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Proceedings of the Twenty-Second Annual Rutgers Turfgrass Symposium

January 11, 2013

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William A. Meyer, Associate Director

The Center for Turfgrass Science

Rutgers, The State University of New Jersey
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Proceedings of the Twenty-Second Annual Rutgers Turfgrass Symposium
In Memory of Dr. C. Reed Funk

(1928 - 2012)

Editors
Faith Belanger and Barbara Fitzgerald

Symposium Organizing Committee

Donald Kobayashi, Chair
Faith Belanger
Bruce B. Clarke
Barbara Fitzgerald
William Meyer
James Murphy

Director’s Opening Remarks:

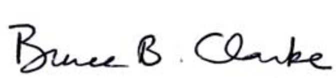
Welcome to the Twenty-Second Annual Rutgers Turfgrass Symposium at the School of Environmental and Biological Sciences/NJAES, Rutgers University. This year’s Symposium is dedicated in honor of Dr. C. Reed Funk who passed away on October 4, 2012. Reed was the father of the Turfgrass Program at Rutgers University and a pioneer in the field of Turfgrass Breeding. Throughout his illustrious career which spanned more than four decades, Reed developed hundreds of cool-season turfgrass cultivars with dramatic improvements in pest and stress tolerance. Many of his germplasm releases, such as 'Manhattan' perennial ryegrass and 'Rebel' tall fescue, are considered landmark cultivars and have served as a foundation for many of the new turfgrass cultivars used throughout the world today. Indeed, Reed's diverse germplasm collection and enhancement programs have revolutionized the turfgrass sod and seed industries.

The Rutgers Turfgrass Symposium was established in 1991 to provide 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 was expanded to include presentations by colleagues at other institutions. This year, we are extremely fortunate to have many of Reed’s close friends and former students present their research at our Turfgrass Symposium. I would like to thank Chris Carson (Echo Lake Country Club), Tim Ford (Institute for the Improvement of Perennial Plants for Food and Bio-Energy), Melodee Fraser (Pure Seed Testing, Inc.), Kevin Morris (National Turfgrass Evaluation Program), Gerry Pepin (PickSeed USA), and Al Turgeon (Pennsylvania State University), as well as Reed’s Rutgers colleagues Stacy Bonos, Jennifer Johnson-Cicalese, Rich Hurley, Peter Kahn, Bill Meyer, and Tom Molnar for speaking at this year’s Symposium. I would also like to recognize the Symposium Planning Committee comprised of Donald Kobayashi (Chair), Jim Murphy, Bruce Clarke, William Meyer, and Faith Belanger and Barbara Fitzgerald (co-editors of the Symposium Proceedings) for their hard work in the preparation of this event. Without their efforts, this year’s Symposium would not have been possible.

Over the past 22 years, the faculty of the Rutgers Center for Turfgrass Science have conducted outstanding research, undergraduate and graduate teaching, and continuing education programs in support of the Turfgrass Industry. In return, the Turfgrass Industry has donated their time and over $4.4 million in the form of research grants, student scholarships (> $100,000/yr), 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 the Turfgrass Industry in the state, region, and nation.

It is with a great sense of anticipation for this year’s program that I welcome you to the Twenty-Second Rutgers Turfgrass Symposium. I hope that you will find it an enjoyable and worthwhile experience.

Sincerely,



Bruce B. Clarke, Director
Rutgers Center for Turfgrass Science

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TWENTY-SECOND ANNUAL RUTGERS TURFGRASS SYMPOSIUM IN HONOR OF DR. C. REED FUNK

School of Environmental and Biological Sciences, Rutgers University
Neilson Dining Hall, Cook Campus

January 11, 2013

Friday, January 11, 2013

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

8:45 AM **Welcome and Opening Remarks –** Dr. James Murphy

9:00 - 10:15 AM **SESSION I:**
(Moderator: Dr. James Murphy)

9:00 – 9:25 **Dr. Stacy Bonos** (Department of Plant Biology and Pathology, Rutgers University) *Breeding Perennial Grasses for a Sustainable Future*

9:25 – 9:50 **Dr. William Meyer** (Department of Plant Biology and Pathology, Rutgers University) *Recent Cultivar Improvements in Kentucky Bluegrass, Tall and Fine Fescue and Perennial Ryegrass: Building on Reed Funk's Legacy*

9:50 – 10:15 **Dr. Thomas Molnar** (Department of Plant Biology and Pathology, Rutgers University) *Expanding Agriculture with Underutilized Perennial Tree Crops: Taking a Great Idea and Making It a Reality*

10:15 – 10:45 AM **Discussion and Poster Session**

10:45 – 12:00 PM **SESSION II:**
(Moderator: William Dickson)

10:45 - 11:10 **Dr. David Kopec** (School of Plant Sciences, University of Arizona) *New Grasses for New Times: Native Species for Potential Development as Turfgrasses*

11:10 – 11:35 **Dr. Melodee Fraser** (Director of Research, Pure Seed Testing, Inc., Rolesville, NC) *Improving Cool and Warm-Season Turfgrasses in the Southeast United States*

11:35 – 12:00 **Dr. Peter Kahn** (Department of Biochemistry and Microbiology, Rutgers University) *Perennial Plants for Sustainable Production of Food and Bioenergy and for Restoration of Damaged Land*

12:00 - 1:00 PM **Lunch**

1:00 – 2:15 PM **SESSION III:**
(Moderator: Dr. Peter Kahn)

1:00 – 1:25 **Dr. Jennifer Johnson Cicalese** (Department of Plant Biology and Pathology, Rutgers University) *Breeding the American Cranberry in New Jersey - Recent Challenges and Successes*

1:25 – 1:50 **Kevin Morris** (Executive Director, National Turfgrass Evaluation Program, Beltsville, MD) *Reed Funk's Impact on Turfgrass Evaluation and Improvement Programs in the United States*

1:50 – 2:15 **Dr. Gerard Pepin** (Executive Vice President and Director of Research, PickSeed USA, Tangent, OR) *Reed Funk's Influence on the Turfgrass Seed Industry in the Pacific Northwest*

2:15 – 2:45 PM **Discussion and Poster session**

2:45 – 3:35 PM **SESSION IV:**
(Moderator: Dr. Joshua Honig)

2:45 – 3:10 **Tim Ford** (President and Director of Plant Breeding Research, IPPFBE) *Improving Perennial Plants for Food and Bioenergy*

3:10 – 3:35 **Dr. Richard Hurley** (Department of Plant Biology and Pathology, Rutgers University) *Reed Funk's Influence on the Seed Industry in the United States and Abroad*

3:35 – 3:45 PM **Discussion and Summary of Symposium**

3:45 – 5:00 PM **Cocktail reception**

5:00 – 8:00 PM **Dinner MC – Dr. Bruce B. Clarke** (Chairman, Department of Plant Biology and Pathology, Rutgers University)

2009 Video Interview of C. Reed Funk

Dr. Al Turgeon (Department of Plant Science, Pennsylvania State University) *Remembering a 50-Year Friendship with Reed Funk*

Carol Jean Petersen (Daughter of C. Reed Funk)

Chris Carson (Echo Lake Country Club) *Dr. Reed Funk's Legacy is Deeply Rooted – An Industry Perspective*

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PLENARY PRESENTATIONS

Breeding Perennial Grasses for a Sustainable Future

Stacy A. Bonos, Eric N. Weibel, Eric Koch, William A. Meyer, Sergio Sosa and Laura Cortese

Department of Plant Biology and Pathology, Rutgers University

After Dr. Reed Funk spent his productive career building and growing the turfgrass breeding program at Rutgers he founded the non-profit charitable organization, Improving Perennial Plants for Food and Bioenergy (IPPFBE). As a tribute to Dr. Funk's contributions, we will discuss our continued efforts to develop turfgrasses requiring less inputs and our goal to develop perennial grasses for bioenergy.

Bentgrass Breeding Program

When Dr. Funk initiated the turfgrass breeding program in the 1960's, bentgrasses were not a major focus of the program. However with support that the breeding program generated over the years, the bentgrass breeding program has expanded. The main goal of the Rutgers turfgrass breeding program is to develop pest and stress tolerant turfgrasses that can be utilized throughout the United States and beyond. This overall breeding goal transcends the bentgrasses as well. With bentgrass species being particularly susceptible to a number of important diseases including dollar spot (caused by *Sclerotinia homoeocarpa* F.T. Bennett), copper spot (caused by *Gleosercospora sorghi* D.C. Bain & Edgerton); anthracnose (caused by *Colletotrichum cereale* Manns sensu lato Crouch, Clarke and Hillman) and brown patch (caused by *Rhizoctonia solani* Kühn), breeding for improved disease resistance has been one of the major goals of the bentgrass breeding program. In addition to diseases, in the bentgrass breeding program we are also trying to improve traffic, drought and salinity tolerance, as well as overall quality under reduced inputs. It is our hope that through these breeding efforts, bentgrasses can be grown on golf courses in a more sustainable manner with fewer additions of pesticides, fertilizers, water, and energy. Now more than 50 years later, new bentgrass cultivars have been developed with improved disease resistance and stress tolerance. Recently developed cultivars with these characteristics include '007', 'Barracuda', 'Luminary', 'Focus', 'Proclamation', and 'Pin-Up'. These cultivars have exhibited high quality in recent National Turfgrass Evaluation Program trials across the country.

