizing a potential pathogen in the presence of the mutant bacterium, while the wild type bacterium attaches to its host largely undetected.

Development of Mating Disruption Technology for the Oriental Beetle

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The oriental beetle (OB), *Anomala orientalis*, has become the most important turfgrass insect pest in NJ, CT, RI, and southeastern NY. In a turfgrass survey in NJ (120 sites: golf courses, athletic fields, home lawns), an average of 62% of white grubs found were OB. An increase in OB significance is likely to occur in other areas where the OB it is already established, i.e., all coastal New England and Middle Atlantic states as well as OH, VA, NC, SC, WV, and TN.

Mating disruption with sex pheromones is widely used as an environmentally safe, non-toxic alternative to broad-spectrum insecticides for several moth species. However, only recently has mating disruption technology been considered as a possibility to manage white grubs. Polavarapu et al. (2002) showed the feasibility of OB mating disruption in large-scale field experiments in blueberries and ornamental nurseries using a microencapsulated sprayable formulation of its sex pheromone.

Microencapsulate sprayable sex pheromone formulations

We previously tested the feasibility of using microencapsulated sprayable sex pheromone formulations for OB mating disruption in turfgrass. OB flight was monitored with traps lured with OB sex pheromone. At 7–10 days after the first males were trapped the formulations were sprayed onto turf areas on lawns and golf courses measuring around 0.4 ha in size. The spray was immediately watered in with 6 mm overhead irrigation. Treatments efficacy was measured by trapping male beetles throughout the flight season and estimating grub populations in September using soil/sod core samples.

Our research showed that mating disruption is feasible in turfgrass with reductions in adult trap captures of up to 88% and reduction in larval populations of up to 74%. The 3M formulation used in the 2002 and 2003 experiments appeared to be the most effective formulation at rates as low 25 g ai/ha per season. However, all formulations lost efficacy within 14 days independent of rate used and had to be applied twice during the flight season. More frequent applications could further improve the formulation's efficacy but would make the approach very cumbersome. In addition, 3M has stopped production of their sprayable formulation. We believe that sprayable formulation can be improved but we doubt that a sprayable formulation can cover the entire flight season with one application.

We also found that OB sex pheromone can contaminate clothing articles that come into contact with sprayed surface. These articles could then attract male OB outside of treated areas. Athletic shoes walked for 30 min through pheromone-treated areas at 1 DAT were sufficiently pheromone-contaminated to attract significant numbers of male OB when bioassayed in a non-treated area. Contamination and male attraction had significantly declined when shoes were walked at 8 DAT. However, no complaints were reported by the superintendents on the golf courses used for our experiments.

Dispersible sex pheromone formulations

Our research over the last 3 years has demonstrated that dispersible pheromone formulations can overcome the limitations of sprayable formulations. In 2005, small scale (~0.1 ha replicates) field trials with different types of dispersible OB pheromone formulations indicated the potential of dispersible formulation based on reductions in OB male trap captures in the treated areas.

In 2006, we conducted two field trials. In a large scale (~0.4 ha replicates) trial, we compared wax-based beads by Suterra applied at 1 bead every 3.05 m × 3.05 m to smaller more numerous soywax-based granules by USDA-ARS NCAUR applied uniformly, both at 25 g ai/ha. Our observations on trap captures and male attraction to caged females showed very similar results that indicated that both the Suterra beads and the USDA granules can disrupt OB mate finding to a high degree (90–99%), but only the Suterra beads were effective over a sufficiently long period and had a high seasonal reduction in male OB trap captures (94%). We also tested the ability of OB males to find OB females using cages that trapped the attracted males. The Suterra formulation provided 88–100% reduction in male positive cages with virgin females over the first month after application and was significantly more effective and persistent than the USDA formulation. However, our observations on the inherently extremely variable OB larval densities did not support these trends with 50% reduction by the USDA granules but only 38% (nsd) reduction by the Suterra beads. In small scale field trial (~0.1 ha replicates), application pattern (3.05 m × 3.05 m vs. 6.1 m × 6.1 m) had no effect on reduction in trap captures by Suterra beads (98–99%).

In large-scale field trials in 2007 we tested formulation that had been further improved in laboratory studies during the off-season. Dispersible pheromone formulations by Suterra and USDA, both applied uniformly, both suppressed OB larval densities by 69%, but significantly so only by the Suterra formulation. However, the Suterra formulation persisted longer than the USDA formulation with respect to suppression in male OB trap captures (97% seasonal) and reduction of male-positive virgin cages (86–100% at 8–25 DAT). Experiments also showed that the dispersible formulations do not pose a contamination liability. We suspect that immigration of mated females from non-treated areas limited the larval suppression in our experiments.

Unfortunately, movement of OB females, albeit crucial to the success of mating disruption, is still poorly understood. We will address some of the relevant questions in research over the next 2 years. While the females generally seem to move relatively little, it is likely that the 15 m buffer we left between the borders of our treated plots and where we collected grub data is not sufficient. Successful mating disruption in other crops with moth species is generally practiced over much larger areas than the 0.4 ha replicates used in our experiments. Should mating disruption be implemented in turfgrass it would probably need to be practiced over larger areas. Since preventive white grub treatments are already typically applied over entire fairways and to most fairways on many golf courses, such large areas application do not seem unpractical on golf courses or athletic fields.

Update on QTL Markers for Dollar Spot Resistance in Creeping Bentgrass

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One of the major challenges in breeding creeping bentgrass is improving disease resistance. Dollar spot disease, caused by the fungus *Sclerotinia homoeocarpa* F.T. Bennett, is one of the most important diseases of creeping bentgrass because it accounts for a majority of the fungicides applied to golf courses in temperate areas. The goal of this research project is to create a genetic linkage map of creeping bentgrass and identify Quantitative Trait Loci (QTL) associated with dollar spot disease resistance. Once these QTLs are identified, these markers have the potential to identify favorable gene combinations which can enhance traditional plant breeding methods, reduce the evaluation time associated with identifying dollar spot resistant germplasm and increase the efficiency of breeding disease resistant cultivars.

A mapping population of creeping bentgrass generated from a cross between a dollar spot resistant and susceptible genotype was developed. Additionally, two backcross populations and a pseudo F_3 population were also developed to confirm the QTL identified in the original population. These populations were analyzed for dollar spot disease resistance and DNA marker polymorphism. These DNA markers were used to develop a genetic linkage map of creeping bentgrass and then subsequently identify Quantitative Trait Loci (QTL) associated with dollar spot resistance.

Replicated, mowed spaced-plant trials of the pseudo F_2, pseudo F_3 and backcross populations were inoculated with a virulent isolate of *S. homoeocarpa* on June 30, 2003 (Crenshaw isolate – isolated from Crenshaw creeping bentgrass) and inoculated with a different virulent isolate (PRG isolate – isolated from perennial ryegrass) in a separate study on June 24, 2006. These spaced-plants were evaluated throughout the growing seasons (2003 and 2004 for the Crenshaw isolate and 2006 and 2007 for the PRG isolate) for dollar spot disease using a 1-9 rating scale. Disease response was similar in both years for each isolate. Significant mid-parent heterosis was observed in the backcross generations in both years for the Crenshaw isolate but not the PRG isolate indicating the presence of non-additive gene effects for some isolates but not others. Results from classical genetic studies (presented in this issue) support the idea that dominant genes may be associated with susceptibility to the Crenshaw isolate only and only additive genes are associated with the PRG isolate.

