RUTGERS

New Jersey Agricultural Experiment Station

Proceedings of the Twenty-Fourth Annual Rutgers Turfgrass Symposium

January 16, 2015

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William A. Meyer, Associate Director

The Center for Turfgrass Science

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Thomas Molnar, Chair
Faith Belanger
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Barbara Fitzgerald
Barbara Zilinskas

Proceedings of the Twenty-Fourth Annual Rutgers Turfgrass Symposium

Barbara Zilinskas and Barbara Fitzgerald, Editors

Director's Opening Remarks:

Welcome to the Twenty-fourth Annual Rutgers Turfgrass Symposium at the School of Environmental and Biological Sciences/NJAES. The Symposium was established in 1991 to provide Rutgers faculty, students, and staff with an annual forum for the exchange of ideas on a wide range of topics in turfgrass science. Over the years, this format has expanded to include presentations by colleagues at other institutions. I would like to thank Mr. Dana Lonn (The Toro Company) for presenting this year's keynote address entitled, "*Emerging Technology in Turfgrass Maintenance*," as well as Dr. John Inguagiato (University of Connecticut), Dr. Yiwei Jiang (Purdue University) and all the Turf Center faculty and students who have agreed to present their research at this year's symposium. I would also like to thank Drs. Bingru Huang, Donald Kobayashi, Thomas Molnar, and Ning Zhang for serving as session moderators, and the Symposium Planning Committee comprised of Drs. Thomas Molnar (Chair), Faith Belanger, Bruce Clarke, and Dr. Barbara Zilinskas and Ms. Barbara Fitzgerald (co-editors of the Symposium Proceedings) for their hard work in the preparation of this year's program. Without their hard work, this year's Symposium would not have been possible.

The faculty and students in the Turfgrass Center continue to be recognized for excellence in research, teaching and outreach. In 2014, Dr. Jim Murphy was named a fellow of the Crop Science Society of America (CSSA), Dr. Bill Meyer received the prestigious Impact Award from the National Association of Plant Breeders, and Dr. Bruce Clarke was the recipient of the Col. John Morley Distinguished Service Award from the Golf Course Superintendents Association of America (GCSAA). Our graduate students also received several major awards for their research accomplishments. Lisa Beirn received the Watson Fellowship from the GCSAA as well as a Best Oral Paper Award at the CSSA annual meeting in Long Beach, CA in 2014. Chas Schmid received 1st place honors in the Graduate Student Oral Paper Competition last fall at the annual meeting of the Northeast Division of the American Phytopathological Society held in Portsmouth, NH, and David Jespersen and Chas Schmid just received notice that they will be co-recipients of the Watson Fellowship in 2015.

Over the past 24 years, Turf Center faculty have continued to conduct outstanding research, undergraduate and graduate teaching, and continuing professional education and service programs in support of the Turfgrass Industry. In return, the Turfgrass Industry have donated their time and over $4.6 million in the form of research grants, student scholarships (> $80,000/yr.), fellowships (the Henry Indyk Endowed Graduate Fellowship), buildings (the Ralph Geiger Education Complex and the C. Reed Funk Equipment Facility at Hort Farm II), equipment, and gifts to the Rutgers Turfgrass Program. We are indeed fortunate to have such a close partnership with our Turfgrass Industry colleagues in the state, region, and nation.

It is with deep pride and a sense of anticipation for the bright future of the Turf Center and its stakeholders that I welcome you to this year's Turf Research Symposium. I hope that you will find it an enjoyable and a worthwhile experience.

Sincerely,

Bruce B. Clarke

Bruce B. Clarke, Director
Rutgers Center for Turfgrass Science

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TWENTY-FOURTH ANNUAL RUTGERS TURFGRASS SYMPOSIUM

School of Environmental and Biological Sciences, Rutgers University

January 16, 2015

Foran Hall, Room 138A

Friday, January 16, 2015

8:30 - 8:50 AM **Registration, Coffee and Donuts**

8:50 – 9:00 AM **Welcome**
Dr. Bruce Clarke, Director – Center for Turfgrass Science and
Dr. Bradley Hillman, Director for Cooperative Research, NJAES

9:00 - 10:00 AM **SESSION I: BREEDING**
(Moderator: Dr. Thomas Molnar)

9:00 – 9:20 **Dr. Lindsey Hoffman** (Department of Plant Biology and Pathology, Rutgers University) *Breeding Switchgrass for Improved Resistance to Anthracnose Disease*

9:20 – 9:40 **Dr. William Meyer** (Department of Plant Biology and Pathology, Rutgers University) *Overcoming the Challenges of Breeding Cool-Season Turfgrasses for Low-Input Turf*

9:40 – 10:00 **Megan Muehlbauer** (Department of Plant Biology and Pathology, Rutgers University) *Genetic Characterization of New Eastern Filbert Blight-Resistant Germplasm from Turkey, Latvia, and Lithuania*

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

10:30 – 12:00 PM **SESSION II: STRESS TOLERANCE/PHYSIOLOGY**
(Moderator: Dr. Bingru Huang)

10:30 – 10:50 **Dr. Yiwei Jiang** (Department of Agronomy, Purdue University) *Association Mapping of Abiotic Stress Tolerance in Turfgrass: Opportunities and Challenges*

10:50 – 11:10 **David Jespersen** (Department of Plant Biology and Pathology, Rutgers University) *Development and Confirmation of Candidate Gene Markers for the Selection of Heat Tolerant Bentgrass*

11:10 – 11:20 AM **Discussion session**

11:20 – 12:00 **Keynote: Dana Lonn, P.E.** (Managing Director CATT, The Toro Company) *Emerging Technology in Turfgrass Maintenance*

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

1:00 – 2:00 PM **SESSION III: ENDOPHYTES**
(Moderator: Dr. Ning Zhang)

1:00 – 1:20 **Dr. Faith Belanger** (Department of Plant Biology and Pathology, Rutgers University) *Epichloë festucae-Festuca rubra Interactions*

1:20 – 1:40 **Dr. James White (**Department of Plant Biology and Pathology, Rutgers University) *The Application of Growth-Promoting Endophytes in Turfgrasses*

1:40 – 2:00 **Dr. Thomas Gianfagna** (Department of Plant Biology and Pathology, Rutgers University) *Creating Safer Pasture Grass Through Chemical and Biological Analysis and Selection of New Tall Fescue (Festuca arundinacea Schreb.) Germplasm*

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

2:30 – 3:30 PM **SESSION IV: PATHOLOGY / PEST MANAGEMENT**
(Moderator: Dr. Donald Kobayashi)

2:30 – 2:50 **Lisa Beirn** (Department of Plant Biology and Pathology, Rutgers University) *Metagenomic Insights into the Microbial Community Structure of Poa annua Turf*

2:50 – 3:10 **Dr. John Inguagiato** (Department of Plant Science and Landscape Architecture, University of Connecticut) *Enhancing Cultural Control of Anthracnose and Summer Patch… and the Ultimate Solution*

3:10 – 3:30 **Dr. Albrecht Koppenhöfer** (Department of Entomology, Rutgers University) *Towards Sustainable Management of the Annual Bluegrass Weevil*

3:30 - 3:45 PM **Discussion and Closing Remarks**

3:45 PM **Social and Poster Session**

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PLENARY PRESENTATIONS

Breeding Switchgrass for Improved Resistance to Anthracnose Disease

Lindsey Hoffman[1], Laura Cortese[1], Eric Weibel[1], Lisa Beirn[1], JoAnne Crouch[2], and Stacy Bonos[1]

[1]*Department of Plant Biology and Pathology, Rutgers University*
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Switchgrass (*Panicum virgatum* L.) is a perennial, warm-season, bunchgrass that is native to most of North America and is adapted to growing in a wide variety of environmental and climatic conditions. Switchgrass has the potential to persist in diverse habitats due to the existence of both upland and lowland ecotypes that differ at the genotype and phenotype level. Switchgrass plants have been shown to grow well in marginal soils along with providing several ecosystem services including soil stabilization and erosion control, bioremediation of contaminated soils, and promotion of wildlife habitats for certain bird and animal species. Altogether, these characteristics make switchgrass a viable alternative to corn (*Zea mays* L.) as a bioenergy feedstock for cellulosic ethanol production.