Switchgrass Breeding Program

In 2006, a native warm-season grass breeding program for biofuel was initiated at Rutgers University, with support from the Center for Turfgrass Science. Switchgrass (*Panicum virgatum* L.) is a C4 perennial warm-season grass native to the eastern two-thirds of the United States and chosen as a model bioenergy feedstock species by the Department of Energy due to its high productivity across a wide geographic range, suitability for marginal land, low water and nutrient requirements, and positive environmental benefits. However, it has several limitations, including poor germination, which results in slow and inconsistent establishment and heavy weed competition. Additionally, switchgrass ecotypes are highly regionalized so that no one cultivar performs consistently across a wide range of variable environments. Prior to the initiation of this project, switchgrass had not been evaluated in NJ for bioenergy characteristics. Since that time we have been working toward breeding switchgrass with improved biofuel characteristics for the northeast. Projects include improving germination, growth and production on marginal land and disease and pest tolerance. We have found that selection for heavier seed can improve germination rates, which should help improve establishment of switchgrass. We have also found that breeding for improved production on marginal land will most likely involve selection on marginal sites and selecting clones that have stable performance across locations. In addition, we found that disease resistance is a heritable trait that we should be able to improve through selection and progeny testing.

Recent Cultivar Improvements in Kentucky Bluegrass, Tall and Fine Fescue and Perennial Ryegrass: Building on Reed Funk's Legacy

William A. Meyer, Ronald F. Bara, Melissa Mohr, Dirk Smith,
Stacy Bonos, Eugene Szerszen, James Cross, and Priti Saxena

Department of Plant Biology and Pathology, Rutgers University

The Rutgers Turfgrass Breeding Project on Kentucky bluegrass, perennial ryegrass tall and fine fescue has been making continual improvements since it was started by Dr. C. Reed Funk in the early 1960's. During this period, the new improved cultivars have been entered in the National Turfgrass Evaluation Program trials (NTEP) since its inception in the late 1980's by Rutgers and their collaborators. These cultivars have been at the top of these trials. Many of the new cultivars have been the result of extensive collections from old turf areas in the United States and Europe. Since 1996, over 20,000 new cool-season collections from Europe and North Africa have been evaluated prior to their inclusion in the Rutgers breeding project.

Kentucky Bluegrass

Kentucky bluegrass (*Poa pratensis* L.) is a widely used turfgrass in North America. Many new cultivars have improved resistance to leaf spot (*Drechslera poae*), dollar spot (*Sclerotinia homoeocarpa*) brown patch (*Rhizoctonia solani*) and summer patch (*Magnaporthe poae*). In the 2005 Kentucky bluegrass NTEP, over one-half of the top Kentucky cultivars were derived from the Rutgers breeding program after 5 years. Some of these were 'Bewitched', 'Diva', 'Avid', 'Rythum', 'Bluestone', 'Bluenote', 'Fullback', 'Shiraz', 'Zinfandel', 'Rhapsody', 'Skye' and 'Midnight II'. Many of these have had improved wear tolerance.

Perennial Ryegrass

Perennial ryegrass (*Lolium perenne* L.) is a popular wear tolerant turfgrass used in mixtures and as a popular seed to repair disturbed and weak turf areas. The major disease of perennial ryegrass for many years from the mid-90's to mid-2005 was gray leaf spot (*Magnaporthe oryzae*). Thirty-four sources of resistance were discovered in the Rutgers breeding project that are now being used in commercial perennial ryegrass cultivars. Some of the new resistant cultivars are 'Paragon GLR', 'Pangea GLR', 'Karma', 'Wicked', 'SR-4650', 'Evolution', 'Pizzazz 2', 'Rinova', 'Protegé', 'Sideways', 'Sox Fan', 'Octane' and 'Fiesta IV'.

Other breeding improvements being presently worked on are dollar spot, stem and crown rust and brown patch resistance. Over 90% of the new 2010 NTEP top performing gray leaf spot resistant ryegrasses are from the Rutgers program.

Tall Fescue

Tall fescue (*Lolium arundinacea* [Schreb.]) Darbysh.) is growing in the Northeastern U.S. and other areas of the U.S. This species has a deep root system that helps it survive dry and hot spells. New cultivars have been shown to produce tillers laterally at a rapid rate. In the 2006 thru 2011 NTEP trial, 19 of the top entries were from the Rutgers breeding program. Some examples of the top rating cultivars were 'Faith', 'Falcon V', 'Cochise IV', 'Monét', 'LS-1200', 'Penn RK4', 'Wolfpack II', 'Shenandoah III', 'RKS', and 'Firecracker LS'.

Brown patch (*Rhizoctonia solani* L.) is the most important disease of tall fescue. Each cycle of selection has shown a small increase in disease resistance of tall fescue. In our 2011 fall seeding of tall fescues rated during the summer of 2012, all of the top 25 varieties were new experimental varieties from the Rutgers breeding program except for 'Falcon V', which is a commercial variety.

Fine Fescue

The fine fescues include three important species: hard fescue (*Festuca brevepilia* R. Tracey) Chewings fescue (*F. rubra* L. subsp. *commutata* Fallax [Thuill] Nyman) and strong creeping red fescue (*F. rubra* L. subsp. *rubra*). All of the species have sources of maternally borne *Epichloë* endophytes that improve drought tolerance as well as confer enhanced resistance to diseases and above-ground feeding insects.

Hard Fescue

This species produces the highest turf quality, best low maintenance and wear tolerance and resistance to dollar spot and red thread (*Laetisaria fuciformis*). In the NTEP trials on fine fescue, the cultivars 'Reliant IV', 'Firefly', 'SR-3100', 'Predator', 'Scaldis II', 'Berkshire', 'Oxford', 'Matterhorn', 'Gotham', and 'Nordic' are improved cultivars.

Chewings Fescue

This species is a popular component in shade mixtures with the second best performance to wear. Some of the top performing cultivars are 'Radar', 'Intrigue I' and II', 'Longfellow II and III', 'Zodiac', '7 Seas', 'Shadow II', 'Zodiac', 'Fairmont', 'Rushmore', 'Culumbra II', 'LaCross', 'Ambassador' and 'Ambrose'.

Strong Creeping Red Fescue

Strong creeping red fescue is a popular choice in lawn mixtures with Kentucky bluegrass and perennial ryegrass. It has a very extensive rhizome system similar to Kentucky bluegrass. This species needs the biggest improvement for wear tolerance. Some of the top performing cultivars are 'Navigator III', 'Wendy Jean', 'Pathfinder', 'Aberdeen', 'Miser', 'Lustrous', 'Razor', 'Epic', 'Fortitude' 'Celestial'.

Expanding Agriculture with Underutilized Perennial Tree Crops: Taking a Great Idea and Making It a Reality

Thomas J. Molnar

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A program for the genetic improvement of underutilized perennial crops was started at Rutgers University in 1996 by Dr. C. Reed Funk. After having immense success with turfgrass breeding at Rutgers, and seeing to it that the turf program was left in capable hands, Dr. Funk embarked on an even more ambitious project to improve underutilized crops for food production, animal feed, and more. He began by focusing on temperate nut trees, as they showed considerable genetic potential that was largely untouched by modern breeding. The first stage of the program, considered an exploratory and experimental stage, consisted of wide germplasm collection of nearly all of the known temperate nut tree species, including a broad diversity of seed sources and accessions from within each species. This list includes several walnut (*Juglans* spp.) species, hickories and pecan (*Carya* spp.), hazelnuts (*Corylus* spp.), chestnut (*Castanea* spp.), almond and apricot (*Prunus* spp.), and pistachio (*Pistacia vera*). New germplasm from all of these species was collected from across North America, as well as Europe and Central Asia, until 2002. At the peak of the exploratory phase, over 25,000 nut trees of the various species were planted across several Rutgers research farms, but primarily at the Adelphia Turfgrass research and extension center located in Monmouth County, NJ.

During the first decade of the program, the various plantings were assessed for both general adaptation of the species' as a whole and for each individual plant within its species. These evaluations were done to identify the species that were best adapted to New Jersey climatic and soil conditions, to target specific limiting factors (breeding objectives), and to identify outstanding genotypes within the species. Focused breeding efforts would begin after this point. Some of the trees started to produce nuts as early as 2000. This provided additional characteristics to evaluate, along with the presence of disease, and pest tolerance. By 2002, it was quite clear that hazelnuts, which consist of several cross-compatible species, were the best adapted to New Jersey's climate. They had the fewest pest problems and the young trees were bearing considerable amounts of nuts within four years from planting without pesticide applications or pruning. The only obstacle to hazelnut production in the eastern US was the native fungal disease eastern filbert blight (EFB), caused by *Anisogramma anomala*. However, plants showing resistance to EFB were already being discovered in our trials. It also became apparent that market conditions were positive for the expansion of hazelnuts as a crop, with high demand across worldwide markets and only a limited availability of high-quality hazelnut kernels. Based on these points, starting in 2004, the program became largely focused on developing the potential of hazelnuts. Subsequently, an even wider germplasm collection period was initiated within this genus. In addition to collections made within the large USDA collection located in Corvallis, OR, and private nurseries and breeders across North America, new collections were assembled of hazelnut germplasm from Russia, Ukraine, Moldova, Estonia, Latvia, Lithuania, Poland, Turkey, the Republic of Georgia, Italy, Kyrgyzstan, and Uzbekistan. At this time, we began systematic breeding efforts with the targeted objective of developing EFB-resistant plants that produce high yields of superior-quality kernels. Today, we plant around 7,000 trees from controlled crosses annually. Our collection, now growing across several farms, holds over 35,000 hazelnut plants, consisting of foreign germplasm collections as well as targeted breeding progeny. From our earliest work, we have selected 14 superior trees that have been clonally propagated and are now growing in replicated test trials to evaluate yield and kernel quality in New Jersey, New York, Pennsylvania, Nebraska, and Ontario. We are finding that many farmers are interested in hazelnuts as a crop due to their high market value and low input needs, including limited hand labor compared to many other horticultural crops. We hope to identify our best plants for release to growers by 2016.