We have identified approximately 200 unique SSR markers in creeping bentgrass. Initial genetic linkage maps of each original parent based on approximately 200 SSR markers were developed. The dollar spot susceptible parents was developed from 202 Single Dose Allele (SDA) SSR markers and covered 944 cM. The dollar spot resistant parent was developed from 182 SDA markers and covered 822 cM. Four putative QTL markers have been identified for the Crenshaw isolate and one different putative QTL marker was identified for the PRG isolate. This research will be useful in improving our understanding of and breeding for dollar spot disease resistance in creeping bentgrass.

Identification of QTL Associated with Drought Tolerance in Creeping Bentgrass

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Drought stress is a major issue worldwide and severely limits turfgrass growth and productivity. Improvement of selection efficiency in breeding for drought tolerance is of great need. One method to improve breeding selection practices is the identification of quantitative trait loci (QTL) for traits associated with drought tolerance. QTLs allow researchers to locate a given trait(s) of interest and subsequently use them for marker-assisted selection in breeding. Creeping bentgrass (Agrostis stolonifera L.) is a species that is widely used as a turfgrass and currently available cultivars could benefit from marker-assisted selection and breeding for enhanced drought tolerance. The objective of this study was to identify QTLs for drought tolerance traits including relative water content (RWC), osmotic adjustment (OA), water use efficiency, turf quality (TQ) and electrolyte leakage (EL) using a bentgrass mapping population. The mapping population was developed by crossing ‘L93’ with 7418-3. This study evaluated a subset of the F2 population consisting of 102 progeny plants. Plants were grown in a sand:soil 1:1 mix in a greenhouse and exposed to drought stress for 21 d by completely withholding irrigation. Seven possible QTLs were found on four linkage groups on the map of the drought tolerant parent for each of the physiological traits. Significant overlap of the chromosome regions between RWC and EL and between TQ and RWC was observed, suggesting that important markers in these regions could have great potential for future use in marker-assisted selection.

Breeding and Evaluation of Kentucky Bluegrasses, Perennial Ryegrasses and Tall Fescues for Wear Tolerance

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Most turf trials established in the United States are used to evaluate visual quality and occurrences of pest incidence on the turf. My father, a golf course superintendent referred to them as university beauty trials. At Rutgers, we have worked to develop and improve what we call the Rutgers Turfgrass Wear Simulator (1). The original machine was a modified Sweepster with large rubber blades to abuse the turf. The present machine has a Sweepster Head on a Toro rotary mower power source.

During the summer and fall of 2007, turfgrass trials located at Hort Farm II, North Brunswick, New Jersey and the Adelphia Research Center, Freehold, NJ were subjected to uniform wear by the latest machine. All of these trials were being maintained at moderate fertility, irrigated as necessary to prevent wilt and mowed once or twice a week at 1 ½ " (3.3 cm).

Most of these trials were replicated cultivar trials with 3 replications in a randomized complete block design. Two of the trials were single replication progeny turf trials. The tall fescue trial established in the fall of 2004 contained 1,000 single plot progenies. These were treated with 22 passes of the wear machine from August 27th through October 23rd 2007. These progenies were evaluated for wear tolerance on a 1-9 basis after wear was halted with 9 = best wear tolerance. There was a range of wear quality from 1-9. Those single plant progenies (46) with ratings of 7, 8 and 9 were tillered out for increase to initiate cycles of recurrent selection for wear tolerance. This same procedure was used on the 2006 perennial ryegrass trial that contained 1,600 plots. Wear was applied 16 times starting on September 21st until October 23rd, 2007. Performance at the end of the wear treatment ranged from 1 to 8 with 70 superior progenies with improved wear tolerance were selected to cycle for recurrent selection.

A replicated perennial ryegrass trial at Adelphia was worn 16 times with a schedule similar to the above perennial ryegrass trial. There were a total of 124 entries with a range in performance for average wear quality in November 9th from 6.3 to 2.7. The 10 ten entries were IS-PR315, HP-3, Palmer V, SR-4600, IS-PR316, MSH, APR-1980, APR-2024, APR-2025, and RAD-PR-28. Commercial cultivars with a rating of 3.3 included Headstart 2, Calypso II, Hawkeye and Ringer.

Two replicated tall fescue trials at Adelphia were worn during the fall of 2007. The 2004 trial received 28 passes and the 2005 trial received 18 passes. The wear ratings in the 2004 trial ranged from 6.1 to 2.7 with the entries ATL-58, ATM-18, CR-3, ATF-1226, Inferno, CR1-WT, ATE-21, Six Point, and ATF-1235 topping the trial. The poorest performing cultivars were KY-31 and Southeast. In the 2005 test, the range of wear ratings were similar to the 2004 trial with PST-5DH, PST-R5EP, Millennium-SRP, IS-TF-47, RK6, Shenandoah III, IS-TF-138, SR-8650 and PST-SYN-R5B4 topping the trial while KY-31 and Water Saver were the poorest rating entries.

There were two 2004 Kentucky bluegrass trials worn during July 2007 at Hort Farm II in North Brunswick, NJ. Both the Cooperative Turfgrass Breeders Test and the Rutgers replicated trials received 32 passes of wear prior to the August 14th rating for wear quality. The range in wear quality was from 7.3 to 2.7 in the CTBT trial. The top entries were A03-3, SRX-003004, A97-1287, H94-305, 102-371, A01-250, A00-4135 and Eagleton.

In the 2004 Rutgers Kentucky bluegrass trial, the range in performance was from 7.7 to 1.0. The top entries were A99-2559, H94-467, A04-49, Bewitched, H99-338, Cabernet, U-1885, H01-49, A99-2758, A99-2852 and RSP.

It is interesting to note that a majority of the top performing cultivars in the Kentucky bluegrass trials were from the Mid-Atlantic type such as Cabernet, RSP, Eagleton or hybrids from RSP. Their superior heat tolerance appears to contribute greatly to their wear tolerance in the summer.

It will be exciting to evaluate the superior wear tolerance of recent progenies of tall fescues and perennial ryegrasses selected for improved wear tolerance in the future. It appears that vigorous plants with superior disease resistance and heat tolerance will contribute to wear tolerance in the future.

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POSTER PRESENTATIONS

Gene Action of Dollar Spot Resistance in Creeping Bentgrass as Affected by Isolate and Host Genotype

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Genetic resistance to dollar spot disease incited by Sclerotinia homoeocarpa F.T. Bennett is a promising component of sound integrated disease management programs. Previous research indicates that dollar spot resistance is quantitatively inherited with no evidence of major disease resistance genes; however, the response of creeping bentgrass genotypes to different isolates has not been evaluated. The objectives of this study were to evaluate the response of creeping bentgrass crosses to three different isolates of S. homoeocarpa, evaluate disease progression, determine gene action, and identify number of loci involved in resistance to individual fungal isolates. Four hundred plants of each of three reciprocal controlled crosses were established in a field trial in a randomized complete block design in the fall of 2000 and 2002. Eight backcross and four F_2 populations were also included in the 2002 trial. One hundred progeny of each cross were inoculated with one of three isolates (identified as 'Crenshaw', 'PRG', and 'S9') of S. homoeocarpa, or a mixture of the three isolates and evaluated for dollar spot disease. Mid-parent heterosis and minimum number of loci calculations were determined from the crosses. Generation mean analysis was conducted on six generations for each cross using SAS Quant (Gusmini et al., 2007). This analysis is used to determine gene effects.