Over the past decade, targeted breeding has resulted in the development and release of several improved switchgrass cultivars that exhibit increased vigor and yield compared to older cultivars. Research has also classified a number of biotic and abiotic factors that may negatively impact the cultivation of switchgrass in the United States. Specifically, anthracnose (caused by *Colletotrichum navitas*) has been identified as a disease that may cause significant reductions in biomass yield on a yearly basis. Limited information exists, however, on the direct impact of anthracnose to switchgrass production and on methods for mitigating yield losses. Therefore, research is necessary to quantify the damage associated with anthracnose and to identify cultivars that are more resistant to infection.

Preliminary research conducted in 2008 and 2009 at the Rutgers University Plant Biology Research and Extension Farm in Adelphia, New Jersey indicated that significant variation in susceptibility to anthracnose infection exists among switchgrass cultivars. This study led to subsequent field evaluations at three locations in New Jersey consisting of one site with prime agricultural soil and two with marginal soils. A total of 14 commercially available cultivars were visually assessed for anthracnose severity (from natural inoculum) in 2010. This analysis found that certain cultivars were more susceptible to anthracnose than others and severity varied by location suggesting a significant genotype x environment interaction. Additional research has been initiated to quantify the impact of anthracnose on biomass yield and preliminary data suggest that anthracnose may reduce biomass yield up to 15% in certain cultivars when not treated with fungicides.

Along with field research, laboratory studies have also been initiated in order to understand the biology of the fungus and expedite the process of breeding anthracnose resistant switchgrass cultivars. As a relatively new classified species, little is known about the diversity of *C. navitas* in switchgrass and the genetic similarity to other *Colletotrichum* species. Consequently, research has been initiated to identify and amplify SSR primers from genome sequences in the *Colletotrichum navitas* genome in order to capture the best image of *Colletotrichum* diversity. A total of 96 samples, consisting of six *Colletotrichum* species, were screened with 50 primer sets to find reliable SSR markers. In total, 20 markers were identified for future genotype characterization. A high degree of variability was also detected among the *Colletotrichum* isolates evaluated and multiple isolates were found on a single switchgrass plant. All together, this suggests that breeding for anthracnose resistance may be somewhat difficult.

Overall, the research that has been conducted over the past few years has provided greater insight into the underlying factors of anthracnose infection of switchgrass. As research continues to progress, the main focus will be on developing and releasing new cultivars of switchgrass with enhanced anthracnose resistance.

Overcoming the Challenges of Breeding Cool-Season Turfgrasses for Low-Input Turf

William A. Meyer, Stacy A. Bonos, Eric N. Weibel, Austin Grimshaw, Henry Que, Ron Bara, Melissa Mohr, Dirk Smith, and Trent M. Tate

Department of Plant Biology and Pathology, Rutgers University

Increased environmental concerns and greater restrictions on water and fertilizer have resulted in an increasing demand for turfgrasses that are well adapted to low-input situations. Breeding cool-season turfgrass that require little to no inputs creates a new set of challenges. These challenges include increasing the biotic and abiotic stress tolerances of the grasses. The breeding program here at Rutgers is evaluating tall fescue, fine fescues, and Kentucky bluegrass for low input environments. Each of these species has strengths and weaknesses that can be improved through our breeding efforts. Tall fescue has a very extensive root system that improves the drought tolerance; however with reduced fertility, diseases such as red thread and dollar spot can become problematic. For the fine fescues, there are many attributes that make it well suited for low-maintenance such as a reduced fertility requirement and various tolerances to low fertility such as dollar spot and red thread through the presence of endophytic fungi. These endophytic fungi also give resistance to above ground feeding insects, thus reducing the needs for chemical control methods. One of the major challenges to overcome with Kentucky bluegrass is increased resistance to crown and stem rusts. To be usable in these low-input situations, these various turfgrasses must endure these abiotic and biotic stresses while maintaining acceptable density and cover. Another trait that is important to all the species is wear tolerance under low maintenance. These new challenges that come with breeding turfgrasses for low-input situations must be overcome by utilizing new breeding strategies and selection so we can develop new elite cultivars.

The breeding program has been evaluating these cool-season turfgrass species under low maintenance conditions since 2008. These trials are maintained at 2.5 inches with a rotary mower mowed no more than once per week and receive no supplemental irrigation and less than 2 lbs N/ 1000 sq ft. per year. Another trial was initiated in 2010. In the 2010 trials, Kentucky bluegrass was separated from the other species due to the higher N requirement of this species. The hard fescues exhibited the best quality under low maintenance even when wear was imposed on the plots. This is the opposite of what you find under high maintenance conditions. For the Kentucky bluegrasses, the hybrids with the cultivar Washington and to a lesser extent the Mid-Atlantic ecotypes tend to have better quality and vigor under low maintenance. Currently, we have new Kentucky bluegrass low maintenance trial with over 1,000 entries. Nearly half of our tall fescue (4,000 + plots) and fine fescue trials (2,000 + plots) are being maintained at low maintenance. The goal of these efforts is to identify cultivars and germplasm that perform well under these conditions and intercross the best performing lines in order to develop new cultivars with excellent low maintenance performance. This research should help conserve our natural resources and improve our environment by reducing pollution, in addition to providing recreational benefits.

Genetic Characterization of New Eastern Filbert Blight-Resistant Germplasm from Turkey, Latvia, and Lithuania

Megan Muehlbauer, John Capik, Kaitlin Morey, Josh Honig, and Thomas J. Molnar

Department of Plant Biology and Pathology, Rutgers University

Eastern filbert blight (EFB), caused by the fungus *Anisogramma anomala*, has been a major impediment to establishing a commercial hazelnut (*Corylus avellana*) industry in the eastern United States. The fungus causes large cankers that girdle stems and ultimately kill susceptible hazelnut trees. The most cost-effective and sustainable way to manage this disease is to utilize host genetic resistance. In 2004 and 2005, seed-based germplasm collections were made in Turkey and Latvia and Lithuania, respectively. The goal was to screen large populations to identify novel EFB-resistant plants. Seeds were germinated, and nearly 1,000 total trees were planted in the field in 2005 and 2006 and exposed to high disease pressure. Trees were evaluated for response to disease in 2013, and nearly all (>95%) were found to be highly susceptible to EFB. However, 46 were found to be resistant or tolerant. These trees represent some of the first EFB-resistant/tolerant plants identified from Turkey, Latvia, and Lithuania. To better understand their origins and genetic relationships, 26 simple sequence repeat (SSR) markers were used to obtain molecular fingerprints. Also included in the study were 37 reference cultivars to which the new plants could be compared. SSR population data were visualized as clusters in a phylogenetic tree and the resulting populations confirmed using the Bayesian analysis software STRUCTURE as well as by an analysis of molecular variance. The results showed clear groupings of the new Turkish and Latvian/Lithuanian seedlings with plants of similar seed lots and similar origins (i.e., the Turkish seedlings group closest to known Turkish cultivars). Based on relationships to the reference cultivars, from which no EFB-resistant plants in their respective genetic groups were previously known, the SSR data support the hypothesis that we identified new resistant plants of diverse genetic origins. These new plants will be very useful in maintaining genetic diversity in breeding lines as we develop advanced-generation, EFB-resistant plants.