Our research has also focused on applied objectives geared towards enhancing hazelnut breeding techniques and developing durable disease resistance. This includes the development of more rapid greenhouse and field resistance screening protocols, studying the inheritance of disease resistance and the identification of novel sources of resistance, assessing the pathogenic variation of *A. anomala*, including the development of molecular biology tools to assess genetic diversity and population structure of the pathogen, and assisting in its early detection for disease management and efficient breeding. We have also used molecular tools (microsatellite markers) to fingerprint and study the genetic diversity present in our own hazelnut germplasm collections, to map possible genes for disease resistance onto the existing hazelnut genetic linkage map, and to develop new markers for use in marker assisted breeding and gene pyramiding.

Based on our breeding and research results, we are confident that hazelnuts will be considered a tangible, low-input option for farmers to grow in the northeastern United States within the decade. Additionally, we have not abandoned the earliest tree plantings of the different nut species, but have instead narrowed our collections down to the best-adapted, best-performing individual trees within each species. Within these collections a small number of trees show promise for continued genetic improvement and should provide the genetic foundation to work with additional nut trees species alongside hazelnut as funding opportunities and research capacity becomes available. The projected success of the hazelnut program, especially once the crop becomes a northeastern U.S. staple, should help us to forge ahead with the development of additional perennial species to further expand our agricultural capacity along the lines Dr. C. Reed Funk envisioned.

New Grasses for New Times: Native Species for Potential Development as Turfgrasses

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The desert southwest is the fastest growing geographical region in the US in terms of population growth and demographic change in terms of new residencies. Much of the populated areas are in true urban centers, which receive 12 inches or less of precipitation a year and experience Reference ET conditions of 80 inches, or more annually. The most common turfgrass utilized is bermudagrass (*Cynodon* spp.). Within bermudagrass, there is genetic variation for traits such as good drought tolerance, salt tolerance, traffic tolerance and mowing height tolerance. Areas of turf that are not sports related in utility could host other species, which would require less cultural management inputs in water and fertility, or tolerate irrigation with poor water quality.

Species that have low growing habits and/or tolerated mowing trials for screening for turf tolerance include the following grasses:

Sprucetop grama (*Bouteloua gracils*, BG): This is a bunchgrass with leaf blades that are about 4 mm in width. The seed of BG germinates quickly. Compared to native accessions of *B. gracilis*, *B. hirsutus* and *Lycurus setosus*, a nominal percentage of clones have tolerated mowing 3x weekly at 75 mm while maintaining adequate density and 95% or more green leaf retention during periods of extended atmospheric and soil drought (irrigated once every 4-6 weeks in summer). Additional studies have shown that BG will maintain a turf cover at 95% or more cover in a seeded/mowed monostand.

Curly mesquitegrass (*Hilaria belangeri*, HB): This grass has wiry stolons, is monoecious and similar in appearance and growth habit to that of Buffalograss (*Buchloe* spp.). It is found in native stands from 2400 to 4500 feet in elevation. An opportunistic collection of 125 clonal accessions was made from a now defunct seed collection field of this species, located in Chandler, Arizona (elevation 1100 feet, with 90 days a year experiencing temperatures of at least 100 F). There appears considerable phenotypic variation for turf type habit and seed production at this time. These clones have been transplanted into the field as replicated clones for mowing response in 2013 and 2014 to determine frequency of plant growth habit types, and to determine broad sense heritability estimates for turf habit and seed yield.

Inland saltgrass (*Distichlis spicata*, IS): A dioecious species with deep rhizomes, IS is a true halophyte A small but important number of clones observed in native stands have a lower growing habit, and can tolerate mowing heights from 5mm to 60 mm. This collection has exhibited moderate broad sense heritability for turfgrass density and overall quality. Salt tolerance is equal too, or better than, that of Seashore paspalum, with certain clones maintaining

98% green leaf retention at salinity equal to, or slightly above that of ocean sea water. Clones of IS have demonstrated positive responses to traffic using a heavy soil roller. IS clone AZ 138 has shown excellent drought avoidance compared to bermudagrass and Seashore paspalum, and is capable of showing no signs of plant stress for up to 14 days after a single irrigation under summer conditions. Hard seed and the fact that the species is dioecious are two ongoing working concerns for its domestication.

Improving Cool and Warm-Season Turfgrasses in the Southeast United States

Melodee Fraser

Pure-Seed Testing, Inc.

Pure-Seed Testing, Inc. (PST) is a turfgrass breeding and evaluation company with headquarters in the Willamette Valley of Oregon. In 1991, PST started a research farm near Rolesville, NC, (PST-East) to work on improving summer performance of cool-season turfgrasses and to develop improved seeded cultivars of bermudagrass [*Cynodon dactylon* (L.) Pers.]. The primary objective of the cool-season turfgrass breeding program is the improvement of tall fescue (*Festuca arundinacea* Schreb.) summer performance, focusing on disease resistance and heat and drought tolerance. Cultivars released from this program include ‘Tar Heel II’, ‘Endeavor II’, ‘Coronado TDH’, and ‘Wolfpack II’. Kentucky bluegrass (*Poa pratensis* L.) turf trials are evaluated for tolerance to heat and drought, low mowing, and wear. Cultivars that have performed well in these trials include ‘Right’, ‘Jump Start’, and ‘Moonlight SLT’. Gray leaf spot [*Pyricularia grisea* (Cook) Sacc.] damage on perennial ryegrass (*Lolium perenne* L.) trials is usually severe during late summer, creating an opportunity to improve genetic resistance. Perennial ryegrasses are also screened for heat and drought tolerance. PST-East has a long-term project devoted to improving the summer performance of strong creeping red fescue (*Festuca rubra* L. subsp. *rubra*), which typically performs poorly in turf trials in this warm, humid climate. Repeated cycles of phenotypic recurrent selection for improved summer performance in strong creeping red fescue have been conducted since 2005, combined with selection for seed yield in Oregon. New experimental cultivars look promising. PST-East also conducts turf trials and screening trials to improve summer performance of bentgrass species (*Agrostis* L.). The warm-season turfgrass breeding program has focused on bermudagrass, with objectives of improving fine turf characteristics; wear, drought, and salt tolerance; and seed yield. Cultivars released from this program include ‘Savannah II’, ‘Transcontinental SMG’, and ‘North Shore SLT’.

Perennial Plants for Sustainable Production of Food and Bioenergy and for Restoration of Damaged Land

Peter C. Kahn
In memory of C. Reed Funk

Department of Biochemistry and Microbiology, Rutgers University

An article entitled "Investing in Perennial Crops to Sustainably Feed the World" appeared in the summer, 2011, issue of *Issues in Science and Technology*, a quarterly journal published jointly by the National Academies of Science, Engineering and Medicine. It may be the last paper of which C. Reed Funk was an author and which was published in his lifetime. The article describes some of the problems of feeding the world's growing population. It goes on to propose a way to ameliorate some of the problems while at the same time reclaiming large areas of damaged land, protecting water supplies, reducing floods, harvesting CO_2 and providing employment to large numbers of people. Much of this abstract is drawn directly from that paper as indicated by the quotation marks.

"The world's food supply is insecure and inadequate and growing more so…. Much of the land on which we depend is losing productivity because of deforestation, development, overgrazing, and poor agricultural practices. Erosion, pollution, and the expansion of deserts are among the consequences…. Water tables are falling as aquifers are pumped at rates exceeding their ability to recharge." The water in "fossil aquifers" was laid down millions of years ago and cannot be recharged, so when these aquifers go dry, agriculture dependent on them ceases. "Nearly 90% of all fresh water used by humans goes for irrigation. … [J]ust 16% of the world's cropland is irrigated, but this 16% produces 36% of the global harvest…. There is evidence that a significant contributing factor to the genocide in Rwanda was the pressure put on the land by rising population and diminished productivity, leading to social decay and murderous political instability…. Rising food prices have been cited as contributing to the revolutions in Egypt and Tunisia and to unrest elsewhere, and the price increases appear to be driven by long-term trends rather than caused by one or a few unusual events."

As important as annually planted grains and soybeans are and will remain, their present methods of cultivation are not sustainable, and world-wide *per capita* production has been declining since the 1980s. We propose to help ameliorate the problems by developing perennial plants. Nut and bean bearing trees, oil producing trees and other plants, fast growing trees to provide wood for fuel and construction would all be part of the mix along with grasses and shrubs. All these anchor and enrich the soil, reducing erosion and water run-off, thus helping to recharge aquifers. A single hectare (2.5 acres) of walnuts alone at current yields would supply 10% of a 2000 calorie diet for 47,000 people. "It is important to realize that food security comes not from one single source of nourishment but from a multiplicity, especially in the face of rising prices and growing climatic instability."

We envision a series of research stations, three to five each in China, South Asia, Africa, South America, North America, Europe, the Middle East, Australia and Japan. The work would be funded by the income from private endowments of $20-$40 million per station. By worldwide budgetary standards this is not very expensive, and the money can be obtained from a variety of private sources. Although many Green Revolution techniques such as classical plant breeding would be employed, the aims would be to develop plants needing as little external input: water, fertilizer, pesticides, etc., as possible. “Research should focus on improvements in yield, nutrition, adaptation to different soils and environments, pest resistance, stress tolerance, and timber qualities.”

“Wherever successful development has taken place, researchers have worked closely with the local farmers and farmers’ associations, local governmental and university staff, and with NGOs.” In addition, the staff of each station would include an economist and a cultural/political analyst, for without the insights these workers would provide, any schemes developed are likely to founder.

Fortuitous circumstances led to an invitation to visit Colombia to discuss setting up a station there. These discussions occupied two weeks in October, 2012. At the request of Colombian researchers and others there, the idea of a station, even one active in several areas of the country, grew into a perennial plant consortium led by the Universidad Nacional (UN). It would include various UN agricultural stations, the Centro Internacional de Agricultura Tropical (CIAT), which is a CGIAR center, Corporación Colombiana de Investigación Agropecuaria (CORPOICA), business associations of oil palm growers and agroforestry firms, other universities, including Rutgers, and Colombian NGOs. Joint research programs as well as exchanges in both directions of students and researchers are intended.