This is the first study conducted on dollar spot disease progression of progeny from resistant x susceptible crosses inoculated with different fungal isolates. The degree of dollar spot disease differed depending on the cross and the isolate evaluated. The Crenshaw isolate (isolated from creeping bentgrass) was more virulent on creeping bentgrass in both years when compared to other isolates including one isolated from perennial ryegrass (PRG). Minimum loci calculations differed depending on the cross and the isolate. Most crosses estimated approximately 2 genes and none of the crosses estimated more than six genes. Mid-parent heterosis calculations were not significant indicating an additive type of gene action. Backcross populations were skewed towards the recurrent parent regardless of resistance or susceptibility. Generation mean analysis support additive gene action across different isolates. Although, there was some evidence to support dominant effects for susceptibility to the Crenshaw isolate. There were no completely resistant phenotypes, and no indication of major genes interacting with the individual isolates. These results support previous research that dollar spot disease is quantitatively inherited and indicate that there may be a few genes interacting in an additive fashion to confer dollar spot disease resistance in creeping bentgrass.

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Virus Populations of *Sclerotinia homoeocarpa*, Causal Agent of Dollar Spot Disease on Turfgrass

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The taxonomically unresolved pathogen currently known as *Sclerotinia homoeocarpa* is the causal agent of dollar spot, the most common disease of cool-season turfgrasses in North America. The pathogen's primary mode of replication is clonal, with disease arising through overwintering stroma or systemically infected host tissue; further dissemination is human-mediated. Fertile apothecia, the sexual structure of the fungus that contains asci and ascospores, have not been reported from North American isolates. Interspecific and intraspecific genetic exchange can be mediated by hyphal anastomosis, or fusion.

In previous studies of *S. homoeocarpa,* a 2.6kbp dsRNA was identified from the Sh12b isolate conspecific with *Ophiostoma* mitovirus 3a-OnuLd (OMV3a-OnuLd) that displayed an aberrant colony morphology and hypovirulent (less virulent than wildtype) phenotype. OMV3a-Sh12B was successfully utilized in pilot biocontrol studies of dollar spot on creeping bentgrass in both field and controlled experimental conditions.

Although this may prove to be an important avenue to pursue in the future, biocontrol is not an explicit goal of our research. Our interest for this project is to determine the relationship between different viruses' fungal phenotype and distribution as a means of shedding light on the effect viruses have on the evolution of *S. homoeocarpa*. Virus populations are to be represented by isolatable dsRNAs. The current sample pool consists of over forty cultures of *S. homoeocarpa* isolated from six different grasses grown in five states. dsRNA extracts from four randomly selected isolates produced unique PAGE banding patterns. Confirmed dsRNAs will be reverse-transcribed and cloned by PCR, and viral cDNA libraries will be created and analyzed *in silico*. Isolates that contain dsRNA and display an aberrant phenotype will be stored for future biological studies.

Evaluation of Bioenergy Characteristics in Ten Switchgrass Populations Grown in New Jersey

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Switchgrass (*Panicum virgatum*) is a perennial warm season grass (C4) native to most of the US with the exception of some northwestern states. It is an outcrossing, self-incompatible polyploid species with a high degree of genetic diversity. There are two main distinct types of switchgrass: Upland and Lowland types. Upland types are typically octaploids (Hopkins et al., 1996), have shorter, finer stems, are better adapted to drier habitats (Lewandowski et al., 2003), and are also typically earlier maturing than lowland types (Parrish and Fike, 2005). Lowland types are generally tetraploid (Hopkins et al., 1996), taller, and more robust than upland types. They have courser stems, a more bunch type growth habit and are adapted to wetter sites (Lewandowski et al., 2003). They typically mature later than upland types and require a longer growing period. In general the two types are genetically incompatible (Barnett and Carver, 1967) and have significant differences in chloroplast DNA (Hulquist et al., 1996). The two types have also been found to have different biomass yields in different environments. Upland cultivars are better adapted to mid-northern latitudes and Lowland types are better adapted to lower latitudes (Parrish and Fike, 2005).

Switchgrass has been used in restoration, buffer strips, as a forage crop, and as an ornamental, but is now emerging as source of alternative energy. The Northeast/ Mid-Atlantic region is the most populated and urbanized region of the United States and responsible for a large amount of the fossil fuels consumed in this country. It is unlikely that it will be economically feasible to transport biomass from far distances to utilize as renewable energy in the Mid-Atlantic and Northeast. Therefore it will be important to identify and breed germplasm specifically for this environment if biomass is going to be a significant source of renewable energy for this region. In addition, researchers have identified the importance of breeding for improved biomass production for specific sites (Fike et al., 2006; Lewandowski et al., 2003; Vogel and Jung, 2001) and suggest that no single switchgrass cultivar is likely to have yield advantages across all locations (Casler et al., 2004; Hopkins et al., 1995).

Ten switchgrass populations were planted in a spaced-plant nursery in the spring of 2006 at the Rutgers University Plant Biology Research and Extension Farm at Adelphia, NJ. In 2007, they were evaluated for several characters contributing to biomass including: winter injury, disease, lodging, maturity, tiller density, plant height, and biomass yield. In general, Lowland cultivars matured later than upland ecotypes, while Northeast ecotypes showed better disease resistance than Midwest ecotypes. Lowland populations SL93 (OK) and Timber (NC) had greatest biomass yields, while the Upland populations Contract (NY) and Cave-in-rock (IL) had the lowest biomass yields.

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What Caused the Recent Emergence of Anthracnose Disease on Golf Course Greens in North America?

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Grasses cultivated as turf make up a major component of the North American landscape. Beginning in the 1990s, anthracnose caused by the fungus *Colletotrichum cereale* emerged as one of the most destructive diseases of golf course turf, with its incidence, severity and geographic range greatly expanded. The sudden emergence of this disease on greens is puzzling. Was the spread of turfgrass anthracnose due to the introduction of novel genotypes or did recent environmental/cultural change provide an opportunity for adaptation by endemic genotypes? Here we present an investigation of the origin of North American turfgrass anthracnose epidemics. Genotypic signatures from four nuclear genes were analyzed from an extensive sample of pathogenic turfgrass isolates and non-pathogenic prairie and cereal crop isolates from the US, Canada, Japan, New Zealand, Germany and the Netherlands. Eleven genetic populations were identified: three turfgrass pathogen groups, six prairie/cereal-derived groups and one diverse group comprised of both turf and non-turf isolates. High levels of genetic diversity, ecosystem specificity, turf host specificity and recombining populations provided evidence of endemic populations assuming a pathogenic lifestyle in response to changing environmental conditions on golf courses. Endemism is also consistent with the observation that North American turfgrass populations and genotypes of *C. cereale* are more closely related to one another than to any international or non-turf isolates.