Association Mapping of Abiotic Stress Tolerance in Turfgrass: Opportunities and Challenges

Yiwei Jiang

Department of Agronomy, Purdue University

The frequency and intensity of abiotic stress is expected to increase as a result of climate changes that will impact turfgrass growth and persistence. The complexity of the inheritance of abiotic stress tolerance varies between stresses and turfgrass species, posing challenges in studying the traits underlying stress tolerance. Association mapping (AM), also known as linkage disequilibrium (LD) mapping, has been developed as a powerful and alternative approach for dissecting complex traits. It measures the non-random association of alleles with specific traits and maps quantitative trait loci based on historical recombination events in diverse germplasm collections. Compared to biparental linkage mapping, AM provides higher resolution. However, population structure and relatedness among individuals in an association panel often confound the association results. In addition, careful evaluation of stress tolerance traits and generation of reliable phenotypic data are important for a successful AM study. Association mapping of abiotic stress tolerance has not been extensively studied in turfgrass species. To date, through candidate genes association mapping, single nucleotide polymorphisms from *LpLEA3* encoding late embryogenesis abundant group 3 protein associated with drought tolerance traits and from C-repeat binding factor (*CBFIII*) associated with cold hardiness have been identified in natural populations of perennial ryegrass. The rapid development of modern sequencing technology allows large numbers of markers to be quickly discovered in turfgrass species, although data computing can pose an obstacle in working on polyploid turf species without genome reference. The opportunities available and challenges faced using association mapping for turfgrass improvement for enhancing abiotic stress tolerance will be discussed.

Development and Confirmation of Candidate Gene Markers for the Selection of Heat Tolerant Bentgrass

David Jespersen, Faith Belanger, Josh Honig, William Meyer,
Stacy Bonos, and Bingru Huang

Department of Plant Biology and Pathology, Rutgers University

Heat is a major abiotic stress which causes premature leaf senescence and decline in visual quality for cool season turfgrass species. Creeping bentgrass (*Agrostis stolonifera*) is a high-value cool season grass species prone to damage upon prolonged periods of elevated temperatures during summer months. Given the wide usage of creeping bentgrass in fine-turfgrass settings, there is a need to develop new cultivars with improved heat tolerance. As with other abiotic stresses, tolerance to heat stress is a complex multigenic trait, and breeding for improved heat tolerance is challenging. The development of candidate gene markers associated with heat tolerance genes could improve selection for heat tolerant lines and provide a better understanding of stress tolerance mechanisms. Previous work which utilized two-dimensional proteomics and subtractive suppression hybridization identified a number of potentially important mechanisms and genes associated with heat tolerance. These mechanisms and genes were associated with metabolic pathways including photosynthesis, respiration, anti-oxidant activity, as well as protein folding and chaperoning.

Candidate gene markers were initially developed using various techniques including allele specific amplification, cleavage amplified polymorphisms, and single strand specific endonucleases. The markers were tested in two bentgrass mapping populations, a colonial bentgrass (*Agrostis capilaris*) x creeping bentgrass hybrid population, and a creeping bentgrass mapping population previously developed for dollar spot resistance. Exploitable polymorphisms were found in eight gene-specific markers in the hybrid mapping population (catalase, cysteine protease, expansin, glyceraldehyde-3-phosphate dehydrogenase, glutathione-s-transferase, heat shock proteins 26, 70, and 101) and in five gene-specific markers in the creeping bentgrass population (chlorophyll A/B binding protein, phenylalanine ammonia-lyase, and heat shock proteins 26, 70 and 90). Both mapping populations were concurrently screened for heat tolerance by exposing plants to prolonged heat stress and evaluating physiological responses. Physiological criteria included visual rating of plant health based on leaf color and canopy density, leaf chlorophyll content, and cellular membrane stability. Individuals from both populations displayed a range of heat susceptibility or tolerance. Physiological results were used in quantitative trait loci (QTL) analysis to associate specific genomic regions with physiological traits of interest. A population of bentgrasses with greater genetic diversity is currently being screened under field conditions at two locations as part of a collaborative project between Rutgers University and the University of Georgia. Candidate gene markers as well as additional SSR markers identified through QTL analysis are being screened to further confirm the utility of these markers in selecting for heat tolerance. Markers successfully confirmed to be associated with heat tolerance in this new population have the potential to be used for marker assisted selection in the creation of improved cultivars with enhanced heat tolerance.

Emerging Technology in Turfgrass Maintenance

Dana R. Lonn, PE, Managing Director, Center for Advanced Turf Technology

The Toro Company

Over many years of talking with customers, we have identified three major priorities. These priorities have stayed very consistent over the years even though the business has changed a lot during the last ten years. Challenges include water management or water use efficiency, labor efficiency and environmental issues including chemical/pesticides, carbon neutrality, and fuel efficiency. Water is the most critical one world-wide. Economic sustainability has come into the discussion in the golf industry with the recession of the late 2000's.

On a world-wide basis, water use efficiency is the most critical. Turfgrass is considered a luxury user of water, and for many years we as an industry have not be an efficient user of water. Water has been applied when it is not required. Turfgrass will have to use less water and will have to use it more efficiently. In order to make the progress that we will require, it will take the application of technology. Improving efficiency is achieved by changing control systems from being open loop control systems to closed loop control systems. We need to take the human out of the irrigation control decisions. This means that we must have sensors and control systems that interact with the weather to assure that irrigation is only applied when it is needed. We need to anticipate the weather so that the soil is as dry as possible when rainfall occurs.

Improved plant materials are also an important part of the equation. Plant materials must have the appropriate wear and aesthetic characteristics that have lower water demands and increased drought tolerance. The time constant for the adoption of new plant materials is fairly long as grass is a perennial crop and it is very expensive to replace.

Labor continues to be the largest cost in turf management. There is consensus that robots will be able to drive vehicles autonomously. DARPA sponsored two challenges that were successfully met. The "Grand Challenge: and "Urban Challenge" were multimillion dollar prizes that were successfully earned which demonstrated the ability for vehicles to successfully navigate and coexist in urban environments. Google has invested millions of dollars to develop driverless cars. Robot mowers that navigate like Roomba vacuums have been moderately successful in Europe. Some are being used to mow soccer pitches. How will this technology be applied more broadly into the turf grass industry?

Remote sensing is a hot topic today. The FAA is under significant pressure to establish some rules that allow the commercial use of drone aircraft. They are being used as a means to collect information about turfgrass. What is the place for this technology as a means to gather data to manage in a more efficient manner? It is all about developing sensors that give us information to make better more effective management decisions. Use of chemicals and pesticides are under increasing pressure especially in Europe. Can remote sensing help us move from preventative to curative treatments?

Today, the cost of fuel has gone down. We believe that is a temporary anomaly. We have been working on ways to improve fuel consumption and reduce the carbon impact of turf maintenance. Lead acid batteries energy 100 times less dense as gasoline/diesel fuel. Yet there are applications for batteries. Hybrids are another option to improve the fuel efficiency.

The bottom line is that there have been many changes in this business, and there are opportunities for significant changes in the relatively near future.

Epichloë festucae-Festuca rubra Interactions

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Strong creeping red fescue (*Festuca rubra* subsp. *rubra*) is an important low maintenance turfgrass species. Strong creeping red fescue plants are often naturally infected with the fungal endophyte *Epichloë festucae*. Endophyte infection is preferred in strong creeping red fescue cultivar development because of the well-documented insect and disease resistance conferred on the host grass. The basis of the insect resistance is known to be due to the synthesis of toxic alkaloids by the endophyte. Endophyte-mediated disease resistance is not a general feature of other grass/endophyte interactions and the basis of the disease resistance is not yet known. We recently reported the presence of an abundantly expressed secreted antifungal protein in endophyte-infected strong creeping red fescue. Whole genome sequences are available several other *Epichloë* species. Most of these other endophyte species do not have genes for the antifungal protein found in *Epichloë festucae* infecting strong creeping red fescue. The uniqueness of this gene suggests it may therefore be a component of the unique disease resistance seen in endophyte-infected red fescue. We are currently characterizing the *Epichloë festucae* antifungal protein.

The Application of Growth-Promoting Endophytes in Turfgrasses

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Turfgrasses host endophytes or epiphytes (fungi and bacteria) that promote growth and improve performance of turf. The beneficial effects of fungal *Epichloë* endophytes in enhancing plant growth and resistance to biotic and abiotic stresses are now well known and relatively well understood. On the other hand, the widespread presence and effects of bacterial endophytes in turfgrasses are less well known and poorly understood. Over the past few years, we began to survey and find applications for bacterial endophytes in turfgrasses. To date, we have examined seed-vectored bacterial endophytes in annual bluegrass, Kentucky bluegrass, perennial bluegrass, red fescue, sheep's fescue and tall fescue. The most frequently isolated seed-vectored bacterial endophytes from these grasses are *Pantoea agglomerans* and species of *Bacillus* (*B. amyloliquefaciens* and *B. pumilus*), although other bacteria are sometimes isolated from seedlings. Based on our experiments, evidence to date suggests that effects of bacterial endophytes on grasses include 1) enhancement in seed germination rates; 2) improvement in the ability of grasses to grow under high saline conditions; 3) increased fungal disease resistance; and 4) improved organic nitrogen scavenging in soils.

