Turfgrass and Environmental Research Online

Using Science to Benefit Golf

The 2010 USGA Turfgrass and Environmental Research Summary is an annual compilation of projects currently funded by the USGA Turfgrass and Environmental Research Program.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 450 projects at a cost of $31 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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2010 USGA Turfgrass and Environmental Research Summary

Jeff L. Nus, Ph.D.
Editor

Since 1983, the United States Golf Association has funded more than 450 university research projects at 39 universities at a cost of over $34 million. The Turfgrass and Environmental Research Program provides direction to these institutions and employs **science as the foundation to benefit golf** in the areas of turfgrass and resource management, sustainable development, and environmental protection. At the end of each year, the USGA provides a summary of the research conducted under this important national program and this report summarizes the results from 2010.

There are two primary goals of the research program. The first is to develop turfgrasses and cultural systems with better stress tolerance and reduced water requirements and pesticide use. To address the USGA's first research goal, 22 research projects were funded in integrated turfgrass management, physiology, breeding, genetics, and course construction practices. The second goal is to investigate environmental issues and sustainable resource management for golf courses. Two of the research projects investigate the environmental impact of golf courses.

The research program actively coordinates and supports research, associated educational programs, and other partnerships to benefit golf, the environment, and people. For example, the USGA, GCSAA, and the National Turfgrass Evaluation Program (NTEP) together have developed turfgrass variety testing programs conducted on golf courses throughout the United States. In addition, the USGA works with state research foundations and superintendent chapters to fund applied research through the Grant-in-Aid Research Program. Nine research projects in this report are funded by the Grant-in-Aid Research Program. This summary also includes a report in the Product Testing category of the USGA Turfgrass and Environmental Research Program.

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The United States Golf Association Turfgrass and Environmental Research Program

Vision

Use science as the foundation to benefit golf in the areas of turfgrass and resource management, sustainable development and environmental protection.

Mission

Coordinate and support research, associated educational programs, and partnerships to benefit golf, the environment, and people.

Goals

Develop turfgrasses and cultural systems with enhanced stress tolerance and reduced supplemental water requirements, pesticide use and costs.

- *Course Construction Practices*
- *Integrated Turfgrass Management*
- *Breeding, Genetics, and Physiology*

Investigate environmental issues and sustainable resource management for golf courses.

- *Environmental Impact of Golf Courses*
- *Wildlife and Habitat Management*

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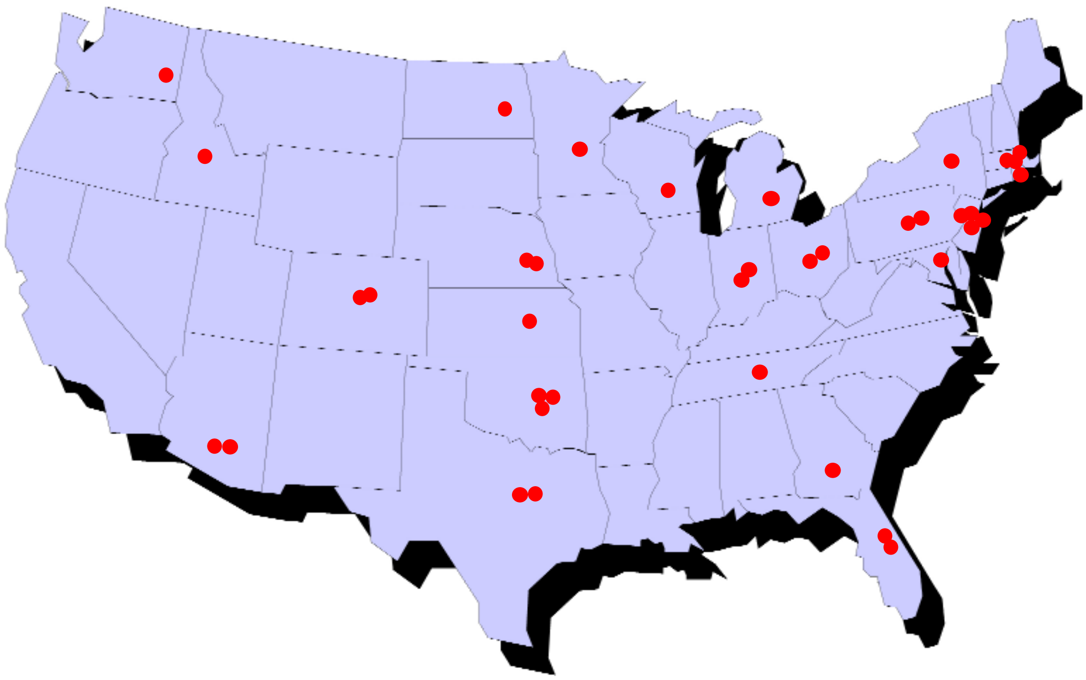
Location of 2010 projects funded by the USGA Turfgrass and Environmental Research Program