Chicken Tractoring on the Home Turf

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The chicken tractor concept is where a flock of birds are confined inside an easily transportable cage that is moved every day over new pasture. It was pioneered and popularized with the publication of *Chicken Tractor: The Gardeners's Guide to Happy Hens and Healthy Soil* by Andy Lee. The increasing demand for pasture based animal products is spurring innovation by homeowners who are keeping small flocks of chickens on backyard lawns: www.backyardpoultry.com. The main objective of this study was to determine the contribution of a mixed cool season grass and clover turf towards the nutrition of a small flock of layers. Additional objectives were to observe the impacts of the grazing birds and the rotational movement of the chicken tractor on turf quality. In May 2007, chicken feed intake was measured daily on four consecutive days while the birds had access to grazing on the fresh green turf. In the next four days the chickens did not have access to pasture while they were confined inside a coup on plywood flooring with bedding. Daily feed intake was on average 11% less during the period when the chickens were on pasture as compared to when they were confined to the coop and off of the turf. Results suggest that a healthy turf can potentially supply chickens with about eleven percent of their nutrition. That nutrition supplied by the grazing of grass and clover leaf tissue likely included some earthworms and insects which chickens were also observed to consume. Chicken tractoring impacts turf quality from bird droppings and from the natural scratching behavior of the birds. Areas grazed by the chickens became visually greener about two after rotation away from the chicken tractor due to nitrogen supplied by chicken droppings. Based on my experience the chicken tractor should be moved every day or more often over areas of thin turf to prevent chicken scratching from causing bare spots and creating an uneven surface area and shallow holes. Chicken tractoring is another way for urban families to enjoy their backyard lawns while producing fresh eggs for family food security and better nutrition.

Determination of Sand Topdressing Rate and Frequency Effects on Anthracnose Severity of an Annual Bluegrass Putting Green

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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.) putting green turf; often resulting in extensive damage and major disruptions in play. Recent research conducted at Rutgers has identified several management practices (nitrogen fertilization, mowing and plant growth regulation) commonly employed on golf courses that influence turf susceptibility to anthracnose. Sand topdressing is a common management practice which has been suspected to enhance this disease, but prior to the current study its effect on anthracnose was unknown. Routine sand topdressing promotes a favorable growing environment by diluting thatch, resisting compaction, and increasing surface infiltration and soil aeration; however this abrasive practice may also wound the plant and increase disease. The objectives of this trial were to evaluate the effects of the following practices on anthracnose severity:

i. Light-frequent (i.e., 0.3 L m^{-2} every 7-d) sand topdressing and incorporation method.
ii. Combinations of sand topdressing rates and application intervals.
iii. Infrequent topdressing schedule (i.e., 1.2 L m^{-2} every 21 or 42-d).

The study was initiated in 2006 on annual bluegrass turf maintained as a putting green at the Rutgers Horticultural Farm 2 in North Brunswick, NJ. Soil pH, P and K were managed based on soil test recommendations common in the northeastern United States. Mowing was performed seven times wk^{-1} at a bench-setting of 3.2 mm. During summer months, N was applied at 4.9 kg ha^{-1} every 14-d, except from 22 June through 3 September 2007 when N was applied every 28-d at the same rate. The study was arranged as a randomized complete block design with four blocks. Thirteen treatments were included and subsets of those were used to answer each of the three stated objectives. Sand rate (0, 0.3, 0.6 or 1.2 L m^{-2}), application interval (7, 14, 21, 28 or 42-d) and intensity of sand incorporation (light or moderate brushing or water as a means of incorporating sand) were the main factors studied. Anthracnose severity was assessed using a line-intersect grid laid over each plot; the number of intersections observed over symptomatic turf was calculated as a percent of total observations to estimate the area of damage resulting from this disease. Comparisons of treatment effects that addressed objectives 1 and 3 were made by orthogonal contrasts. An analysis of variance for treatments associated with objective 2 (rates and frequencies) used a 3 x 3 factorial structure; main effects and interaction means were separated by Fisher's protected least significant difference at the 0.05 probability level, except where noted in the data tables.

Objective 1—Light frequent topdressing (i.e., 0.3 L m^{-2} every 7-d) did not affect anthracnose development from late-June through mid- to late-July compared to non-topdressed plots in 2006 and 2007. However, light frequent topdressing reduced disease severity compared to non-topdressed turf by 20 to 47% from 7 August through 6 September 2006 and 5 to 25% under lower disease pressure in 2007 from 18 July through 5 October. Brushing plots every 7-d with or without sand had no effect on disease severity and no interaction between topdressing and brushing was observed during either year.

Objective 2—Three topdressing intervals (7, 14 and 28-d) and three sand rates (0, 0.3, and 0.6 L m^{-2}) were evaluated. Topdressing interval had no effect on disease until August of each year when this factor interacted with topdressing rate: 7 August through 6 September 2006 and 23 August, 28 September and 5 October 2007. Topdressing rate influenced disease severity earlier in the season than the interval factor; however this effect was not consistent between 2006 and 2007. Topdressing at 0.3 and 0.6 L m^{-2} initially increased disease severity by 10 and 6%, respectively, on 12 July 2006; whereas the 0.6 L m^{-2} decreased severity by 4 and 11% on 25 July and 13 August 2007, respectively. Moreover, as each season progressed, the topdressing rate factor often interacted with the topdressing interval factor. Topdressing rate under the topdressing interval of 28-d had a very limited effect on disease severity in 2006 and no effect in 2007; only the 0.6 L m^{-2} rate reduced disease severity late in August and early September 2006 compared to no topdressing. Under a topdressing interval of 14-d, disease severity was reduced with 0.6 L m^{-2} compared to no topdressing as early as 7 August 2006 and 23 August 2007; whereas reductions in disease severity with 0.3 L m^{-2} compared to no topdressing were not evident until 6 September 2006 and 28 September 2007. Under a topdressing interval of 7-d, disease severity was reduced at both 0.6 and 0.3 L m^{-2} by 7 August 2006 and 23 August 2007; both rates produced a similar reduction in severity compared to no topdressing.

Therefore, contrary to the initial hypothesis, sand topdressing had a cumulative beneficial effect and frequent applications provided the most rapid and substantial reduction of anthracnose. The rate of 0.3 L m^{-2} needed to be applied every 7-d and the 0.6 L m^{-2} application every 14 d for a consistent and relatively large reduction in disease severity to occur. Neither sand topdressing rate consistently affected disease severity under a topdressing interval of 28-d.

Objective 3—Topdressing practices using a greater sand rate (1.2 L m^{-2}) at extended application intervals (21 and 42-d) were also evaluated. Similar to that observed in other sand topdressing trials, the addition of 1.2 L m^{-2} reduced disease compared to non-topdressed turf by 7 August 2006 and 18 July 2007. Topdressing interval of 21-d schedule reduced anthracnose severity to a greater extent than the topdressing interval of 42-d on 28 August 2006 and on a number of dates in 2007.

Previous research conducted at Rutgers indicated that a small (0.4 mm) increase in mowing height can decrease anthracnose severity; this may partially explain the disease reductions observed with sand topdressing. Topdressing may be subtly increasing the effective height of cut. Sand adds structure to the turf canopy providing a firmer surface that would lessen the settling of the mower or gang rollers into the turf compared to non-topdressed turf or turf with less sand in the canopy. Furthermore, as sand accumulates, the position of plant crowns is deeper within the surface of the putting green. This creates a different microenvironment (i.e., mat layer) that probably has a reduced potential for sealing (loss of aeration) and is less susceptible to daily and hourly temperature and water fluctuations which occur most dramatically at the upper surface of putting green turf. Therefore, the improved physical characteristics at the surface of putting greens with routine topdressing may improve turf vigor minimizing anthracnose severity.