It is not fully understood how bacterial endophytes function to enhance seed germination rates. However, because roots are the first structures to emerge from seeds, it is possible that colonization of the emergent seedling root tips by bacteria may result in a signal that increases embryo expansion rates. We have evidence based on another study in corn (Gond et al., 2015) that salt stress tolerance may be the result of the up-regulation of aquaporin genes that are involved in water transport in plants.

We are currently conducting experiments to evaluate this aquaporin up-regulation mechanism in turfgrasses. Enhanced fungal disease resistance is an effect that may relate directly to the action of antifungal lipopeptides by *Bacillus* endophytes colonizing grass hosts. *Bacillus* endophytes colonize seedlings internally and externally upon germination of seeds and produce lipopeptides that are secreted onto seedling tissues (Gond et al., 2015). Lipopeptides inhibit the growth of potentially pathogenic fungi on seedlings or in soils near seedlings.

Our recent experiments using turfgrass seedlings suggest that seed-vectored bacterial endophytes enhance the ability of grasses to obtain organic nitrogen in soils through a process we refer to as 'oxidative nitrogen scavenging' (ONS) (White et al., 2015). In ONS, daylight stimulates grass roots to produce and release hydrogen peroxide that oxidatively denatures microbial exoenzymes in the rhizosphere; at night, when roots no longer secrete hydrogen peroxide, roots and root-associated rhizobacteria secrete proteases that act on the denatured proteins, degrading them and releasing peptides that are absorbed by the roots. We are currently testing individual bacterial endophytes that may be used to increase the ability of turfgrasses to obtain organic nitrogen in soils.

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Creating Safer Pasture Grass Through Chemical and Biological Analysis and Selection of New Tall Fescue (*Festuca arundinacea* Schreb.) Germplasm

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Grazing horses on tall fescue is desirable because this forage grass is high yielding and has high levels of digestible carbohydrate, protein, and minerals. Many of the most productive varieties of tall fescue contain fungal endophytes (*Neotyphodium coenophialum*) that produce alkaloids, which provide insect resistance, but may also be toxic to grazing animals. Unfortunately, mares grazed on tall fescue with high levels of the alkaloid ergovaline (>200 ppb) can suffer from many problems including delayed pregnancy, early embryo death and abortion. Foals exposed to high levels of ergovaline can suffer from abnormal development, weakness, and starvation due to poor milk production by the mother (dam's agalactia). Endophyte-free (E–) tall fescue is not a solution because these varieties do not have the stand persistence of endophyte-containing (E+) tall fescue, and typically a pasture planted in E– tall fescue will be overgrown by more resilient varieties of E+ tall fescue. Nevertheless, not all of the alkaloids in E+ tall fescue are toxic to grazing animals. Peramine and loline are safe and provide insect resistance.

The object of this research is to screen the sizable collection of RU forage tall fescue selections to discover E+ tall fescue that produce significant quantities of peramine and loline, but lack or have reduced quantities of the alkaloids toxic to grazing animals. Our initial screen of 285 forage tall fescue plants that are suitable for the Continental climate of NJ for *Neotyphodium* spp. endophyte used the Agrinostics immunoblot kits for seeds and tillers. Of these, 191 plants (67%) were found to be E+. E+ plants were then subjected to a competitive ELISA assay (Agrinostics) to estimate levels of ergot alkaloids present in the E+ plants. Sixty-six plants were identified as E+, but they contained low amounts of ergot alkaloids. The low alkaloid status was confirmed and quantified by high-performance liquid chromatography (HPLC) using spectrofluorimetric detection, a highly sensitive and selective technique for ergot alkaloid determination. The levels of ergot alkaloids in these 66 plants ranged from 52 to 200 ppb, i.e., safe levels for horses. Peramine content was quantified in the low ergot plants by HPLC with UV detection. No peramine was detected in seven of the selections; peramine in the remaining plants ranged from 3-123 ppm. Loline alkaloids were determined by gas chromatography-mass spectrometry (GC-MS). We have now selected 17 candidates for seed multiplication and grazing studies that contain peramine and loline, while containing low levels of ergot alkaloids. Our goal is to create E+ forage tall fescue suitable for a Continental climate that is safe for horses and other grazing animals.

Metagenomic Insights into the Microbial Community Structure of *Poa annua* Turf

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Golf course putting greens are unique environments. They require routine management and ongoing applications of chemical products to maintain the conditions suitable for the game of golf. As a result, golf courses are often scrutinized for their environmental sustainability and are increasingly subjected to legislation limiting applications of fertilizers and other products needed to maintain healthy and aesthetically pleasing turf. Research has shown that these practices have little impact on the surrounding environment when chemicals are applied as recommended. However, questions remain about the effects of commonly used chemicals on the resident rhizosphere microbial community, and in turn, how changes to these microbial communities may impact turfgrass health. Culture-based assays have shown that microbial communities are capable of adapting to soil nutrient content, with species composition varying based on changing soil environments. These data suggest that alterations in the nutrient composition of putting green turf are also likely to alter microbial community structure and/or the distribution of rhizosphere microorganisms. However, isolating microorganisms on selective media only captures a subset of the microbiota present, and thus this method may not accurately reflect the larger microbial community. In the current study, our objective was to determine the impacts of a high-input N and K fertility regime on the composition, diversity, and distribution of archaea, bacteria, and fungi in the rhizosphere of *Poa annua* (annual bluegrass) putting green turf.

Two separate field trials consisting of *Poa annua* maintained as putting green turf were sampled for this study. The first trial consisted of plots receiving different potassium treatments (Field 1K study), and the second trial consisted of plots receiving two different treatments of nitrogen (Field 2N study). In the Field 1K study, treatments included either (1) N alone (132 kg N ha^{-1} yr^{-1}); (2) K alone (200 kg K_2O ha^{-1} yr^{-1}); or (3) a combined treatment of N and K (1:1, N:K molar-adjusted ratio; 132 kg N ha^{-1} yr^{-1} and 200 kg K_2O ha^{-1} yr^{-1}). For the Field 2N study, treatments included either (1) a low rate of N (100 kg N ha^{-1} yr^{-1}), or (2) a high rate of N (200 kg N ha^{-1} yr^{-1}). Nitrogen was applied as urea, and K was applied as KCl. Soil was sampled by taking three 15.9 mm diameter x 50.8 mm long soil cores from four replicated plots of each of the three treatments in the Field 1K study and two treatments in the Field 2N study, for a total of 60 samples.

DNA was extracted using the PowerSoil DNA Isolation Kit. Organism-specific DNA regions were PCR amplified from ribosomal DNA of fungi (internal transcribed spacer [ITS] region 1 and 2), bacteria, and archaea (rDNA 16s), with the addition of an overhang sequence to the locus-specific primers which served as primer sites in subsequent steps. Following purification, amplicons were pooled and next generation sequencing libraries were prepared for each of the 60 samples using the Nextera Index Kit. Libraries were normalized and pooled into a single sample, and then diluted and denatured for sequencing on Illumina's MiSeq platform using a 600 cycle MiSeq v3 Reagent Kit. Sequencing reads were subsequently processed using the QIIME pipeline. Statistical analyses were performed using the Vegan package in R and the Calypso web server.