USGA Green Section Turfgrass and Environmental Research Project Grants in 2010

Project Area	Number	Grant $	% of Total
Integrated Turfgrass Management	**8**	**154,771**	**24.6 %**
Sustainable Management	4	75,764	12.0 %
Pathology	3	69,007	10.9 %
Entomology	1	10,000	1.7 %
Breeding, Genetics, and Physiology	**17**	**377,354**	**59.9 %**
Cool-season Grasses	7	161,177	25.6 %
Warm-season Grasses	5	110,193	17.5 %
New or Native Grasses	5	105,984	16.8 %
Environmental Impact	**2**	**41,600**	**6.6 %**
Fate and Transport	2	41,600	6.6 %
Outreach Programs	**12**	**56,500**	**8.9 %**
Grant-in-Aid Research Program	9	31,000	4.9 %
Product Testing	1	16,000	2.5 %
Cooperative Research-Allied Assoc.s	2	9,500	1.5 %
Total	**39**	**$ 630,225**	**100.0 %**

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Integrated Turfgrass Management

Improved turfgrasses developed for use on golf courses require management practices that provide quality playing surfaces while conserving natural resources and protecting the environment. A series of research projects are being funded with the aim of conserving natural resources by reducing the use of water, pesticides, and fertilizers. These studies will focus on the following objectives:

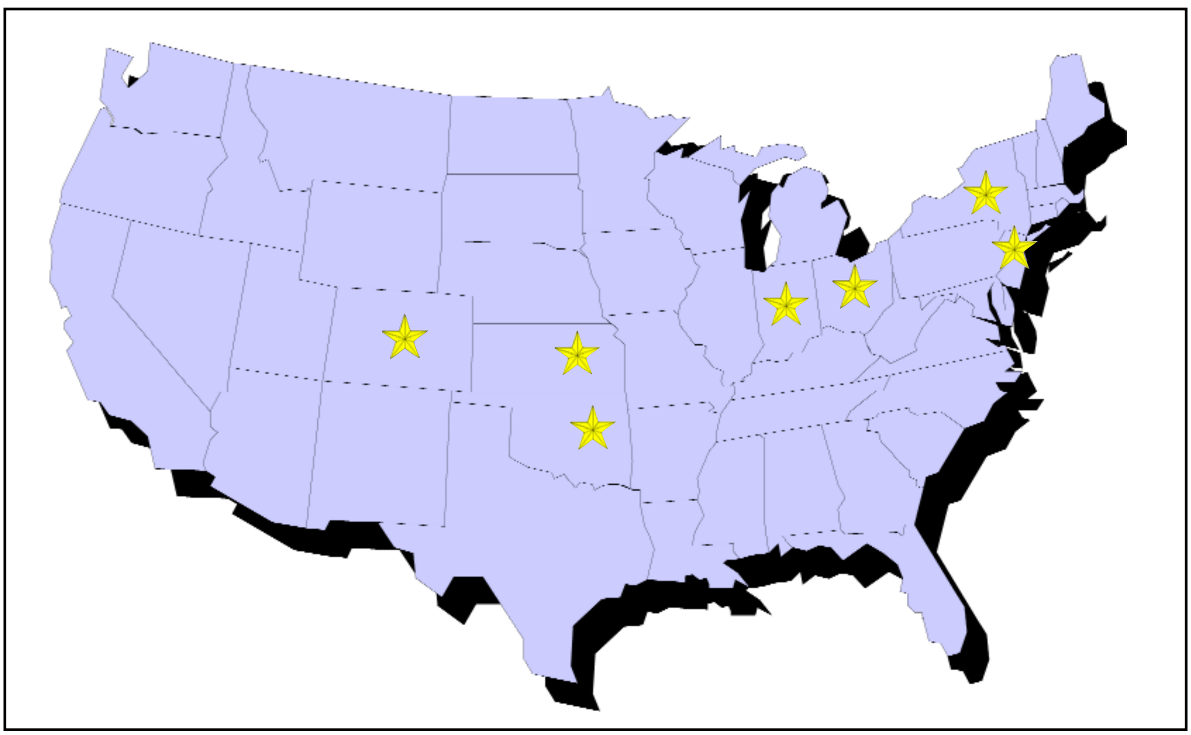
1. Develop cultural practices that allow efficient turfgrass management under unique conditions, such as poor quality soils, shade, and marginal quality water.

2. Determine the range of adaptability and stress tolerance of turfgrasses.

3. Evaluate direct and interacting effects of two or three cultural practices like mowing, irrigation, fertilization, cultivation, compost utilization, and develop programs to control pests and organic matter accumulation (thatch).

4. Investigate pest management practices such as biological, cultural, and mechanical controls, application of turf management practices utilizing IPM and reduced inputs, and pest modeling and forecasting.

The results of these studies should lead to the development of turfgrass management programs that conserve our natural resources and reduce costs, with minimal impairment of playing quality conditions or aesthetic appeal. We encourage regional cooperation among researchers where similar climactic and soil conditions exist.