Colombia is a perfect laboratory for developing an enterprise of this sort. It has highly varied topography and climatic regions ranging from tropical rainforest to high, cold alpine areas and everything in between. It has a skilled and knowledgeable scientific workforce committed to sustainability. What is more, anything learned here can be applied in many other countries.

There is a close association among environmental issues, poverty, democracy and human rights. For his work on the Green Revolution Norman Borlaug won the Nobel Peace Prize in 1970. More recently Wangari Maathai and her associates planted millions of trees to begin reversing poverty and environmental degradation in Kenya. The Nobel Committee recognized her efforts and the social and political work at the village level which accompanied it, including the establishment of thousands of tree nurseries, by awarding her the Peace Prize in 2004. This and other successes can and should be duplicated on a global scale, but time grows short.

Breeding the American Cranberry in New Jersey – Recent Challenges and Successes

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The American cranberry (*Vaccinium macrocarpon* Ait.), one of the few fruit crops native to our continent, has become an important part of the American diet, as juice, sauces and sweetened dried cranberries. Cranberries are also a rich source of dietary phytochemicals believed to have beneficial effects on human health. Since its domestication in the 19th century, cranberry has undergone relatively few breeding and selection cycles. Initiated in 1929, the first cranberry breeding program's objective was to develop varieties with a reduced feeding preference to the blunt-nosed leafhopper, the vector of the phytoplasma 'false-blossom' disease. From this initial program six varieties were released, of which 'Stevens', released in 1950, became the most widely planted cultivar. In the last decade, four varieties have been released from the Rutgers cranberry breeding program: Crimson Queen®, Demoranville®, and Mullica Queen®, with improved yield, color and quality; and Scarlet Knight™, with exceptional traits for the fresh fruit market. Growers have adopted the use of these new varieties and over 1900 acres have been planted, resulting in higher productivity. Improved consistent yields, fruit chemistry, and season of ripening continue to be objectives of our breeding efforts. However, insect and disease resistance are increasingly necessary objectives.

A recent focus of our cranberry breeding project is to develop cultivars with improved resistance to the fruit rot disease complex. Fruit rot is the primary threat to cranberry production in the northeast, and increasingly in other growing regions. In addition, a number of our most effective fungicides may be restricted or prohibited in the near future. Fruit rot is caused by a complex of fungi from at least 12 genera. In 2003, fungicide applications were withheld from our germplasm collection in order to screen for fruit rot resistance. The plots were evaluated using a 1-5 rating scale (where 5=nearly 100% rotten fruit), and by taking counts of rotten fruit from a subset of plots. Severe fruit rot pressure occurred and 70% of the 562 accessions had a rating of '5'. Only 6% showed some resistance (rating of '1' or '2'). Several sources of broad-based field fruit rot resistance (FFRR) were identified. These resistant accessions have now been used in over 130 crosses. Progeny evaluations from initial crosses found that families with a resistant parent had a higher frequency of resistant progeny, indicating potential for improving resistance.

In 2009, 1624 progeny, from 50 crosses among resistant accessions, were planted in field plots. These crosses were of significantly different lineage than the initial crosses; they included parents with the greatest FFRR (US88-30, US88-79, US89-3, US94-176), and crosses where both parents were resistant. In 2011, the final two fungicide applications were withheld from this planting and disease pressure was severe enough to screen for FFRR. Significant differences were found between families and within families, in fruit rot ratings and rotten fruit counts. Moderately high heritability estimates were obtained with offspring-midparent regression (r^2=0.52), indicating additive genetic variance. In addition, introgression of FFRR into higher yielding genetic backgrounds was accomplished. For example, a US88-30 x Crimson Queen progeny exhibited high FFRR, along with good berry size, color, and commercially viable yield (>600b/A est.). However, a few resistant progeny also originated from susceptible parents, suggesting that susceptible plants can carry alleles for resistance, and that multiple loci are involved in resistance. In 2012, these progeny were evaluated again and a significant correlation was found between years in fruit rot ratings (r^2=0.59). Studies involving possible mechanisms of resistance are being conducted but have yet to yield any conclusive evidence.

In association with many others, primarily L. Georgi, our breeding project has recently constructed the first genetic map of American cranberry. The map uses primarily SSR markers, and is comprised of 14 linkage groups totaling 879.9 cM with estimated genome coverage of 82.2%. Thus, the complete map is anticipated to be about 1000 cM. This map, based on four mapping populations segregating for field fruit rot resistance, contains 136 distinct loci, and provides the first foray in the identification of genomic regions (QTL) associated with fruit rot resistance. The development of genomic resources in cranberry will hopefully provide for innovative plant breeding systems that will reduce the time and field space required for evaluation, and facilitate the breeding of unique superior cranberry cultivars to meet the current and future challenges of this important American crop.

Reed Funk's Impact on Turfgrass Evaluation and Improvement Programs in the United States

Kevin Morris

National Turfgrass Evaluation Program, Beltsville, MD

Dr. C. Reed Funk was a pioneer in the area of turfgrass breeding and the development of new, and in some instances, landmark cultivars. However, many people are unaware of his impact on the science of turfgrass evaluation and its influence on, and usefulness to, turfgrass breeding, improvement and management research. This presentation examines Dr. Funk's early leadership in creating a science of turfgrass evaluation through early northeastern regional turf trials, some of the first coordinated turf trials. Dr. Funk's leadership and efforts continued with his involvement in the initiation and early days of the National Turfgrass Evaluation Program (NTEP), as well as his continuing involvement with NTEP throughout the remainder of his career. Dr. Funk's contribution to scientific turfgrass evaluations helped to establish this system as the standard for characterizing and categorizing turfgrass improvements.

Dr. Reed Funk's Influence on the Turfgrass Seed Industry in the Pacific Northwest

Gerard Pepin, PhD, Rutgers 1971

Executive Vice President, Pickseed USA, Tangent, OR

The Pacific Northwest (Oregon, Washington, Idaho) has long been known as the best place on earth to grow grass seed, mainly due to its unique climate. Dr. Reed Funk's breeding work at Rutgers has had a huge effect on the area's seed industry. Before his work began there was little interest in improved varieties and seed was traded mainly as a commodity. The main seed industry suppliers handled cheap lawn seed and forage grasses. There were very few proprietary varieties and no companies specialized in handling them. Now in Oregon there are 37 grass seed producing companies, most handling Rutgers turfgrasses. Dr Funk's efforts plus the passage of the Plant Variety Protection Act in 1970 changed everything.

The peak years of Northwest grass seed production were from 2005-2008. The great recession of 2008 severely reduced grass seed production acres. And now intense pressure from high priced wheat production is reducing acres. Grass seed production is now migrating to Canada, the upper Midwest, and internationally. Even with that, the changes of the last 40 years have been dramatic.

If we use 1972 (40 years ago) as a starting point where the Rutgers influences began to be felt we get the following approximate numbers:

1972 turf type tall fescue production: None
2012: turf type tall fescue production peaked at 200,000,000 + lbs

1972 turf type perennial ryegrass production: about 500,000 lbs
2012: turf type perennial ryegrass production peaked at 200,000,000 + lbs

1972 Kentucky bluegrass improved variety production: about 2,000,000 lbs (mainly 'Merion' and 'Windsor')
2012: Kentucky bluegrass improved variety production: about 30,000,000 lbs

Recognizing the importance of industry cooperation, Dr. Funk was very successful in getting involved with the seed industry at an early date. In his early years (1966-1972) there was a steady stream of influential seed industry visitors, such as Dick Bailey and Bill Rose (Turf Seed), Bob Russell (J&L Adikes) Bob Peterson (Burlingham), Dr. Howard Kaerwer (Northup King), Arden Jacklin (Jacklin Seed) and Peter Loft (Lofts Seed). They saw first hand the value of improved turf grasses which led to the early acceptance of improved varieties and directly resulted in the robust seed industry we now have in the Pacific Northwest, where over half of the world's turf seed is produced.

The first Rutgers improved tall fescue varieties were 'Falcon' (E. F. Burlinghams) and 'Rebel' (Lofts Seed), released around 1975. The first Rutgers improved perennial variety was ‘Manhattan’, selected by Dr. Funk from Central Park in New York, and released to the Manhattan Ryegrass Association about 1971. The first Rutgers improved Kentucky bluegrass varieties were ‘Adelphi’ (J&L Adikes) and ‘Bonnieblue’ (E. F. Burlingham), released around 1972. Many more varieties were to follow among all of these three major turf species.

Dr. Funk was actively supported by the United States Golf Association (USGA) very early in his career. This helped with acceptance of improved varieties by the golf industry and their suppliers and also resulted in a number of improved varieties selected by USGA field representatives like Al Radko and others. Germplasm collected by USGA personnel resulted in great varieties such as ‘Touchdown’, ‘Ram 1’, and ‘Glade’ Kentucky bluegrass.

As the success and importance of Dr. Funk’s work became apparent, seed companies in the Pacific Northwest began to hire their own breeders to work with Rutgers to stabilize, finalize, and improve seed production of new cultivars. Industry breeders have been successful in their Rutgers cooperation and have helped to dramatically increase seed yield through the years. For example a typical perennial ryegrass seed yield in 1970 might have been 800-1000 lbs per acre while cultivars yielding 2400 lbs per acre are commonplace now. So today’s great new Rutgers turfgrasses are generally great seed producers too. This has helped keep grass seed prices fairly stable.

In addition there are many newer turf seed companies established since Dr. Funk’s work began. In the early 1970s there were mainly forage and cheap lawn seed suppliers in the Pacific Northwest. There were no seed companies specializing in improved turf varieties. Now there are listed over 35 turfgrass seed suppliers selling improved varieties, most of which were developed at Rutgers.

The benefits to Pacific Northwest seed growers have been substantial. From small beginnings in the early 1970s, there are now hundreds of thousands of acres of highly profitable turf varieties being grown throughout the region. The high yields and higher prices have favorably impacted the profitability of seed growers compared to farmers growing most other crops.