Multiplexed next-generation Illumina sequencing generated 2.3×10^7 paired-end reads (on average 1.38×10^5 sequences/sample, 253 bp length). The QIIME pipeline picked 8.3×10^5 operational taxonomic units from the 60 samples, 4.1% of which were identified as archaea, 62.1% bacteria, and 30.1% fungi. In all samples, bacteria dominated the rhizosphere compared to other microorganisms. Alpha diversity calculated using the Shannon index revealed high microbial diversity, regardless of fertility treatment. Overall, archaea and bacterial diversity (6.3-6.5) was higher than fungal diversity (4.9-5.0). Within these three microbial groups, there was no statistical difference in alpha diversity between the three samples taken from within each replicated plot ($p = 1.0$), between replicates ($p = 0.178 - 1.0$), or between treatments ($p = 1.0$).

Detrended correspondence analysis (DCA) showed the 36 samples from the Field 1K study clustered separately from the 24 samples from the Field2 N study for both archaea/bacteria and fungal populations, although all samples intersected the central axis. There was no separation of samples based on treatments, replicates, or individual samples within replicate plots.

A total of 23 phyla of archaea and bacteria were identified from the 60 samples, with 13 phyla present at frequencies ≥ 1%. At the genus-level, a total of 909 prokaryotic genera were identified, of which, 31 were archaea and 878 were bacteria. Thirty-seven genera (archaea = 2, bacteria = 35) were present in frequencies ≥ 1% of the total community. Of these 37 genera, six were present at significant abundances within the Field 1K study ($p = 0.05$), while 11 were present at significant levels within the Field 2N study ($p = 0.05$). For example, within the Field 1K study, a clone of SAGMA-X (Archaea, Crenarchaeales) was more abundant in the N and K only treatments, whereas a bacterium in the genus *Rhodoplanes* (phototrophic purple nonsulfur bacteria) was more abundant in the N:K treatment. In the Field 2N study, *Candidatus nitrososphaera* (ammonia oxidizing archaea) was more abundant in plots receiving high rates of N, while *Bradyrhizobium* (N-fixing bacterium) was more abundant in plots receiving low N.

For fungi, a total of seven individual phyla were identified from the 60 samples, with four phyla present at frequencies ≥ 1%. At the genus-level, a total of 393 fungal genera were identified, with 15 taxa present in frequencies ≥ 1%. Of these 10 genera, three were present at significant abundances in the Field 1K study ($p = 0.05$), while five were present at significant levels in the Field 2N study ($p = 0.05$). Within the Field 1K study, *Podospora* (saprophytic filamentous Ascomycete) was most abundant in plots receiving N:K, while *Scleroderma* (ectomycorrhizal Basidiomycete) was most abundant in N only plots. In the Field 2N study, an unidentified clone in the Hypocreales (large order of Ascomycetes) was most abundant in low N treatments, while *Gaeumannomyces* (pathogenic Ascomycete) was most abundant in plots receiving high rates of N.

This study marks the first application of next-generation sequencing to analyze the diversity and distribution of microbial organisms in the rhizosphere of putting green turf. Our results show that archaea, bacteria, and fungal diversity was high regardless of fertility treatment. Although the composition of these communities in *P. annua* turf changed as a result of nitrogen and potassium applications, the observed differences were nominal and limited to just a few microorganisms**.** While the abundance of species changed as a result of fertility treatments, overall diversity was maintained. We also observed distinct differences in microbial communities between the two studies sampled in this research, suggesting that underlying soil properties or additional management practices, such as mowing, may be contributing to the observed microbial profiles.

Enhancing Cultural Control of Anthracnose and Summer Patch...
and the Ultimate Solution

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Annual bluegrass (*Poa annua* L.) is a common constituent of intensively managed turfgrass swards such as putting greens, fairways, and athletic fields throughout the northern United States. This weedy grass species competes well with other more desirable cool-season grasses, particularly where irrigation, supplemental fertilization and fungicides are routinely used. This species' ability to compete with other cool-season grasses and persist under high input maintenance regimes frequently leads to turfgrass managers' adopting it, albeit begrudgingly, and managing it as the primary species in mature turf stands (> 10 years). Despite the ability of annual bluegrass to persist under high input maintenance, this species is known to have poor tolerance to disease and environmental stress. Where annual bluegrass is the primary constituent in swards, turf practitioners must manage these diseases to minimize disruption to playing surfaces. Alternatively, turf managers may consider renovating annual bluegrass turf surfaces with new bentgrasses with improved abiotic and biotic stress tolerance. However, due to annual bluegrass' prolific seed production, successful renovation is challenging, and also interrupts play for a prolonged time discouraging this practice. Research to improve management of common diseases of annual bluegrass as well as development of best management practices for transitioning turf surfaces to more sustainable turfgrasses are needed by turfgrass managers depending on the their management goals.

Anthracnose (caused by *Colletotrichum cereale* sensu lato Crouch, Clarke, and Hillman) is a detrimental disease of annual bluegrass (ABG; *Poa annua* L.) putting greens. Ethephon and trinexapac-ethyl applied together for seedhead and vegetative control can reduce anthracnose severity, although this effect has been inconsistent in previous research. Moderate nitrogen fertilization can improve ABG tolerance to anthracnose. However, the influence of seasonal N programming on the ability of plant growth regulators to reduce anthracnose is not well understood. A two year field study was established in 2013 to evaluate potential interactions between seasonal nitrogen fertilization programs, ethephon (ET), and trinexapac-ethyl (TE) application interval on anthracnose severity of ABG putting green turf. Nitrogen treatments included spring or fall applications of 48.8 kg ha^{-1}, or a split application of 12.2 and 36.6 kg ha^{-1} applied spring and fall, respectively. Ethephon was applied at 0 or 3.81 kg a.i. ha^{-1} twice in April. Trinexapac-ethyl treatment intervals consisted of none, 14 day interval, or every 200 growing degree days (GDD) base 0°C from mid-Apr through July 2013 and August 2014, applied at 0.05 kg a.i. ha^{-1}. Surprisingly, N had little effect on anthracnose severity during 2013. However, spring N treatments consistently reduced disease severity compared to fall only treatments from late June through early August 2014. Ethephon initially reduced anthracnose severity, although it had no effect later in the 2013 season. Ethephon-treated turf consistently had reduced anthracnose severity throughout 2014. Trinexapac-ethyl consistently reduced anthracnose severity regardless of application interval in both years. However, TE applied every 200 GDD reduced disease severity more than TE every 14-d during July and August. No consistent interactions were observed. Results to date suggest spring rather than fall N fertilization and ET, and TE applied based on a GDD model can reduce anthracnose on annual bluegrass putting green turf.

Summer patch is a common disease of annual bluegrass and Kentucky bluegrass turf areas caused by *Magnaporthe poae*. The disease is often most problematic in areas with poor drainage. Supplemental manganese fertility has been purported to reduce summer patch severity although the effect of this practice on disease is unknown. A three year field study was initiated on a Kentucky bluegrass (*Poa pratensis*) turf maintained at 3.8 cm in June 2011 to determine the effects of soil compaction, cultivation and manganese fertilization on the incidence and severity of summer patch. The study was established as a split plot design arranged in a 2 x 3 x 2 factorial with four blocks. The main plot factor was compaction, the subplot factors were cultivation and manganese fertilization. Compaction treatments received 64 passes with a 1361 kg sheepsfoot roller in 2011 and 32 passes in 2012 - 2014. Cultivation treatments were conducted using a Toro ProCore aerifier with 1.9 cm tines spaced on 2.54 cm centers in late May. Manganese was applied monthly as a manganese sulfate ($MnSO_4$) solution containing 293 kg ha^{-1} from May through October. Compacted plots consistently had more summer patch compared to non-compacted lanes. Both cultivation treatments enhanced summer patch severity compared to non-cultivated plots in 2012 and 2013. Solid tine cultivation in the absence of Mn fertility resulted in the greatest disease severity. Interestingly, Mn fertility greatly minimized the severity of summer patch regardless of cultivation treatment during 2013.