Roughstalk Bluegrass Control in Creeping Bentgrass Fairways with Bispyribac-sodium and Sulfosulfuron

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Bispyribac-sodium and sulfosulfuron are new ALS-inhibiting herbicides registered for use in creeping bentgrass fairways for selective roughstalk bluegrass control but limited comprehensive investigations have been conducted to evaluate efficacy for long-term management. Field experiments were conducted from June 2005 to October 2006 (Study 1), June 2006 to October 2007 (Study 2), and June 2007 to October 2007 (Study 3) on a fairway at New Jersey National Golf Club in Basking Ridge, NJ. Bispyribac-sodium was applied twice at 37, 74, or 111 g a.i./ha or thrice at 37 or 74 g/ha. Sulfosulfuron was applied twice or thrice at 6.5, 13, or 26 g a.i./ha or once at 26 g/ha. Applications were made at 220 L/ha and a non-ionic surfactant was included at 0.25% v/v for sulfosulfuron treatments. Creeping bentgrass chlorosis from herbicides was acceptable (< 20%) by 2 to 3 weeks after applications while all treatments provided substantial reductions in roughstalk bluegrass cover (>90%) by late July. However, roughstalk bluegrass had regrown by October in all three years suggesting herbicide applications visually eliminated foliage but did not control vegetative reproductive structures. Since roughstalk bluegrass has a wide genetic diversity, further investigations are needed to determine if these results are correlated with biotype tolerance to herbicide applications or from ineffective herbicide translocation. Overall, bispyribac-sodium and sulfosulfuron effectively eliminated roughstalk bluegrass ground cover in summer months but regrowth during fall months prevented long-term successful control.

Genetic Improvement of Perennial Crops for a Sustainable Future

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The need to produce enough food for the additional 3 billion people projected to populate the earth in the next 50 years, while eliminating world hunger, stabilizing climates, improving our environment and reducing the use of fossil fuels by increasing the production of biofuels will require not only a continuation of the Green Revolution, but also a very significant expansion. This can be done by dramatically increasing (possibly doubling) biomass production throughout the world using perennial trees, shrubs, grasses, legumes, and forbs adapted to land not suitable for sustainable production of cultivated annual crops. The implementation of this Expanded Green Revolution will require planting billions of genetically improved, highly-productive trees on much of the over two billion hectares of the world's degraded forests. A majority of the 850 million hectares of destroyed or degraded forests of the tropics should be planted to exceptionally productive perennial plants, such as oil palms, hybrid eucalyptus and other food, timber, and bioenergy crops. Hundreds of millions of trees should be added to urban and suburban landscapes, farm woodlots, roadsides, waterways, etc. It is essential to restore and improve the world's very extensive and often degraded rangelands with genetically improved grasses, shrubs, legumes, and other forbs. Additionally, managing forests, rangelands, etc. to where plants are maintained in their rapid growth phase will maximize productivity and CO_2 uptake from the atmosphere. At Rutgers University, exciting progress is being made in the genetic improvement of underutilized perennial crop plants for improved nutrition, ample amounts of bioenergy, environmental enhancement, timber, and soil improvement. Effective plant breeding programs similar to ours with supporting programs in ecology, forestry, agronomy, horticulture, pathology, soil sciences, etc. should be established for various ecosystems throughout the world to identify and improve suitable species, to properly and sustainably implement their use, and ultimately to make a major contribution to a sustainable future.

Tolerance of Kentucky Bluegrass and Tall Fescue to Traffic Stresses in 2007

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Kentucky bluegrass (*Poa pratensis* L.) and tall fescue (*Festuca arundinacea* Schreber) are often established on highly used sports fields and individual cultivars may differ greatly in response to traffic stresses. Evaluation of cultivar performance under traffic stresses during individual seasons (spring, summer, and fall) is needed since sports field use is often season-specific.

Entries comprising the 2005 National Turfgrass Evaluation Program (NTEP) Kentucky bluegrass test were seeded in September 2005 with the objective of determining the seasonal wear tolerance and recovery among Kentucky bluegrass cultivars and experimental selections. Entries comprising the 2006 NTEP Tall fescue test were seeded in September 2006 to assess the seasonal wear and compaction (traffic) tolerance and recovery of tall fescue cultivars and experimental selections. Both trials were established on a sandy loam in North Brunswick, NJ.

The experimental design for both trials was a randomized complete block with three replications. Wear was applied using a modified Sweepster that permitted control of both operating speed (2.5 mph) and paddle rpm (250 rpm). Eighteen (18) wear passes were applied to the Kentucky bluegrass trial over three (3) days in summer 2007 (6 passes on 25 July; 6 passes on 26 July; and 6 passes on 27 July); visual ratings of the fullness of live cover were taken to assess wear tolerance after 6, 12, and 18 passes of the wear simulator and recovery at 10, 19, and 56 days after wear (DAW). Wear was previously applied to this test in October 2006. The tall fescue trial was subjected to 24 passes with the wear simulator applied over three (3) days in fall 2007 (8 passes on 2 October; 8 passes on 3 October 2007; and 8 passes on 4 October). Visual ratings of the fullness of live cover were taken to assess wear tolerance after 8, 16, and 24 passes of the wear simulator. After wear simulation, ten (10) passes of a 1264-kg vibratory pavement roller were applied on 10 October to compact the soil. Visual ratings of the fullness of turfgrass cover were taken on 10 October (5 DAW) and 1 November (22 days after compaction [DAC]).

Kentucky bluegrass entries that had the greatest fullness of turfgrass cover after 18 passes of the wear simulator in July 2007 were ‘Harmonie’, CP 76-9068, CPP 822, CPP 821, ‘Julia’, NA-3257 and ‘Bariris.’ The entries, DLF 76-9075, PSG 366, A95-410 and RAD-504, were among cultivars that had the lowest fullness of cover in both October 2006 and July 2007.

Fullness of cover ratings indicated that more than 2 dozen tall fescue entries maintained good to excellent cover at 0 DAW and fair cover 22 DAC. The commercially available entries in this group included ‘Rebel IV’, ‘Titanium’, ‘Firenza’, ‘Hemi’, ‘Turbo’, ‘Bullseye’, ‘Rembrandt’, ‘Padre’ and ‘Biltmore.’ Results of previous traffic tolerance research reported that Padre was among the top performing tall fescue cultivars the 2001 NTEP tall fescue trial evaluated under simulated wear and compaction during 2002 and 2003 in North Brunswick, NJ. Among the tall fescue entries with the lowest fullness of turf canopy at 22 DAC were

'Hunter' and 'Ky-31' as well as two commercially-available blends that were not part of the 2006 NTEP tall fescue test. These blends were: Pennington's Best ('Forte' [33%], 'Prospect' [33%] and 'Signia' [33%]); and Water Saver ('Labarinth' (RTF) tall fescue [34%], 'Aztec II' [24%], 'Focus' [20%], and 'Rendition' [20%]).

Various Kentucky bluegrass and tall fescue cultivars have demonstrated excellent wear and wear and compaction tolerance (fullness of turf canopy) after simulated traffic stresses were applied in 2007. Wear will be applied to the Kentucky bluegrass test in spring 2008; the tall fescue test will be subjected to wear and compaction in summer 2008. Data generated from these trials will assist turfgrass managers in selecting cool season turfgrasses for highly used sports fields and other recreational areas.

Calcium Silicate and Calcium Carbonate Soil Amendments for White Grub Suppression

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White grub infestation is a widespread problem of golf, sports and lawn turf. In the Northeast, viable turf root systems are needed to maintain cool season turf stands during summer heat and drought stress periods. In order to curb the destruction to root systems by various *Scarabaeidae* species' larval feeding, insecticides and various cultural practices are implemented requiring time, money and labor, increasing the cost to maintain turfgrass stands.