Northwest seed industry cooperation with the Rutgers breeding program started by Dr. Funk continues to this day. The Rutgers experience, expertise and the New Jersey climate combine to produce elite turfgrasses that usually outperform varieties developed anywhere else. A quick look at the National Turfgrass Evaluation Program (NTEP) results confirms the dominance of Rutgers-developed varieties.

Dr. Reed Funk’s legacy continues to be felt. Under the capable guidance of Drs. Bill Meyer and Stacy Bonos, the Rutgers/Pacific Northwest turf seed connection is still thriving and will continue into the future. Continual improvements will keep coming from Rutgers. It is the best turf breeding program in the world.

Improving Perennial Plants for Food and Bioenergy

Tim Ford, President and Director of Plant Breeding Research

Improving Perennial Plants for Food and Bio-Energy (IPPFBE)

Improving Perennial Plants for Food and Bioenergy, Inc. (IPPFBE) is a 501.c.3 non-profit tree and perennial crops breeding station with eight sites in northern Utah and southern Idaho. It includes a large geographical area and represents even more potential regions throughout the semi-arid areas of the world. These zones account for a large percentage of the earth's terrestrial surface. IPPFBE believes that the earth provides abundant resources that can be used for the benefit of life by wise and prudent stewardship. The breeding of enhanced varieties of perennial plants such as trees, shrubs, forbs, and grasses can restore balance to the natural environment and produce abundant food, timber, and energy for humankind and conserve and enhance the quality of the earth's soil and the health of its people.

We have the ability to dramatically improve our environment, lifestyles, health, and future prosperity by dramatically increasing world biomass production to harvest excess carbon dioxide from the atmosphere. This would ensure adequate supplies of more nutritious and health promoting food, reduce our addiction to and dependence on fossil fuels, enhance our environment, and mitigate many of the causes of global warming and its disastrous effects. The greatest opportunities for increasing biomass production involve planting billions and eventually trillions of genetically improved trees and other perennial plants along with harvesting and replacing dead, dying, and inferior plants with adapted, productive cultivars to obtain a high percentage of plants in their rapid growth phase.

Perennial trees, shrubs, grasses, legumes and other forbs adapted to land not suitable for sustainable production of cultivated annual crops will produce much of the added food, timber, fuel, and fiber needed to feed, house, and supply energy to the current world's poor and hungry as well as to the projected population increases of the future. What is more, great opportunities exist for the genetic improvement and culture of hundreds of species of underutilized perennial plants capable of sustainable growth and production on the vast areas of degraded and other lands unsuitable for cultivated annual crops. We at IPPFBE are all very thankful for the generosity shown by many people, foremost Dr. C. Reed Funk.

POSTER PRESENTATIONS

SOLiD-SAGE of Endophyte-Infected Red Fescue Reveals Numerous Effects on Host Transcriptome and an Abundance of Highly Expressed Fungal Secreted Proteins

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The symbiotic relationship between endophytic fungi of the genera *Epichloë* and *Neotyphodium* with cool season grasses is well known. Several benefits such as resistance to herbivores, and improved drought tolerance to the hosts have been reported in these associations. However one benefit that appears to be unique to *Festuca rubra* (fine fescue) grasses is endophyte-mediated disease resistance to fungal pathogen diseases. In order to gain a better understanding of this rare occcurence, we performed a large scale quantitative transcriptome comparison using SOLiD-SAGE (Applied Biosystems) of endophyte-free and *Epichloë festucae*-infected *F. rubra*. This approach revealed over 200 plant genes involved in a wide variety of physiological processes that were statistically significantly differentially expressed between the two samples. Analysis of the endophyte transcripts revealed many expressed genes that were surprisingly abundant, with the most abundant fungal tag representing over 10% of the fungal mapped tags. Many secreted proteins were found to be abundantly present. The second most abundantly expressed fungal gene encodes a secreted antifungal protein. This antifungal protein is of particular interest in regards to the endophyte-mediated disease resistance. Similar genes in *Penicillium* and *Aspergillus* spp. have been shown to have antifungal activity. Strikingly, only one isolate of *E. festucae* and *Neotyphodium gansuense* var *inebrians* have an antifungal protein gene in the 10 epichloae whole genome sequences available. The uniqueness of this gene in *E. festucae* from *F. rubra*, its transcript abundance, and the secreted nature of the protein, all suggest it may be a candidate for involvement in the disease resistance conferred to the host, which to date has been reported only in the fine fescue–endophyte symbiosis.

A New Fungal Genus for the Two Causal Agents of Dollar Spot Disease of Turfgrass

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Dollar spot is one of the most economically important fungal diseases of warm- and cool-season turfgrass species. The disease is common, widespread, and persistent, with more money spent to control it than any other turfgrass disease. F.T. Bennett first described the cause of dollar spot as *Sclerotinia homoeocarpa* in 1937; however, the 'true' identity of this fungus has been the subject of much debate since the early 1970s. True *Sclerotinia* species produce apothecia from tuberoid sclerotia, a characteristic that is lacking in *S. homoeocarpa*, indicating that this pathogen was incorrectly named as part of the genus *Sclerotinia*. Morphological and rDNA sequence data has suggested that this pathogen is more accurately placed in the Rutstroemiaceae family than the Sclerotiniaceae family; however, additional data are needed to test this hypothesis. In the current study, our objectives were to use multilocus phylogenetic analysis and morphological assessments to determine the true identity of the fungus responsible for dollar spot disease of turfgrass, and to use this data to provide an accurate, valid, revised name for this important pathogen.

Eighty-four cultured fungal isolates belonging to the Sclerotiniaceae and Rutstroemiaceae families were evaluated in this study. These samples included isolates of *Ciboria*, *Lambertella*, *Lanzia*, *Monilinia*, *Poculum*, *Rutstroemia*, and *Sclerotinia* species, along with representative isolates of the dollar spot pathogen from both warm- and cool-season turfgrass hosts and three of Bennett's original strains. An additional 53 'fungarium' specimens (fungarium = dried fungal specimens or dried plant material exhibiting signs of fungal pathogens) were obtained from the U.S. National Fungus Collections in Beltsville, MD to provide anchors for phylogenetic trees. Samples ranged from 40 to 135 years old and included type specimens of species in the *Rutstroemia* and *Lambertella* genera. Preserved apothecia produced by the dollar spot pathogen in the U.K. during the early 1970s were also included in this study.

DNA was extracted from living fungal strains using standard protocols; however, all fungarium specimens and a small subset of living fungal strains required special handling. Specifically, fungarium specimens were purified using a proprietary resin compound to remove contaminant plant polysaccharides, whereas 24 living fungal strains required whole-genome amplification (WGA) using high-fidelity isothermal multiple displacement-based synthesis to produce DNA of sufficient quantity and purity to serve as templates for PCR amplification. Molecular data were generated through sequencing of eight standard phylogenetic markers from the 84 cultured samples: rDNA internal transcribed spacer region [ITS], calmodulin [CAL], translation elongation factor 1 alpha [TEF1], DNA replication factor Mcm7, actin, beta tubulin, and the large [LSU] and small subunits [SSU] of the rDNA. A custom PCR primer set was designed to amplify a ~200 bp fragment within the ITS1 marker from the degraded DNA of the fungarium specimens and the preserved apothecia. The majority of DNA sequences were generated directly from the amplification product, however, amplicons from the fungarium specimens and the 24 strains subjected to WGA required cloning prior to DNA sequencing. Individual phylogenetic gene trees were produced for each region, followed by one complete analysis that included all eight regions from the cultured isolates and the sequence data generated from the fungarium specimens.

Phylogenetic analysis revealed that the generic taxa *Ciboria*, *Lanzia*, *Lambertella*, *Poculum*, and *Rutstroemia* are polyphyletic. That is, they did not form a group that contained all members of a respective species. Despite these inconsistencies, isolates of the dollar spot fungus consistently clustered together in well-supported (posterior probability = 1) monophyletic groups across individual gene trees and multilocus phylogenies, distinct from the other samples. When compared to isolates of *Rutstroemia firma*, the type taxa for the genus *Rutstroemia*, the dollar spot isolates did not cluster with this species, indicating that they are not members of this genus. Within the dollar spot clade, two sub-clades were apparent (posterior probabilities = 1) in all gene trees. The first clade contained dollar spot isolates from North America, Asia and the European mainland, while the second clade consisted of dollar spot isolates only from the United Kingdom, including those isolates originally used by Bennett to describe the species. While the exact significance that this geographic differentiation plays in the disease cycle remains to be determined, it is clear that these two clades are genetically distinct from one another and represent unique species that are both capable of causing dollar spot disease symptoms on turfgrass.

The results of this research support the hypothesis that the dollar spot pathogens are not members of the genus *Sclerotinia*. Previous research has suggested that the dollar spot pathogens are more appropriately placed within an existing genus in the Rutstroemiaceae family such as *Rutstroemia*; however, our results demonstrate that this classification is not accurate. In fact, the segregation of the dollar spot isolates from all other known genera in the Rutstroemiaceae shows that these pathogens are not a member of any named genus in either the Rutstroemiaceae or Sclerotiniaceae families. Given these findings, we propose erecting a new genus for the dollar spot fungus. Further, our results support establishing two species within this new genus. The first species will describe those isolates collected by Bennett in the 1930s and other strains originating from the United Kingdom. The second species will describe the isolates of dollar spot disease originating from North America, Asia, and mainland Europe. In this presentation, we will provide an overview of the new names that will be proposed to identify the two pathogens that cause dollar spot on cool- and warm-season turf.