Fairways are the largest acreage of intensively managed turf on golf courses. Recently developed CBG varieties offer significant improvements in environmental stress and disease tolerance compared to earlier varieties. Consequently, some courses have considered exploring options for renovating existing fairways to new bentgrass varieties for improved fairway performance under stressful conditions and reduced maintenance inputs. The goal of this project is to develop fairway renovation practices to rapidly and effectively transition to new more sustainable creeping bentgrass varieties. The objectives of this research are to: 1) assess the impact of seedbed preparation techniques on the efficacy of glyphosate applied at various intervals prior to surface disturbance, 2) determine seedbed preparation techniques and seeding equipment to optimize germination of creeping bentgrass while minimizing annual bluegrass contamination of the surface in glyphosate- and dazomet-treated areas, and 3) evaluate the effect of renovation strategies and post-renovation management practices for rapidly transitioning established fairway turfgrasses to improved bentgrass varieties at various timings.

Towards Sustainable Management of the Annual Bluegrass Weevil

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The annual bluegrass weevil (ABW), *Listronotus maculicollis*, is a serious and expanding golf course pest in the Northeast. Recently, decreased efficacy of pyrethroid adulticide applications and pesticide-resistant populations are reported from an increasing number of golf courses with 10-40% of golf courses in different areas reporting problems in managing this pest. The efficacy of most insecticides against pyrethroid-resistant ABW populations seems to be reduced on average by 15-57%. However, for highly pyrethroid resistant ABW populations, pyrethroids and some other compounds often provide no control whatsoever. There is a need to develop a better understanding of the extent and scope of insecticide resistance as a base for optimizing the use and longevity of existing insecticides for ABW management. Nonetheless, there is also a dearth of effective and feasible monitoring techniques and alternatives control options for ABW. The overall goal of this project is to optimize existing ABW monitoring methods, develop alternative management strategies, and integrate them in order to achieve significant ABW suppression with reduced chemical input.

Insecticide resistance

Topical bioassays were conducted to determine resistance levels and cross resistance patterns to the major insecticide modes of actions in adult ABW. Nine different populations were collected from golf courses with different histories of insecticide use and ABW infestation. Six concentrations of the insecticide active ingredients (AI, technical grade) were applied topically (1 µl/adult) using microapplicators. Treated ABW were placed in Petri dishes lined with moist filter paper with food provided. Mortality was evaluated 72 h after treatment,and the lethal dose killing 50% of tested individuals (LD_{50}) was determined. Resistance ratios were calculated ($RR_{50} = LD_{50}$ of resistant / LD_{50} of susceptible population) and their significance determined.

The populations collected at Rutgers Horticultural Farm 2 (HF), North Brunswick, NJ and at Pine Brook GC (PB), Manapalan, NJ were relatively pyrethroid-susceptible and were considered susceptible. The other populations had various levels of pyrethroid resistance/tolerance, with RR_{50} ranging from 14 to 343 for bifenthrin and 8 to 324 for λ-cyhalothrin. Pyrethroid resistant populations also demonstrated elevated tolerance to chlorpyrifos (RR_{50} 3.3-15.5), clothianidin (RR_{50} 2.9-9.7), and spinosad (RR_{50} 3.0-5.1). Topical assays with indoxacarb and chlorantraniliprole did not yield meaningful dose-response curves due to low mortality for the resistant populations. Different types of assays may need to be employed to study these compounds.

To develop diagnostic assays for resistance monitoring and detection, greenhouse and laboratory assays were conducted using one susceptible and four resistant populations. Four to five concentrations of formulated bifenthrin (Talstar Pro) (range 0.01-600x of labeled rate) and chlorpyrifos (Dursban) (range 0.001-3x) were tested against five populations in Petri dish assays; corresponding insecticide AIs (technical grade) concentrations were tested in vial assays. Ten adults were introduced per dish/vial. Mortality was evaluated 72 h after treatment, and lethal concentrations (LCs) determined. A greenhouse test was conducted to validate results of the lab assays. Four to five concentrations of the formulated insecticides were sprayed on pots with established grass. Ten adults were introduced per pot immediately after treatment application. Adults were extracted 72 h later, and survival rates were recorded for LC determination. Our preliminary data suggest that RRs obtained from different assay types, except vial assays, were proportionally similar. We did not observe significant differences among populations in vial assays. However, resistance levels could be determined in any of the conducted assays. The Petri dish assay was the simplest and the least labor intensive assay. More replications are needed to validate our findings and determine diagnostic doses for practical use.

These observations combined with other studies further show the widespread incidence of insecticide resistance among ABW populations. Resistance likely develops on a per-golf course base rather than being spread between courses. More research is needed to validate our findings and to determine diagnostic doses for this assay type. Future research will also address the mechanisms responsible for resistance and examine resistance pattern across golf courses (e.g., fairways vs. greens) and across the season (overwintered generations vs. spring and summer generations).

Biological/biorational control

Our prior research had demonstrated that entomopathogenic nematodes can provide acceptable control levels of moderate ABW densities but may be overwhelmed by very high densities. In 2013, we observed in greenhouse and field tests that combined application of nematodes and imidacloprid tended to improve nematode efficacy against ABW. To examine the effect of split application on efficacy of nematodes and nematode-imidacloprid combination, we conducted a field study in 2014. The nematode *Steinernema carpocapsae* and imidacloprid were either applied alone or in combination at full rate (2.5 billion IJs/ha and 336 g AI/ha, respectively) or half rates either as single (May 30) or split (May 30 + June 5) applications. Larval survival was evaluated 11 days after the first application.

Highly variable ABW densities made detection of significant differences challenging. Nonetheless, all treatments except imidacloprid alone provided significant control. Nematode rate had no significant effect in the single and combination treatments. Nematode imidacloprid combinations (77-78%) but not nematodes alone (50-58% control) were significantly better than imidacloprid alone. Split application of nematodes, whether for nematodes alone (88%) or in the combinations (both 95%), showed the greatest potential. This research needs to be repeated in 2015. However, thus far the findings suggest that where imidacloprid is already used for white grub control, its combination with split nematode application could be a highly effective option for ABW larval control. Future research will also address whether entomopathogenic nematodes and their combination with imidacloprid or other compounds would offer a viable alternative for the management of insecticide-resistant ABW populations.

In ongoing research with other biological and biorational control agents, we are finding that products based on azadirachtin and on bacterial fermentation, but not products based on the entomopathogenic fungus *Beauveria bassiana*, can provide control of resistant and non-resistant ABW. However, the efficacy of these products is too low to replace standard chemistry against susceptible populations. However, if used against highly resistant populations, these products may offer a viable alternative. Some of these products have also shown synergistic interactions with standard insecticides against resistant populations.

Semiochemicals and behavior

ABWs tend to aggregate at overwintering sites. To investigate whether ABWs produce aggregation and/or sex pheromones, a series of behavioral bioassays were conducted. The biological significance of ABW headspace volatiles was tested in Y-tube olfactometer assays. Weevils were given a choice between volatiles collected in the headspace of males or females feeding on *P. annua* and of *P. annua* only. Overwintering adults were not responsive to any tested extracts. Spring generation males (70%) preferred female + *P. annua* extract to *P. annua* only extract.

Short distance attractiveness of ABW-produced volatiles was tested in pitfall assays. Plastic containers were filled with moistened sand and four wells were arranged in the center. Wells were baited with head space extracts of males + *P. annua*, females + *P. annua*, *P. annua*, or solvent only. Spring generation males and females were placed centrally in the arena. After 24 h, the number of weevils in each well and outside of wells was determined. Similarly to the Y-tube assays, only males tended to be attracted to female headspace volatiles. Fewer males and females were recovered from non-baited wells than from wells baited with male/female extracts.

To test for presence of aggregation pheromones during the overwintering stage, ABW males or females were given a choice: 1) between female- or male-baited sides and a control, and 2) between male- and female-baited sides of overwintering experimental arenas kept in incubators under overwintering conditions (10 h light, 6°C: 14 h dark, 4°C). Weevil position was recorded after 24 h. Numerically, most males and females tended to choose the side baited with females. Male baits had a weak effect only on female choices. No preferences were observed between male or female baits. In 83% of replicates, introduced weevils were found in one group, confirming the tendency of ABWs to aggregate during the overwintering stage.