During a recent experiment in Somerset County, New Jersey a Keyport silt loam soil, mixed turf stand, with an initial pH of 5.2, was amended with Calcium Carbonate or Calcium Silicate to adjust the pH to a range of 6.3-6.5 by applying a rate of 150 lbs/1000 ft^2 CCE (calcium carbonate equivalent). Grub populations in the treated plots were reduced by more than 50% when compared with the controls. This experiment will be repeated for a second year and an additional experiment is planned to differentiate between pH and calcium effects on native grub populations.

Kentucky Bluegrass Susceptibility to Powdery Mildew Disease Varies Among Soils and in Response to Silicon Fertilization

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Silicon has been shown to play a role in plant metabolic pathways during stress and aide in suppression of diseases such as powdery mildew. Although silicon is an abundant element in the earth's crust, not all forms found in soils are plant available. The silicon content of native soils varies due to parent material, organic matter content and degree of weathering.

Eighteen soils were collected from the surface 15 cm to represent a diversity of New Jersey soils. Most of the soils were obtained from relatively undisturbed sites throughout north and south New Jersey in December 2006 and January 2007. The soils were tested for pH, available silicon, and nutrient availability and maintained in their natural field moist condition prior to the addition of Calcium Silicate and/or Calcium Carbonate for a target pH of 6.5. The same amount of silicon was applied to each calcium silicate amended soil. Supplemental calcium carbonate was added as needed to all treatments in an attempt to achieve the desired soil pH. Kentucky bluegrass variety "Midnight" was seeded at the rate of 2.0 lbs/1000 ft^2. Plant nutrients were applied as needed to soils to ensure that nutrition, other than Si, was not a limiting factor. Plants were observed and rated for disease incidence during a 6 week period from mid March through the last week of April. The 18 soils by soil series name and texture were as follows: Marlton sandy loam, Lakehurst sand, Lakewood sand, Atsion sand, Aura sandy loam, Downer loamy sand, Freehold sandy loam, Evesboro sand, Gladstone gravelly loam, Washington loam, Duffield silt loam, Nassau silt loam, Califon loam, Turbotville loam, Halsey silt loam, Adrian muck, Quakertown silt loam, and Hazelton sandy loam.

Disease incidence and severity varied, with plants in some soils responding to the silicate amendment while others exhibited no apparent response. Plant uptake of Si, determined from removed leaf tissue, also varied by soil. Results showed differing responses of seed germination rate, shoot density and height, all dependent on soil series. Some soil series, such as, Marlton, Aura, and Washington exhibited a benefit from Si fertilization as a delayed onset of powdery mildew symptoms, while Duffield series benefited from Si fertilization later in the trial. Kentucky bluegrass grown on Lakehurst, Lakewood, Atsion, Freehold, Evesboro, Gladstone, Califon, Halsey, Adrian and Quakertown soils exhibited no benefit from silicon amendment while Marlton and Aura soils exhibited good disease suppression throughout the duration of the study. The most unique disease response was shown with Downer, Nassau, Turbotville, and Hazelton soil series where a negative response to disease pressure was apparent on Kentucky bluegrass plants receiving silicon nutrition. Due to the varied response of Kentucky bluegrass to Powdery Mildew disease pressure on different soils, further research is needed to understand the reasons for such inconsistent responses among soil types and to Si fertilization.

Curvularia, a Ubiquitous Fungus with Potential for Pathogenicity to Zoysiagrasses

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Curvularia species are ubiquitous and are typically considered to be secondary pathogens or saprophytes. A foliar blight of zoysiagrass has been observed in NC since 2002. The disease is most active when temperatures are 21°C to 30°C. Initial symptoms normally appear as small, chocolate brown spots with dieback from the tips. Continued infection can result in blighting of irregular patches up to 15 cm in diameter. Microscopic analysis revealed *Curvularia* conidia consistently associated with the disease. To determine the pathogenicity of these fungi, twenty-one isolates were obtained from 6 locations. Analysis of ITS rDNA sequences indicated 2 isolates most closely related to *C. lunata* while other isolates appeared more closely related to *C. pallescens.* Spore morphology was consistent with *C. lunata* for all isolates. Pots of 'Emerald' and 'El Toro' zoysiagrass were inoculated with one of five *C. lunata* isolates in a greenhouse at 26C. Isolates varied in aggressiveness, inducing symptoms in 1 to 3 weeks. Continued disease progress resulted in blighting similar to that observed in the field. This is the first report of Curvularia blight of zoysiagrass in the United States, it was previously reported in Japan, where it is called 'dog footprint'.

Irrigation Management Affects Anthracnose Disease of Annual Bluegrass Putting Green Turf

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Irrigation management is essential for maintaining plant health and playability on golf course greens. Maintaining greens under the conditions of low water availability may increase firmness and ball roll distance (green speed), but will also require daily hand watering or syringing to prevent severe drought stress. Continued low water availability can weaken plants and potentially predispose turf to anthracnose (*Colletotrichum cereale*). Conversely, over-watering of greens can lead to increased algae and moss development while increasing the potential for mower scalp and lowering traffic tolerance. The objective of this study was to examine the effects of irrigation management on anthracnose severity of annual bluegrass (*Poa annua*) putting green turf. Treatments were designed to simulate four irrigation programs to produce soil water conditions ranging from excessively wet to excessively dry. Irrigation programs were simulated in this study by replacing a portion of potential evapotranspiration (excessive irrigation, 100% evapotranspiration [ET]; sufficient irrigation, 80% ET; deficit irrigation, 60% ET; insufficient irrigation, 40% ET) on a daily basis. Meteorological data acquired each day from an onsite weather station was used to calculate potential ET based on the Pennman-Monteith equation. Since rain could not be excluded from the field site, daily water replacement was adjusted as necessary based on the amount of rain as well as the water holding capacity of the Nixon sandy loam. The appropriate volume of water was applied to individual plots using a hand held hose equipped with a flowmeter and showerhead nozzle. Plots were monitored throughout the day for visual symptoms of wilt stress and received ≤ 2.5 mm of water whenever wilt was observed. Subsequent hand waterings were preformed as wilt stress re-occurred. Anthracnose severity was greatest on plots irrigated at 40% ET replacement and tended to decrease as irrigation amount increased in 2006 and 2007. Turf irrigated at 60% ET had less disease than 40% ET, but more than 80 and 100% ET on 28 July 2006 and throughout 2007; except on 9 June 2007 when turf maintained at 60% ET had similar disease severity as turf receiving 40% ET replacement. Differences in anthracnose development between 80 and 100% ET were observed on only 2 of 11 observation dates during two years of study. Anthracnose severity increased in plots irrigated at 100% ET on 25-August 2006 similar to turf receiving 40% ET irrigation; whereas, the moderate irrigation levels of 60 and 80% ET had the lowest disease severity. While this relationship was not apparent in 2007, plots maintained at 100% ET did have large amounts of algae in both years of the study which lowered turf quality equivalent to plots maintained at 40% ET. These results show that under-watering of annual bluegrass greens can lead to increased anthracnose and reduced turf quality. Irrigation management that supplies adequate but not excessive soil water for plant growth can lead to reduced anthracnose severity and improved turf quality without encouraging algal development.

A Genomics Approach to Understanding Dollar Spot Resistance in Colonial Bentgrass

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Improvement in dollar spot resistance is one of the main objectives in current creeping bentgrass breeding programs. Colonial bentgrass has good resistance to dollar spot and therefore may be a source of novel genes or alleles that could be used for genetic improvement of creeping bentgrass (Belanger et al., 2003, 2004, 2005a,b). We have a population of plants generated by crossing a dollar spot resistant interspecific hybrid with a creeping bentgrass plant in which some of the progeny have excellent dollar spot resistance, which is originating from colonial bentgrass. We are focused on trying to identify the genetic basis of dollar spot resistance in colonial bentgrass using this backcross population. Our approach is to generate a genetic linkage map of colonial bentgrass. To do this we have developed a new approach to mapping genes (Rotter et al., 2007a) using our colonial and creeping EST sequences (Rotter et al., 2007b).