Growth and Physiological Responses of Creeping Bentgrass (*Agrostis stolonifera* L.) to Elevated Carbon Dioxide Concentrations

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Atmospheric CO_2 levels are predicted to double over the next century and research to date has focused mainly on effects to harvest yield only in agronomic crops. Little work has been performed investigating effects on vegetative growth of cultivated perennial grass species such as turfgrass. The objective of this study was to investigate effects of doubling ambient CO_2 on growth and physiological activities in a widely-utilized turfgrass species, creeping bentgrass (*Agrostis stolonifera* L. 'Penncross'). Plants were established in fritted clay medium and maintained under controlled-climate, well-irrigated conditions. Mature plants were trimmed to identical heights and placed in closed-top growth chambers set to 23.5/18.0 °C (day/night), 50% relative humidity, 800 µmol $m^{-1}s^{-1}$ (PAR), and either ambient (400±10 ppm) or elevated (800±10 ppm) CO_2 levels for twelve weeks. Turfgrass grown under elevated CO_2 displayed dramatic morphological changes compared to ambient controls including significant increases in stolon length (faster growth rate), stomatal density, and net weight of shoots and leaves. Elevated CO_2 caused a reduction in specific leaf area, leaf chlorophyll content, and total nonstructural carbohydrate content in shoots, while net root weight increased slightly and root-to-shoot ratio was unaffected. Increased rates of lateral spread and decreased rates of leaf vertical elongation are highly desirable traits in the turfgrass industry. Results from this study provide a basis for further investigation of mechanisms underlying changes in morphology and carbohydrate content in turfgrass plants responding to increased CO_2 levels and will also facilitate research into CO_2 interactions with abiotic stress such as drought and heat.

Nitrogen Fixation in Grass Seedlings: the Role of 'Air Roots' in Providing Nutrients for Seedling Development

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Plants contain diazotrophic bacteria that are the sources of nutrients used by plants to fuel growth and development. Some plants employ specialized plant organs such air roots that function in cultivation and extraction/oxidation of nutrients from symbiotic bacteria. Air roots are roots that do not penetrate soils but instead interface with the atmosphere. Epiphytic orchids, bromeliads, ferns and many vines (e.g., poison ivy, English ivy) produce air roots. In these plants the air roots contain intracellular bacteria that fix atmospheric nitrogen. These intracellular bacteria are oxidized in root hairs of air roots in order to extract nutrients that support plant growth. Cool-season grasses (e.g., tall fescue and perennial ryegrass) possess air roots in the seedling stage. On germination of the seed the first (primary) root that emerges is an air root. This air root generally extends over the surface of the soil. Shoot and soil penetrating roots form afterward. Experiments that we have conducted involving $15N_2$ isotope assimilation studies suggest that grass air roots function efficiently in atmospheric N_2 fixation. Several species of diazotrophic bacteria (including *Pantoea agglomerans* and *Pseudomonas* sp.) colonize the surface of air roots. These bacteria are degraded/oxidized by H_2O_2 that is secreted by the roots. However, surface bacteria may provide only a fraction of the nutrients that fuel grass seedling growth and development. Within cells of the air roots we have additionally observed intracellular bacteria that colonize the nuclear cavity of cells. The nuclear cavity is expected to be an area where oxygen is minimal and nitrogenase enzymes may function optimally. To date we have not been unable to isolate these nuclear-colonizing bacteria. We hypothesize that the intra-nuclear bacteria also provide nitrogenous nutrients for the developing seedling. We are presently working to identify these bacteria and are conducting experiments to evaluate their importance in nitrogen fixation in seedlings of cool-season grasses.

Fall Application Regimes of Methiozoline for Annual Bluegrass Control on Creeping Bentgrass Putting Greens

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Field studies were conducted in New Jersey from 2010 to 2012 to evaluate the use of methiozolin for annual bluegrass control in creeping bentgrass putting greens at Riverton, Metedeconk, and Charleston Springs Country Clubs. Methiozolin treatment regimes were 0.5, 1.0 and 2.0 kg/ha applied twice in Sept/Oct, Oct/Nov, and once in Nov. Methiozolin at 0.5 and 1.0 kg/ha were also applied three times in Sept/Oct/Nov. Annual bluegrass populations were high at Riverton (> 50%), low at Charleston Springs (<10%) and initially low at Metedeconk. However, by late Fall plots at Metedeconk averaged 30 to 40% annual bluegrass cover. Creeping bentgrass injury was not evident until the following March at all three locations. At Charleston Springs, creeping bentgrass injury was 33 and 24% when methiozolin was applied at 2.0 kg/ha in Oct/Nov and Sept/Oct, respectively. but less than 10% with all other treatments. However, in late March creeping bentgrass injury increased to 65 and 30% with these two treatments. In addition, injury with all other treatments increased to 9 to 30%. At Metedeconck, creeping bentgrass injury was most evident in Late March with 60 and 80% injury observed when methiozolin was applied at 2.0 kg/ha in Sept/Oct and Oct/Nov, respectively. Injury with other treatments ranged from 10 to 60%. At both locations, creeping bentgrass recovered rapidly with 30% injury or less with all treatments in early May. Many treatments which had shown noticeable injury in late March had completely recovered by early May. Annual bluegrass control was 85% or greater at both locations when methiozolin was applied at 1.0 kg/ha or greater regardless of application timing. Similar results were observed at Riverton when methiozolin was applied at 1.0 kg/ha or greater. These studies suggest that methiozolin can effectively reduce annual bluegrass populations dramatically when applied in the Fall. Studies were duplicated at Charleston Springs and Howell Country Clubs in the fall of 2012 with the elimination of the 2.0 kg/ha but similar treatment regimes. Methozoline again reduced annual bluegrass populations dramatically but required application rates of 1.0 kg/ha, especially when applied in October/November. In contrast to the previous year injury to creeping bentgrass was minimal with all application regimes at Charleston Springs but severe at Howell. However, creeping bentgrass did recover into the Spring.

AgroEcology of Organic Lawn Care

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Grass thrives on fertile soils around the world wherever tree cover is limited, herbivores roam, and climatic conditions are favorable. Grassland soils typically have naturally high levels of fertility and are among the most productive and agriculturally important land areas. Under the right conditions, growing grass naturally builds humus rich fertile soils. Human management and input is not a requirement to make grass to grow. However, in the case of the land area surrounding our homes, a modest level of husbandry can transform our "personal grassland" into a beautiful verdant sod we enjoy as lawn. Cool season grasses, especially the improved cultivars of Kentucky bluegrass, perennial ryegrass, and tall fescue, are capable of producing a dark green dense sod on most soils of New Jersey. A key factor is creating the right soil conditions before seeding or establishment to allow these grasses to grow and express their natural genetic potential. Organic methods of farming are in many ways rooted in agroecology, especially with respect to soil fertility. One of the fundamental principles of organic farming is to create soil fertility conditions that optimize the biological and physical conditions along with nutrient supply such that crops (and animals, including people) thrive and resist challenges from pests and disease. From the organic perspective, soil fertility is a much broader term than its use in conventional agriculture where it tends to be defined primarily in terms of chemistry. Soil fertility in organic farming is more inclusive and has historically considered qualitative factors such as soil health. Soil fertility is a function of the whole farming ecosystem where biology fully employs synergisms among diverse organisms in the cycling of nutrients and organic matter while producing plant and animal benefits. In the case of organic lawn care, what needs to be accomplished is translation of organic farming principles into this uniquely managed ecosystem. Cultural practices must be adapted to a grass growing area while achieving acceptable quality for human utility and viewing pleasure. In organic farming the main function of growing grass is the feeding of livestock such as cattle. But in the case of an organic lawn, the mechanical lawn mower displaces the living grazing cow. On pasture grazed by herbivores, roughly 80% of the plant nutrients derived from the soil are returned to the soil as manure. This local nutrient cycling goes a long ways towards sustaining soil fertility. In the case of organic lawn care, the practice of mowing and leaving clippings, wherever possible, serves essentially the same function.

The above is a preamble for a publication that will describe how to implement the general principles of organic culture as they apply to organic lawn care. The highlights of organic culture include 1) practicing the law of return, 2) composting, 3) amending soils with naturally occurring materials as may be necessary to supply essential nutrients, 4) deep tillage to break up soil compaction, 5) seeding lawns with the best adapted cultivars from conventional plant breeding, 6) encouraging biodiversity by accepting of legumes or having some tolerance for "weeds" in the landscape, 7) treating the landscape as a whole living system, 8) avoiding the use of prohibited materials as outlined in the USDA

National Organic Program standards, 9) employing careful management rather than input substitution, and 10) communicating with honesty and integrity about what is being labeled organic lawn care.

Proteomic Profiling for Metabolic Pathways Regulated by Cytokinin, Ethylene Inhibitor and Nitrogen for Improved Heat Tolerance in Creeping Bentgrass

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Heat is a major abiotic stress affecting creeping bentgrasses leading to premature senescence and decline in overall quality. Previous studies have separately shown that applications of nitrogen, cytokinins or ethylene inhibitors may have a beneficial role for heat tolerance by delaying damaging stress induced senescence, although the mechanisms of such treatments are not fully understood. 'Penncross' plugs were transferred to plastic pots and moved to a growth chamber. Plants were exposed to heat stress at 35/30 C (day/night temperatures) for 4 weeks. Treatments consisted of 1) urea, a commonly used nitrogen source, applied at a rate of 45.36 g / 92.9 meters^2, 2) Zeatin-riboside a naturally occurring form of cytokinin applied at 25 µM concentration, and 3) aminoethoxyvinylglycine, an ethylene inhibitor, applied at 25 µM concentration. Additionally, a combination of all three of the previously mentioned treatments and a control consisting of water were also applied. All were applied at a volume which saturated the canopy three days prior to the stress treatment, and then at weekly intervals during the stress period. Throughout the stress period overall turf quality ratings were taken along with chlorophyll content and membrane stability measurements to estimate the progress of leaf senescence and plant health. At three weeks of heat treatment the ethylene inhibitor, cytokinin and combination treatment all had maintained significantly higher levels of over all quality. The nitrogen and combination treatment had maintained significantly higher chlorophyll content and the ethylene inhibitor, cytokinin, nitrogen and combination treatment all had significantly lower electrolyte leakage compared to the control treatment, demonstrating superior membrane stability also at three weeks of heat stress. Leaf tissue samples were also collected for protein analysis. Proteins were extracted and subjected to 2D SDS-PAGE to separate proteins and software was used to identify those spots that had differentially accumulated during treatment. Proteins altered by the application of nitrogen, cytokinins, and ethylene inhibitor under heat stress included those involved in photosynthesis, energy production and respiration, as well as proteins associated with stress defense, all of which are important metabolic pathways related to heat tolerance. Examining the protein changes associated with these treatments under heat stress will help determine important mechanisms responsible for delaying senescence and this information can than be used to create more heat tolerant plants.