POSTER PRESENTATIONS

Protein Metabolism in Association with Improved Drought Tolerance by Elevated Carbon Dioxide in Creeping Bentgrass (*Agrostis stolonifera*)

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Atmospheric carbon dioxide (CO_2) concentration has been increasing and is predicted to further increase in the future along with climate changes such as decline in water availability and increased evaporative demand on plants. Previous studies have shown that elevated CO_2 can mitigate damaging effects of drought stress in creeping bentgrass (*Agrostis stolonifera*), but the mechanisms of this improved drought tolerance are not fully understood. Furthermore, there is far less information available describing effects of elevated CO_2 concentration on root growth and the subsequent impact on plant responses to drought stress as compared to above ground plant parts. The specific proteins and associated metabolic pathways controlling plant functions regulated by CO_2 that may contribute to improved growth and drought tolerance are not fully understood. The objective of this study was to examine which specific proteins or related metabolic processes may be altered by elevated CO_2 and the consequential effect of proteomic changes on whole-plant drought tolerance. In this growth-chamber study with creeping bentgrass growing in fritted clay medium, elevated CO_2 concentration (800 µl L^{-1}) promoted shoot and root growth compared to the ambient CO_2 concentration (400 µl L^{-1}) under well-watered conditions. Following 20 d water withholding (SWC >7.0%), creeping bentgrass plants grown in elevated CO_2 displayed improved visual quality and maintained higher water status of leaves and less cellular membrane damage of leaves and roots. Elevated CO_2 also increased root growth relative to shoot growth with greater root length and surface area in the upper 0-10 cm root zone compared to ambient CO_2 treatment. Proteins were extracted from leaves and roots of creeping bentgrass exposed to either elevated or ambient CO_2 concentration under well-watered or drought stress conditions. Drought- and CO_2-responsive proteins were separated with two-dimensional electrophoresis and identified using mass spectrometry. Drought- and CO_2-repsonsive proteins were mainly classified into the following functional categories: cellular structure and growth, energy, metabolism, and stress defence. The improved plant growth and mitigation of drought stress in creeping bentgrass under elevated CO_2 could be mainly associated with alteration of proteins governing primary metabolism involving nitrogen metabolism, energy metabolism involving respiration, and stress defense by strengthening antioxidant metabolism and chaperone protection. Specific proteomic changes in creeping bentgrass leaves and roots in relation to improved physiological function due to elevated CO_2 concentration and drought stress interaction will be discussed.

Evaluation of Hard Fescue (*Festuca brevilipa*) for Summer Patch (*Magnaporthe poae)* Resistance

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Communities and local governments around the country are currently focusing on reducing environmental effects and reducing the costs of recreational and homeowner landscapes. One of the main areas of concern is maintaining turfgrass areas. Currently research is being conducted in all facets of turfgrass breeding to develop lower maintenance turfgrass cultivars to fill the need for these grasses. Hard fescue (*Festuca brevilipa)* has been identified as a potential candidate species for immediate application. Hard fescue has been shown to be drought resistant and require less mowing and fertilization compared to traditional species used in lawn and recreational sites. However, one of its drawbacks is that it has shown to be very susceptible to the pathogen, summer patch (*Magnaporthe poae)*. Summer patch can cause severe damage to a turfgrass stand and require complete renovation. With the use of fungicides, summer patch can be controlled; however, for a low maintenance situation, the use of fungicides and other pesticides is undesirable.

Thirty-five hard fescue selections were visually evaluated in the summer months of 2013 and 2014 for resistance to summer patch at the New Jersey Experiment Station's Adelphia research farm. Selections were planted as a space plant nursery and inoculated with the summer patch pathogen. Resistance was measured on a visual scale from 1-9 (9= no symptoms). Significant differences were seen over the two years regarding resistance within the selections. Selections also showed consistency from 2013 and 2014 in regard to resistance. Selections that performed well included A10 198 , A10 207, and A10 219 with ratings of 6.28, 6.30, and 6.59. Traditional cultivars such as Beacon and Aurora Gold performed the worst and suffered severe summer patch symptoms with ratings of 3.59 and 3.95. These plants are undergoing further testing to determine the narrow sense heritability of summer patch resistance within the hard fescue species. This information will provide insight into the level of resistance that can be obtained through traditional breeding strategies.

Nitrogen Fertility, Mowing Height and Topdressing Effects on Anthracnose and Playability of Annual Bluegrass

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Anthracnose disease of annual bluegrass (*Poa annua* L.) putting greens, caused by *Colletotrichum cereale* Manns, can be suppressed by increasing nitrogen fertility, mowing height, and sand topdressing. Interactive effects of these practices on disease severity and ball roll distance of annual bluegrass turf remain unknown. A 3-yr field trial was initiated in 2012 in North Brunswick, NJ to evaluate the effects of mowing height, N fertility, and sand topdressing on anthracnose severity and playability of annual bluegrass turf. Treatments were all combinations of mowing height (2.3 and 3.2 mm), N fertility (100 and 200 kg ha^{-1} yr^{-1}), and sand topdressing (46.4 and 97.6 tonne ha^{-1} yr^{-1} during 2012; 36.6 and 80.6 tonne ha^{-1} yr^{-1} during 2013 and 2014). Trinexapac-ethyl was applied weekly at 0.05 kg a.i. ha^{-1}, and light-weight vibratory rolling was performed three times wk^{-1} to maintain surface conditions similar to commercial putting greens. As expected, increased N fertility, mowing height, and sand topdressing reduced disease severity, reported as the area under the disease progress curve (AUDPC). Nitrogen fertility accounted for the majority of the variation in AUDPC, and mowing height accounted for a slightly greater amount than sand topdressing. Interestingly, more frequent sand topdressing produced greater disease suppression when turf was maintained under low N or low mowing (compared to high N or high mowing, respectively) in 2012 and 2014. Recovery from disease damage was enhanced by higher mowing, increased N fertility, and more frequent topdressing. Long-term recovery was hindered the most by low mowing under infrequent topdressing. In regard to ball roll distance (green speed), the relative importance of management factors differed from that observed with AUDPC responses. Increased mowing height caused a substantial reduction in ball roll distance, whereas greater N fertility and sand topdressing had minimal effects on ball roll distance. These findings suggest that priority should be given to lowering mowing height rather than reducing N fertility or sand topdressing rates to increase ball roll distance without greatly increasing anthracnose severity.

Comparing Herbicides for the Control of False Green Kyllinga

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During the past two years, turf managers in New Jersey have reported difficulty controlling False Green Kyllinga (*Kyllinga gracillima*). Greenhouse and field trials were conducted in winter and late summer of 2014, respectively, to assess the efficacy of herbicides on False Green Kyllinga found in southern New Jersey. The greenhouse trial was conducted at Rutgers University on plants collected from Atlantic County, NJ, and the field trial was conducted at an Ocean County park in Tuckerton, NJ. In our greenhouse and field trials, we evaluated sulfentrazone, halosulfuron, mesotrione and triclopyr at the label rates and timings that would be respectively used to control yellow nutsedge (*Cyperus esculentus*) in the New Jersey area. In the greenhouse trial, products that contained sulfentrazone controlled False Green Kyllinga. Percentage of injury approached 100% by the end of the trial. Halosulfuron also controlled False Green Kyllinga but required a sequential application. Treatments that contained mesotrione or triclopyr had slow activity on False Green Kyllinga, but once followed by a sequential application, injury approached 100%. Halosulfuron provided excellent control in the field trial compared to sulfentrazone, mesotione and triclopyr treatments. Injury between 60 to 80%, either as a single or sequential application, was observed from treatments that contained halosufluron. Sulfentrazone treatments provided only 40 to 60% injury. Treatments that contained mesotrione and triclopyr provided roughly 8 to 30% percent injury, either as a single or sequential application.