Our current colonial bentgrass genetic linkage map covers 1161 cM and consists of the expected 14 linkage groups, 7 for the A1 genome and 7 for the A2 genome. Of particular significance is that we can now make assignments of each linkage group to either the A1 or A2 genome. The linkage group assignments are based on the wheat chromosome designations since colonial bentgrass and wheat are both members of the Pooideae and both have a base chromosome number of 7. Although there are numerous exceptions, the wheat chromosomes are largely derived from specific rice chromosomal regions (LaRota and Sorrells, 2004). We used the rice-wheat chromosomal relationships to make the linkage group assignments. In general, the rice/wheat relationship is conserved in the colonial bentgrass linkage groups, making linkage group assignments simple. Making these linkage group assignments is of considerable practical utility for any future efforts at fine mapping to narrow genomic regions of interest identified from QTL or other analyses.

The mapping population has been field tested for dollar spot resistance. Overall, about 15% exhibited resistance. This number suggests there may be 3 colonial bentgrass genes needed to confer dollar spot resistance. This is a reasonable number of genes to permit marker assisted breeding in the future. Our current hypothesis is that all 3 proposed genes are required for resistance and that the effect is qualitative rather than quantitative. We therefore compared the genome compositions of the resistant plants looking for colonial bentgrass markers that are found in all the resistant plants. This analysis revealed 2 large regions on linkage groups 2A1 and 3A1 that were consistently found in the resistant plants. These regions may therefore contain the 3 proposed colonial bentgrass genes responsible for dollar spot resistance. It is interesting that these regions are in the A1 genome. The diploid species velvet bentgrass (*A. canina*) is considered to be the origin of the A1 genome in colonial bentgrass (Jones, 1956) and it also has good resistance to dollar spot. We are currently trying to map more genes in these areas in order to narrow down the region of interest.

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Identification of Heat-Responsive Proteins in Two *Agrostis* Species Contrasting in Heat Tolerance Using Two-Dimensional Electropheresis and Mass Spectrometry

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Protein metabolism plays key role in plant adaptation to heat stress. The objective of this study was to identify novel, up-regulated, or down-regulated proteins associated with heat tolerance in two *Agrostis* grass species contrasting in heat tolerance. Thermal *A. scabra* adapted to geothermal soils to temperatures up to 45oC and creeping bentgrass (*A. stolonifera*) adapted to cool climatic regions were examined. Plants were grown in growth chambers with different temperatures (20°C - optimum control, 30°C – moderate heat stress, and 40 °C – severe heat stress). Roots were harvested for proteomic analysis at 2 and 10 days after treatment. The root proteins were separated by two-dimensional polyacrylamide gel electrophoresis, and identified by mass spectrometry. More than 300 protein spots were reproducibly resolved and detected on each gel. Statistical analysis showed that more than 70 proteins were differentially expressed in roots exposed to 30°C and 40 °C compared to those grown at 20^{o}C and between thermal *A. scabra* and *A. stolonifera* under heat stress. The number of proteins altered in their expression by heat stress increased with increasing temperatures or stress severity. MALDI-TOF mass spectrometry revealed that proteins with diverse functions were induced or degraded under heat stress, including those involved in stress defense, carbon and energy metabolism.

Root Protein Expression Associated with Thermotolerance of Geothermal and Turf-Type Agrostis Grass Species

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Extensive research has focused on changes in protein metabolism of leaves in relation to plant thermotolerance. Limited information is available on protein changes associated with root thermotolerance. In this study, we examined the relationship of the expression pattern of heat shock proteins (HSP) in roots and thermotolerance for two Agrostis grass species contrasting in heat tolerance: heat-tolerant Agrostis scabra adapted to the geothermal soils and heat sensitive Agrostis stolonifera used as turfgrass. Roots of both species were exposed to increasing temperature (17, 24, 31, 38 and 45oC) and durations (2, 4, 24 and 48 h), while shoots were maintained at optimal growth temperature (17oC) in growth chambers. Total soluble protein content significantly decreased after 4 h at 45oC in both grass species and continued decreasing with prolonged treatment duration. Western blot analysis detected that constitutive HSP70 was consistently expressed after 2 h at all temperatures while inducible HSP70 started to accumulate after 4 h at temperatures above 24oC. HSP60 was highly induced at elevated temperatures after 4 h of exposure. A. scbara had stronger or earlier expression of HSPs than A. stolonifera, especially at lethal high temperatures (40 and 45oC). HSP17.6 (Class I) was primarily heat-induced, with enhanced expression with increasing temperatures and duration, particularly in heat-tolerant A. scabra. Our results suggested that HSP expression, particularly small molecular weight HSPs, may play important roles in controlling root thermotolerance in cool-season grass species.

A Summary of 10 Years of Turfgrass Germplasm Collection in Central Asia

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For more than ten 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. The first turf grass collection was organized in 1997 by Drs. David Zaurov and James Murphy. In the same year, Dr. Murphy became the first U.S. scientist to present a seminar about turf science in Uzbekistan. In 1998, Dr. C. Reed Funk visited Uzbekistan and presented a seminar about turf grass breeding. In recognition of their achievements in the field of turf science, their role in introducing this field of study to Central Asia and their help in building scientific infrastructure, Drs. Murphy and Funk were recognized by Uzbek academic institutions. In 1998, Dr. Murphy was awarded an Honorary Professorship at Tashkent State Agrarian University and in 1999 Dr. C. Reed Funk was made an Honorary Academician of National Academy of Science of the Republic of Uzbekistan. In 2000, Dr. William A. Meyer and Dr. Funk were made Honorary Academicians of the Agricultural Academy of Science of Kyrgyz Republic.

A successful strategy for the genetic improvement of North American turfgrass species has been by the introduction, evaluation, and incorporation of desirable traits from unique accessions from around the world. Until recently, turfgrass germplasm from Central Asian has been not 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 collected and obtained potentially valuable turfgrass germplasm from Central Asia.

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. From 1997 to date, 3,511 accessions of turfgrass have been collected in Central Asia and evaluated by breeders at Rutgers University (Table 1).

Table1. Turfgrass species collected from Central Asia, 1997-2006.

Country	Species	Number of Accessions
Uzbekistan	*Lolium perenne*	1,247
Uzbekistan	*Poa pratensis*	1,704
Uzbekistan	*Festuca rubra*	37
Uzbekistan	*Deschampsia* cespitosa	6
Uzbekistan	*Deschampsia koelerioides*	2
Uzbekistan	*Agrostis palustris*	4
Kyrgyzstan	*Lolium perenne*	63
Kyrgyzstan	*Poa pratensis*	131
Kyrgyzstan	*Festuca pratensis*	23
Kyrgyzstan	*Festuca rubra*	187
Kyrgyzstan	*Poa angustifolia*	20
Kyrgyzstan	*Festuca sulcata*	87
Total accessions:		3,511

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. For these trials, the U. S. scientists provided seeds of turfgrass cultivars, equipment and technical assistance in setting up the field plots for partners in Uzbekistan. The 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. Visiting researchers toured the Rutgers research facilities and were provided with methods for establishment of a turfgrass collection, nursery, and breeding program. This cooperative exchange has provided Rutgers scientists with access to unique germplasm that is now incorporated into the turf breeding collection and, more importantly, has been a successful international collaboration.