Role of Plant Volatiles in Host Recognition and Preference by Annual Bluegrass Weevil, *Listronotus maculicollis* (Coleoptera: Curculionidae)

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The annual bluegrass weevil (ABW), *Listronotus maculicollis*, is a severe and expanding pest of short-mown golf course turf. Presently, chemical control is the only effective and commonly used management strategy. However, development of resistance to pyrethroids made it clear, that reliance on a single management strategy is no longer sustainable. Annual bluegrass, *Poa annua*, is generally considered to be a preferred host of ABW and/or particularly susceptible to it based on observations that severe ABW damage typically occurs in areas with a high percentage of *P. annua*. However, limited experimental data are available on ABW host plant interaction. Improved understanding of ABW host plant interaction is important in ABW management because host plant resistance could be used as an alternative strategy and plant emitted attractants could be used for monitoring and in an attract-and-kill strategy. The overall objective of this study was to determine the ovipositional preferences of ABW and investigate the role of grass-emitted volatiles in ABW host preference.

A series of laboratory choice experiments was conducted to determine ABW oviposition preferences among *Poa annua* (wild type) and three bentgrass species: 1) creeping bentgrass, *Agrostis stolonifera* L. (cvs. 'L93', 'Penncross', '007' and 'Declaration'); 2) colonial bentgrass, *A. capillaris* L. cv. 'Capri'; and 3) velvet bentgrass, *A. canina* L. cv. 'Greenwich'. Each experimental run had 4 experimental arenas with 4 choices provided for ABW adults (10 males, 10 females): 4 arenas with *P. annua*, cv. 'L93', cv. '007', and cv. 'Greenwich' and 4 arenas with *P. annua*, cv. 'Penncross', cv. 'Declaration', and cv. 'Capri'. Three phenologically different ABW populations were tested separately: 1) overwintering generation adults collected from overwintering sites in fall; 2) overwintering generation adults collected from short cut turf in spring; and 3) spring generation adults hand-picked from short-cut turf in summer.

To determine if plant emitted volatiles play an important role in ABW, a host plant preference experiment with the same methodology as above was repeated but the adults' antennae were painted to block any chemical cues emitted by grasses. Two types of control were used for each run: (1) untreated adults and (2) adults with a similar amount of enamel applied on the elytra to ensure that the paint itself did not affect behavior and oviposition.

The olfactory responses of adults to the 6 bentgrass cultivars ('L-93', 'Penncross', 'Declaration', 'OO7', 'Capri' and 'Villa') and *P. annua* were tested using a Y-tube olfactometer. Two sets of experiments were conducted: adults were given choice between (1) a grass and control or (2) between a bentgrass and *P. annua.*

Headspace volatiles of 6 bentgrass cultivars and *P. annua* were collected using a push–pull volatile collection system in a greenhouse. In each collection run, 3 different bentgrass cultivars and *P. annua* were used. Volatiles were collected for 72 h and samples processed using gas chromatography-mass spectrometry.

Choice bioassays clearly demonstrated that ABW females preferred *P. annua* to other cultivars tested for in experiments with all three phenologically different populations. Differences among bentgrass cultivars were not statistically significant; however, numerically the percent of eggs laid in 'Declaration' and 'Greenwich' plugs was the lowest for all adult types. When ABW were sensory deprived (antennae blocked), females did not exhibit ovipositional preferences (up to 60% of all eggs were laid in bentgrasses). This suggests that grass volatiles are at least partially involved in ABW host plant selection for oviposition. Furthermore, olfactometer assays demonstrated that if given a choice between control and grass plugs, ABW females preferred *P. annua* and were repelled by 'Villa' and 'Declaration'. Males did not exhibit any preference or repellency. If given a choice between *P. annua* and bentgrass cultivars, females preferred *P. annua* to all tested cultivars, except 'Capri'.

Eighteen different compounds were identified in headspace volatile blends of *P. annua* and 6 bentgrass cultivars. Most identified compounds were monoterpenes and sesquiterpenes. Volatile profile of *P. annua* differed from those of bentgrasses, especially creeping bentgrasses (cvs. 'Declaration' and '007'). Principal component analysis and the score plot of two main principal components (PC1 versus PC2) showed that the volatile blend composition of *P. annua* and bentgrasses slightly overlap, and *P. annua* was most distant from creeping bentgrass cvs. *P. annua* emitted higher quantities of the green leaf volatile 3-hexenyl acetate and the terpenoid linalool, whereas creeping bentgrasses emitted more of the terpenoids: borneol, camphene, and sabinene, α-pinene, camphene, sabinene, terpinolene and ocimene. The highest amount of E-α-bergamotene was emitted by velvet bentgrass 'Villa'.

Cryptic Population Genetic Structure of *Waitea circinata* var. *circinata* Infecting Turfgrass

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Waitea circinata var. *circinata* (henceforth, WCC) is an emerging pathogen of turfgrass in North America that causes brown ring patch. Here, we deployed seven highly polymorphic microsatellite markers for population genetic study of this pathogen. We analyzed the genetic diversity and structure of eastern and western US populations of WCC, as well as the association with host, colony growth rates, and sclerotium emergence. Genetic diversity and genotypic richness were higher in eastern than in western populations, but the two populations were not strongly differentiated from each other on average (F_{ST} = 0.014), indicating exchange across taxonomic boundaries. Interestingly, Bayesian clustering analysis revealed three cryptic populations within each of these geographic subdivisions. The majority of isolates from mixed stands of annual bluegrass and creeping bentgrass tended to cluster together, but the association was poorly supported by UPGMA clustering, suggesting that turfgrass cultivar may not be the organizing factor in that subdivision. Other phenotypes showed no obvious correspondence with the Bayesian clusters, but isolates that were in close proximity did tend to cluster together. Analysis of increasing population divergence with geographic distance (IBD) revealed a significant within population expansion ($R^2 > 0.1088$, $P < 0.05$), which became more stochastic among populations ($R^2 = 0.0381$, $P = 0.062$). The Bayesian clustering also supported differentiation of sclerotium emergence phenotype ($Q_{ST} > F_{ST}$), suggesting that natural selection has caused evolutionary divergence of the sclerotium phenotype, in response to divergent environmental conditions. However, Q_{ST} = 0.201 suggests that the two populations have not been isolated for a long period of time.

Comparing the Rutgers Wear Simulator, Cady Traffic Simulator, and Brinkman Traffic Simulator

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Machines have been developed to impart wear (Rutgers Wear Simulator [RWS]) or the combined stresses of wear and compaction (Cady Traffic Simulator [CTS] and Brinkman Traffic Simulator [BTS]) on turfgrass. The objective of these trials was to evaluate the effects of traffic simulators on tall fescue (*Festuca arundinacea* Schreb. 'Falcon V'), perennial ryegrass (*Lolium perenne* L. 'Derby XTreme'), and Kentucky bluegrass (*Poa pratensis* L. 'Midnight II'). Each species-trial was seeded September 2010 on a loam in North Brunswick, NJ. Treatments consisted of a control and 28 passes of the RWS, CTS, and BTS (4 passes per week) from 5 Oct. to 17 Nov. 2011. Quality, bruising, divoting and fullness of turf canopy (FTC) were visually assessed. Green cover was determined by digital image analysis. All machines reduced FTC by 8 passes compared to the control in all species-trials. On tall fescue, the RWS and CTS reduced quality and FTC more than the BTS; reductions were more rapid with the CTS. On perennial ryegrass, reductions in quality and FTC were more similar among machines. In Kentucky bluegrass, reductions in quality and FTC occurred most rapidly with the CTS and BTS but these parameters were similar among all machines by the end of the trial. Green cover at the end of the traffic period was lowest and bruising injury was more severe in RWS plots for all species-trials. Divot injury was virtually absent with the CTS and most severe with the BTS for all species-trials.
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A Viability Assay to Evaluate Direct Effects of Biological Control Agents on Fungal Cells

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There is substantial interest in understanding the mechanisms by which bacteria can biologically control diseases of turfgrass and other plants. However, few methods are available that can quantify direct effects of bacteria on fungal cells. Here we describe an *in vitro* cell suspension assay using the tetrazolium salt MTT as a viability stain to assess the direct effects of the soilborne bacterium *Lysobacter enzymogenes* strain C3 on hyphal cells of filamentous fungi. The effects of bacterial cell density, fungal age and the physiological state of fungal mycelia on fungal cell viability were evaluated over 72 h periods. As expected, increased bacterial cell density correlated with reduced fungal cell viability over time. However, bacterial effects on fungal cell viability were also influenced by both age and physiological state of the fungal mycelium. Cells from one-week-old mycelia lost viability at a greater rate compared with two-week-old mycelia. Likewise, loosely-packed hyphal cells obtained from the lower layer of the mycelial pellicle lost viability at a greater rate compared with cells from the hardened upper layer of the mycelial pellicle. Results of this study indicate that the tetrazolium salt MTT can be used effectively to measure reduction in fungal cell viability during interactions with bacteria. Furthermore, this cell suspension assay provides a rapid means to screen antimicrobial agents, including new and novel antifungal compounds as well as potential biological control agents, to evaluate their effectiveness against various turfgrass pathogens.