Hollow Tine Cultivation and Vertical Cutting Effects on Velvet Bentgrass

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Compared to other species, velvet bentgrass (*Agrostis canina* L., VBG) is reputed to accumulate excessive thatch that can create an unacceptable soft or “puffy” playing surface. The objectives of this field study were to determine the effects of vertical cutting and timing of hollow tine cultivation on playing surface characteristics of VBG maintained as a putting green turf. The trial was initiated in September 2010 on a seven-year-old ‘Greenwich’ VBG turf mowed at 2.8 mm. The study used a 2 x 2 x 2 factorial arranged in randomized complete block design with four replications. The factors were vertical cutting, September hollow tine coring, and April hollow tine coring. Coring was done with 12.7-mm i.d. tines and created a lateral and medial hole spacing of 41- and 58-mm, respectively; coring holes were backfilled with medium sand. Vertical cutting was applied in April using scarification reels and as often as biweekly during the summer using vertical cutting reels. Sand topdressing was applied biweekly at 0.4 L m^{-2}. As expected, turf quality and color was reduced immediately after September and April coring. Once coring holes had healed, turf quality and color were either not affected or slightly improved by coring. Coring initially lowered surface hardness but increased hardness later in the season. Vertical cutting treatment increased the surface hardness throughout the season. In all three years, vertical cutting produced a subtle but significant reduction in turf quality and color after treatment; improvements in color occurred but less frequently. All cultivation techniques reduced mat depth and the amount of organic matter in the mat layer; however coring, regardless of timing, produced the greatest reduction. Vertical cutting reduced the depth and amount of accumulated organic matter in the mat but did not affect the concentration of organic matter.

Using Two Simulators to Apply Traffic to the 2012 NTEP Tall Fescue Test

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Tall fescue (*Festuca arundinacea* Schreb.) cultivars are increasingly being established on sports fields throughout the cool temperate and transitional climatic regions of the United States. The objective of this study was to assess the turf performance under traffic stress of tall fescue cultivars and selections in the 2012 NTEP Tall Fescue Test. Three replications of 116 entries were seeded in September 2012 on a loam in North Brunswick, NJ. The test was mowed at 6.4-cm and irrigated to avoid severe drought stress. Traffic was applied as a single strip across each tall fescue plot once a week for eight weeks (18 April to 2 June 2014) and consisted of one pass of both the Rutgers Wear Simulator and Cady Traffic Simulator. Trafficked and non-trafficked strips of each tall fescue were visually assessed for uniformity of turf cover (1 to 9 scale) and fullness of turfgrass canopy (FTC; 0 to 100% scale); digital image analysis was used to determine percent green cover (0 to 100%). Data were analyzed as a 2 (no traffic and traffic) x 116 (entries) factorial strip-plot design. Traffic reduced uniformity of turf cover, FTC, and percent green cover of tall fescue relative to the non-trafficked control. Entries with the best FTC, percent green cover, and uniformity of turf cover after spring traffic were Firebird 2, U43, PPG-TF-135, B23, DZ1, Hemi, PPG-TF-152, U45, W45, IS-TF 330, Falcon V, PST-5GRB, PST-5EV2, Rhambler 2 SRP, PPG-TF-139, RAD-TF-92, W41, PPG-TF-137, PST-5BPO, and PSG-GSD. Analysis of variance indicated a traffic x entry interaction for uniformity of turf cover. Traffic stress did not affect the uniformity of turf cover for Firebird 2, RZ2, and PST-5GRB. Additionally, many differences in uniformity of cover were evident among entries receiving traffic, whereas, few differences were evident without traffic.

Effects of *Epichloë festucae* Endophyte on Heat and/or Drought Tolerance in *Festuca rubra*

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Epichloë spp. are endophytic fungal symbionts present in many turfgrass species (1). It is well established that endophyte (*Epichloë coenophiala*)-infected (E+) tall fescue (*Festuca arundinacea*) shows better drought tolerance and recovery than endophyte-free (E-) plants (2, 3). Studies about effects of endophytes on heat stress response of turfgrass are lacking. Strong creeping red fescue (*Festuca rubra* L. ssp. *rubra*) is a perennial fine fescue and an important turfgrass in temperate regions. Strong creeping red fescue is often naturally infected with *E. festucae,* and infection provides benefits to the host, such as insect and pathogen tolerance (4). However, studies on the effects of endophytes on drought stress in fine fescue are lacking. The objective of this study was to determine whether *E. festucae* has effects on strong creeping red fescue under heat stress, drought stress, and both stresses combined. We compared endophyte-free and endophyte-infected fine fescue (5) and found that there were no significant differences between them under heat stress, drought stress, or the combination of both. The endophytes did not improve abiotic stress resistance of the host. All plants with or without endophytes could recover from the stress. The combination of heat and drought stress impacted plants the most. Separately, fine fescue is more sensitive to drought stress than to heat stress, based on turf quality, chlorophyll content, electrolyte leakage, relative water content and MDA content. Under well-watered condition, the plants were tolerant to heat stress at 35°C. We could expect that higher temperature might impact plants.

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Use of Medium-Fine Sands for Topdressing Velvet Bentgrass and Annual Bluegrass Putting Greens

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The particle size of sand can impact the ability to incorporate topdressing into the turf canopy, and unincorporated sand can interfere with mowing and play on putting greens. Two field trials were initiated to determine the effect of sand size on incorporation, turf quality, and root zone hydraulic properties. The first trial was initiated in 2010 on 'Greenwich' velvet bentgrass (*Agrostis canina* L.) turf maintained at 2.8 mm. Treatments included topdressing biweekly at 0.15 and 0.3 L m^{-2} with medium-coarse and medium-fine sands and included an untreated control arranged in a RCBD with three replications. A second trial was initiated in 2011 on annual bluegrass [ABG; *Poa annua* L. f. *reptans* (Hausskn) T. Koyama] turf maintained at 2.8 mm and evaluated the effect of sand size on anthracnose disease (caused by *Colletotrichum cereale* Manns). Treatments were arranged in a RCBD with four replications and included medium-coarse, medium and medium-fine sands applied at 0.15 L m^{-2} biweekly and a control. Digital image analysis was used to document the putting surface disruption due to unincorporated sand following topdressing events. Medium-coarse sand required more time for sand to dissipate from the turf surface after topdressing compared to the finer sands in the velvet bentgrass trial. Increasing topdressing rate (0.15 to 0.3 L m^{-2}) dramatically increased the quantity of unincorporated sand remaining on the turf surface with medium-coarse sand; in contrast, no increase or only a slight increase in unincorporated sand occurred with medium-fine sand. Substantially more medium-coarse sand was removed by mowing than finer sands, which was supported by digital image analysis. Once sufficient sand accumulated within the turf canopy and thatch, all topdressing sands improved overall performance of velvet bentgrass and annual bluegrass turf. Additionally, topdressing with finer sand produced equivalent or better turf quality than plots topdressed with medium-coarse sand. Medium or medium-fine sand has not been observed to negatively affect soil hydraulic properties. The lack of negative effects of medium and medium-fine sand on measured parameters suggests that further research is warranted. Less disruption to putting surface at even higher topdressing rate may encourage golf course superintendents to apply adequate topdressing during summer when they normally would not.

Development and Application of a TaqMan Real-time PCR Assay for Rapid Detection of the Summer Patch Pathogen of Turfgrass

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In North America, one of the most important root diseases of *Poa* and *Festuca* turf is summer patch, caused by *Magnaporthiopsis poae* (=*Magnaporthe poae*). Detection and identification of *M. poae* in infected roots by conventional culture-based methods is difficult and time consuming. In turfgrass breeding and management evaluation studies, an important question to address is whether the better performance of some grasses is simply because of the absence of the pathogen in certain plots. In this study, a culture-independent TaqMan real-time PCR assay has been developed for *M. poae* that enables pathogen detection from the field samples within a few hours. The assay was validated with the target pathogen, closely related fungal species, and a number of other microorganisms that inhabit the same host and soil environment. This TaqMan real-time PCR assay is more sensitive (detecting as little as 3.88 pg genomic DNA of *M. poae*), rapid, and accurate compared to direct microscopic observation and isolation on a selective medium. The real-time PCR detection results correspond closely to visual assessments of disease severity in the field. Utilization of this assay in diagnostic laboratories will enable turfgrass managers to more quickly and effectively detect and potentially reduce fungicide usage through early and accurate identification of the pathogen.