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

Are Endophyte-Produced Reactive Oxygen Species (ROS) Responsible for Improved Fungal Disease Resistance and Environmental Stress Tolerance in Endophyte-Enhanced Turfgrasses?

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Endophytic fungi are an important means to improve performance of many turf species. They are commonly found in cool-season grasses and have been documented to make turfgrasses more resistant to insect feeding, suppress fungus diseases and make grasses more drought and heavy metal tolerant. Research has shown that some endophyte-infected grasses show enhanced resistance to certain fungal diseases of grasses, including red thread and dollar spot diseases (Bonos et al., 2005; Clarke et al., 2006).

When challenged by an exogenous invader, plants and animals frequently present defensive reactions by secretion of reactive oxygen species (ROS). Also, some fungi are endowed with the ability to recognize potential competitors and respond by the generation of peroxides, another ROS moiety (Silar, 2005). ROS secretion is the most basic and least costly defensive mechanism exhibited by aerobic organisms. Recently, ROS has been demonstrated to be produced and secreted by a perennial ryegrass endophyte; and ROS was proposed to be critical in maintaining the mutualistic fungus–plant interaction (Tanaka et al., 2006), although details of the mechanism of how ROS impacted the interaction between endophyte and plant was still not clear. We propose that ROS secretion by endophytes may explain several phenomena exhibited by endophyte-enhanced grasses, including improved disease resistance and environmental stress tolerance in grasses.

In fine fescue grasses, endophytes frequently produce a dense network of mycelium on plant surfaces where endophytes may interact antagonistically with potential pathogens to either prevent disease progression or permit it, depending on the outcome of the endophyte-pathogen interactions. Developing an understanding of the endophyte-enhanced disease resistance phenomenon is the primary target of this particular research project.

Initially we conducted a survey of numerous fine fescue plants to identify E+ and E- clone pairs showing differences with respect to how E+ and E- plants respond to internally-generated ROS using the 'diquat dibromide test'. In this test diquat dibromide forces plant cells to generate ROS resulting in clorosis in the plant tissues. Differences between E+ and E- clones would suggest that the endophyte modifies plant response with respect to ROS tolerance. Typically grasses under stress will show a reduced tolerance in this ROS test (becoming clorotic more rapidly); and improved tolerance to ROS in the diquat dibromide test reflects either production of ROS quenching compounds (e.g., proline) by the plant or symbiotic endophyte (e.g., mannitol, trehalose, or other reducing carbohydrate) or may reflect that plants are under reduced stress.

When endophyte-infected (E+) and endophyte-free (E-) plants of fine fescue (*Festuca rubra*) from greenhouse collections were treated with diquat dibromide to examine their susceptibility to internally-produced, E+ plants of fine fescue clone #33 showed more clorosis due to the production of the internally-produced ROS than E- plants; conversely, fine fescue clone #17 demonstrated the opposite reaction with E+ plants showing more tolerance to internally-produced ROS than E- clones. These two sets of fine fescue clones were selected for further research to determine how the endophytes were modifying tolerance to internally-generated ROS. We propose that differences in the production of ROS (perhaps concentrations) may be responsible for the modification in plant response to internally-generated ROS. If the endophyte from clone #17 is producing and secreting ROS into grass apoplasts, grass cells may be adjusting their tolerance to ROS through secretion of proline (a known ROS-quenching compound previously associated with improved drought and heavy metal tolerance in endophyte-enhanced grasses), essentially resulting in plants that are more resistant to ROS. Conversely, the endophyte of clone #33 may not be secreting ROS, or may be secreting lower concentrations of ROS, which are not stimulating plant cells to adjust tolerance to ROS. The enhanced sensitivity to internally-generated ROS in E+ plants of clone #33 may be due to increased stress on these plants due to presence of the endophyte.

To further evaluate ROS production by these endophytes and test their effectiveness at inhibiting pathogens, we isolated the endophytes from both clones (#17 and #33) and cultured them together with *Sclerotinia homoeocarpa*, the causal agent of 'dollar spot' disease of turfgrasses. After staining with the ROS specific stain nitroblue tetrazolium (NBT), there was a ROS reaction in the form of an orange reaction line between the endophyte from clone #17 and the colonies of *S. Homoeocarpa*. This orange ROS reaction may be attributed to tetrazolium precipitant resulting from the action of dehydrogenases secreted by *S. Homoeocarpa* in response to high levels of ROS secreted by the endophyte. Tetrazolium salt forms a deep orange colored precipitate when dehydrogenated. Moreover, purple zones that formed around the colonies of the endophyte from clone #17 were also an indication of non-reduced ROS. The purple zones became lightened (ROS shadow) in the proximity of the *S. Homoeocarpa* colonies, suggesting that the pathogen was responding defensively to ROS secreted by the endophyte. Pronounced inhibitory zones were also evident between the clone #17 endophyte and the colonies of *S. homoeocarpa*, attesting to the capability of this endophyte to inhibit the pathogen using ROS. In the co-culturing experiments using the endophyte from clone #33, the orange line and ROS shadow near the pathogen was not evident, suggesting that the pathogen did not respond defensively to the endophyte. The endophyte from clone #33 also did not produce zones of inhibition of the pathogen, indicating that it was not effectively inhibiting the pathogen.

Our preliminary results in these two studies are consistent with a model for the mechanism of endophyte-enhanced disease resistance in grasses where endophyte-produced ROS plays a prominent role as a defensive agent; with observations in endophyte-modification of plant response to internally-generated ROS and *in vitro* co-culturing experiments supporting this 'ROS Defensive Model'. If this model is correct, it should be possible to select endophytes with enhanced disease protection capabilities by screening for ROS production *in vitro*; and employing these endophytes to produce more disease tolerant turf cultivars. Further, ROS production by endophytes may play roles in enhancing drought tolerance (through osmotic adjustment involving proline) and heavy metal tolerance (through the ROS quenching effects of proline). ROS production by endophytes would stimulate plant cells to produce and secrete proline into the plant apoplasts where the proline combines with ROS and any reactive heavy metals, resulting in plants that show enhancements in how they respond to these environmental stresses. Direct effects of endophyte-produced ROS on pathogens may enhance disease resistance in pathogens susceptible to inhibition by ROS. It should also be possible to conduct *in vitro* experiments to survey turf pathogens that are sensitive to endophyte-produced ROS to identify turf pathogens where endophytes may successfully be employed to enhance turf grass resistance to specific pathogens.

Additional studies are planned to evaluate this ROS Defensive Model as the mechanism of disease protection in endophyte-enhanced grasses. We intend to further examine the expression of ROS related genes of endophytes cultured with and without *S. Homoeocarpa* to evaluate whether the endophytes may be responding to the presence of pathogens by enhancing production of ROS. We intend to identify the specific ROS moieties secreted by grass endophytes. Further, using high-ROS and low-ROS endophytes we plan to evaluate the potential for producing turf grass cultivars that show superior environmental stress tolerance characteristics due to the effects of proline.

We have previously believed that endophyte-produced alkaloids (Alkaloid Defensive Model) were primarily responsible for improved disease resistance in endophyte-enhanced turf grasses. The 'ROS Defensive Model' offers an alternate and plausible explanation for improved disease resistance as well as a possible explanation for improved environmental stress tolerance. Future investigations will be targeted at evaluation of both models.

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