Detection of *Neotyphodium* spp. in Tall and Fine Fescue by Immunoblot Screening

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We have screened tillers and seeds from *Festuca* spp. plants for the presence of endophyte (*Neotyphodium* spp.) using an immunoblot kit from Agrinostics, Ltd. Co. (Watkinsville, GA, USA). This kit is a solid phase stacked immunoblot assay in which monoclonal antibodies generated to *Neotyphodium* spp. cell wall proteins will react to *Neotyphodium* spp. proteins present in *Festuca* spp. tillers and seeds. The limit of detection of *Neotyphodium* spp. in seed is 50 ng/seed and in tillers it is 50 ng/1.6 mm tiller cross section. Immunoblot screening is a more rapid and accurate technique for *Neotyphodium* detection compared to microscopy.

We have screened over 600 plants from a collection of fine fescue from crossing blocks located at the Rutgers Plant Science Research and Extension Farm in Adelphia, NJ. We screened the Chewing's fescue collection, the hard fescue collection, and the strong creeping red fescue collection. Eighty-five percent of tillers obtained from the Chewing's fescue collection were found to be endophyte positive (E+) and 15% were endophyte negative (E-). Tillers from the hard fescue crossing blocks in Adelphia, NJ were 80% E+ and 20% E-, and 100% of tillers from plants from the strong creeping red fescue crossing blocks were E+. There may be a correlation between presence of endophyte and dollar spot resistance in hard fescue.

Seeds were screened from 88 tall fescue cultivars established at the Rutgers Research and Extension Farm in Adelphia, NJ for endophyte as part of the NTEP tall fescue trial. One hundred seeds per cultivar were used for the evaluation. The range of endophyte infection in the tall fescue cultivars ranged from a high of 100% to a low of 0%. There were three cultivars, which had a 0% infection level. There were also eight cultivars, which had infection levels less than 20%. A majority of the cultivars (80%) tested had *Neotyphodium* infection levels ≥90% and the rest (25) had an infection level above 20%, but below 90%. Selections with ≥90% infection levels meet the legal requirements for breeding and use at airports attempting to reduce geese and migratory bird populations in take off and landing zones.

Endophytes are well-known for the ability to improve environmental and biological stress resistance in grasses, but some produce alkaloids that are detrimental to the health of forage animals. A rapid and accurate method for endophyte screening is critical for selecting plant material that is E+ for turfgrass breeding programs but E- for pasture breeding programs.

Distribution and Pathogenicity of Bacteria Associated with Etiolation or Decline in Creeping Bentgrass

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In recent years, bacteria have been implicated as causal agents in multiple cases of decline of creeping bentgrass (CBG; *Agrostis stolonifera* L.), but little research has been completed to characterize potentially pathogenic bacteria in turf. During 2011 and 2012, 156 bacterial isolates were obtained from CBG turf exhibiting etiolation, chlorosis, or general decline. The majority of the isolates were obtained from the southeastern and mid-Atlantic U.S. Symptomatic tissue was surface sterilized by submersion in 10% sodium hypochlorite for 5 min; disinfested samples were then cut and placed in sterile water allowing the endophytic bacteria to emerge from infected tissue. The resulting suspension was then streaked on nutrient agar and distinct colonies were isolated using the T-streak method. Preliminary identification was obtained by sequencing of the 16S and ITS rDNA regions followed by a BLAST search in GenBank. Sixteen genera including several species of *Pseudomonas*, *Pantoea*, *Microbacterium*, *Acidovorax*, and *Xanthomonas* were identified based on high similarity (i.e., >95%) to deposited sequences in GenBank. Selected isolates for each genus were tested for pathogenicity by submerging freshly trimmed 4-wk old 'G-2' CBG seedlings in a bacterial suspension containing 10^9 CFU $ml^{-1}$for 6 min. Inoculated plants were placed on a mist bench (misting 5 min/6 hr) in the greenhouse (28-30 C) for 7-days, followed by placement on a greenhouse bench that received hand-held irrigation applied twice daily. Plants were evaluated periodically for symptom development for 14 days. *Acidovorax avenae*, *Pantoea ananatis*, and *Xanthomonas translucens* visually reduced turf quality compared to the untreated check within 10 days post inoculation. Inoculated plants developed leaf tip dieback that progressed into an overall decline. In the field, the pathogenicity of *A. avenae*, *P. ananatis*, and *X. translucens* was tested by applying 100 ml of a 10^8 CFU/ml suspension of individual isolates to a 113 cm^2 turf area and then covering plants overnight with a clear plastic bowl (355 ml, Amscan Holdings. Inc.). Day and night temperatures during field inoculations were approximately 35 and 20 C, respectively. While dieback or decline was not observed, plants treated with *A. avenae* had significantly more etiolated tillers 48 hr post inoculation compared to those inoculated with *X. translucens*, *P. ananatis*, and non-inoculated plants. Additional research is being conducted to further assess the pathogenicity of *X. translucens* and *P. ananatis* on CBG turf.

Inheritance of Turf Density and Ground Coverage in Tall Fescue [*Lolium arundinaceum* (Schreb.) Darbysh.]

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Tall fescue [*Lolium arundenaceum*, (Schreb.) Darbysh.] (2n=6x=42) is a cool season, perennial, self-incompatible, bunch type turfgrass which spreads primarily by erect tillers. It is widely used in athletic fields, home lawns, golf course roughs and sod production; however, its bunch type growth habit can limit its utility in other areas. Some genotypes in tall fescue are reported to have short rhizomes and/or a rapid tillering rate, suggesting that it may be possible to produce tall fescue cultivars with these traits by selective breeding. Tillers improve longevity, turf density, spreading ability, wear tolerance and compactness, while rhizomes increase recuperative ability from damage, help in persistence under drought and temperature extremes, and improve sod strength.

The growth habit of several tall fescue genotypes was classified as: bunch type which spread by erect tillers; rapid tillering type which spread by rapidly forming lateral tillers; or rhizome type which produce rhizomes along with tillers. Two genotypes from each growth type were selected and allowed to cross in the greenhouse in a diallel crossing scheme which includes all possible combinations of crosses between these six genotypes. Progenies were planted in the field in randomized complete block design with four replications.

Data was analyzed for turf density and ground coverage (cm^2) to estimate narrow sense heritability, maternal effect and heterosis in tall fescue. The narrow sense heritability estimate was higher for turf density than ground coverage. The crosses between bunch types with rapid tillering types exhibited significant heterosis and maternal effects for turf density and ground coverage.

Diallel analysis proved useful to evaluate the performance of parents based on progeny tests, selecting superior parents, and improving breeding efficiency for the rapid tillering rate in tall fescue.

Anthracnose Severity of Annual Bluegrass Turf as Affected by Nitrogen Source

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Anthracnose, caused by *Colletotrichum cereale* Manns, is a common fungal disease of annual bluegrass (ABG) [*Poa annua* L. *f. reptans* (Hausskn) T. Koyama] putting greens in the United States. Previous research at Rutgers University has shown that increasing ammonium nitrate rates up to 9.8 kg ha^{-1} wk^{-1} reduced anthracnose severity compared to lower nitrogen (N) rates. However, additional research is needed to determine the effect of N source on anthracnose severity. The objective of this field study was to evaluate the effect of soluble-N source on anthracnose severity and to determine if soluble-N source alters the effect of N frequency (rate) on this disease during mid-season. This three-year field trial was initiated spring 2010 in North Brunswick, NJ on an ABG turf maintained at 3.2 mm. The study was moved to a second location in spring 2011 because of significant winter injury and remained at this location for the subsequent two years. The experimental design was a randomized complete block design with 4 replications. Nitrogen treatments were applied at 4.9 kg N ha^{-1} every 7- or 14-d as solutions of ammonium sulfate ($(NH_4)_2SO_4$), ammonium nitrate (NH_4NO_3), urea (CH_4N_20), calcium nitrate ($Ca(NO_3)_2$), or potassium nitrate (KNO_3). Analysis of variance from three years indicated that soluble N source had a significant impact on disease severity. In general, potassium nitrate treatments had the lowest anthracnose severity; whereas, ammonium sulfate treatments had the greatest anthracnose severity. Application frequency also had a significant impact on disease severity throughout the study. Weekly applications of soluble N consistently reduced disease severity compared to biweekly applications. Biweekly applications of all soluble N sources tested in this study did not provide a sufficient amount of N required to reduce anthracnose severity. Interaction data from 2011 and 2012 suggest that weekly applications of potassium nitrate were required to significantly reduce anthracnose severity.

Sand Topdressing Programming Effects on Anthracnose Disease of Annual Bluegrass Putting Green Turf

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Sand topdressing applied to annual bluegrass (*Poa annua* L. f. *reptans* [Hauskins] T. Koyama) putting green turf during the summer can reduce the severity of anthracnose (caused by *Colletotrichum cereale* Manns). However, the effects of topdressing during spring and autumn on this disease are not well understood. A two-year field study was initiated in autumn 2010 to evaluate the impact of autumn, spring, and summer topdressing with medium sand on anthracnose severity of annual bluegrass turf mowed at 2.8 mm. The trial was arranged as a 3 x 3 x 3 factorial in a randomized complete block design with 4 replications. Autumn and spring topdressing were applied at rates of 0, 1.2, or 2.4 L m^{-2}. Biweekly summer topdressing was applied at 0, 0.075 L m^{-2} or 0.15 L m^{-2}. To date, interactions among autumn, spring, and summer topdressing have not been observed. In 2011 and 2012, the spring rate effect accounted for more of the variation (10% and 37%, respectively) in disease response than autumn and summer topdressing. Generally, greater topdressing rates provided better disease suppression. Autumn topdressing was more effective in suppressing anthracnose than summer topdressing. Biweekly summer topdressing did not affect anthracnose severity until July 2012, probably because less sand accumulated in the canopy due to the low summer sand rates used in this study.

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