Location of projects funded in 2010 by the USGA Turfgrass and Environmental Research Program under the category of Integrated Turfgrass Management

Developing Best Management Practices for Anthracnose Disease on Annual Bluegrass Putting Green Turf

James A. Murphy, Bruce B. Clarke, Joseph A. Roberts, Charles J. Schmid, and James W. Hempfling
Rutgers University

Objectives:

1. Four field studies on annual bluegrass putting green turf were designed to evaluate the main effect and interactions of (1) irrigation quantity, (2) lightweight rollers and mowing equipment, (3) topdressing and foot traffic, and (4) nitrogen fertilization on anthracnose disease.

Start Date: 2008
Project Duration: 3 years
Total Funding: $90,000

Anthracnose, caused by *Colletotrichum cereale*, is a destructive disease of annual bluegrass putting green turf throughout the United States. The frequency and severity of anthracnose outbreaks on putting greens has increased over the past two decades and management practices employed to improve playability (green speed) on putting greens have been observed to be partly responsible.

Research completed in 2008 and 2009 generated these major conclusions: (1) deficit irrigation (40% daily ET_o replacement) causing wilt stress increased the severity of disease compared to greater irrigation quantities; (2) both sidewinder and triplex mounted vibratory rolling reduced disease severity compared to non-rolled turf under moderate disease pressure; (3) sand topdressing reduced disease severity regardless of foot traffic level; unexpectedly, foot traffic decreased anthracnose regardless of sand topdressing level; (4) frequent summer soluble N fertilization applied at the highest rate (0.1 lb per 1,000 ft^2 every 7 days or 0.2 lb per 1,000 ft^2 every 14 days) had the greatest reduction in anthracnose severity.

A study was initiated in 2009 to identify the rate of soluble N fertilization applied during the summer that would produce the greatest reduction in anthracnose severity. During the first half of the season, N fertilization of 0.4 lb/1000 ft^2 every 7 days consistently produced the lowest anthracnose severity. During the last half of the season (mid-July to mid-August), however, 0.4 and 0.5 lb/1,000 ft^2 every week increased disease and only 0.2 lb/1,000 ft^2 every week was needed for the greatest reduction in anthracnose severity. Integration of data over the entire season (AUDPC) indicated that 0.2 lb/1,000 ft^2 N applied every week had the best overall reduction in disease severity.

Management practices (lower mowing height) used to increase green speed have been partly responsible for the recent increase in outbreaks of anthracnose

A nitrogen programming study examined spring and autumn N fertilization (granular) in combination with summer soluble N fertilization. Spring granular N fertilization reduced disease severity compared to autumn granular N fertilization on all but two rating dates (August 26, 2009 and May 21, 2010). The rate of granular N fertilization also affected disease severity; N applied at an annual rate of 4.5 lb/1,000 ft^2 had less disease than plots that received N at 3.0, 1.5, and 0 lb/1,000 ft^2. An interaction between season and granular N rate indicated that spring N fertilization in combination with greater granular-N rates had the greatest reduction in disease severity while autumn granular N fertilization rate had little influence on disease severity.

Soluble N fertilization during the summer also influenced disease severity in both years of this trial. Nitrogen applied at 0.375 lb/1,000 ft^2/month had the greatest reduction in anthracnose severity compared to N fertilization at 0, 0.094, and 0.188 lb per 1,000 ft^2 per month. Plots that received no summer soluble N fertilization had the greatest anthracnose severity.

A study to determine the effect of soluble N sources on anthracnose severity was initiated in the summer of 2010. Six soluble N sources (ammonium nitrate, ammonium sulfate, calcium nitrate, potassium nitrate, urea, UMAXX 47-0-0) were applied at 0.1 lb/1,000 ft^2 every week or biweekly for 12 weeks. The first year of data indicated that N applied every week compared to biweekly reduced anthracnose severity on two out of the four sampling dates. The nitrogen source effect was also significant on three out of four rating dates.

Summary Points

- Deficit irrigation (40% ET_o) induced wilt stress and intensified anthracnose severity. Irrigation at 80% ET_o often resulted in the lowest anthracnose severity and best turf quality.
- Lightweight rolling every other day with either roller type (i.e., sidewinder or triplex mounted vibratory) increased ball-roll distance and decreased anthracnose severity under moderate disease pressure.
- Sand topdressing reduced anthracnose severity under both foot traffic and non-trafficked conditions. Moreover, daily foot traffic decreased anthracnose severity regardless of sand topdressing level. The lowest disease severity and best turf quality occurred on plots receiving the combination of daily foot traffic with weekly sand topdressing.
- From the short-term perspective of early in the season (spring), anthracnose severity decreased linearly as the rate of N fertilization increased up to approximately 0.4 lb/1,000 ft^2/week. Over the course of the entire growing season, however, anthracnose severity decreased linearly as the rate of N fertilization increased up to 0.2 lb/1,000 ft^2/week, after which greater N rates increased disease severity.
- Spring granular N fertilization, particularly at greater N rates, contributed to the suppression of anthracnose severity more than autumn fertilization. Increasing the monthly soluble N rate during the summer also decreased anthracnose severity regardless of the granular N regime.

Infection and Colonization of Bermudagrass by Ophiosphaerella herpotricha*, a Causal Agent of Spring Dead Spot*

Nathan R. Walker, Stephen M. Marek, Yanqi Wu, and Damon Smith
Oklahoma State University

Thomas K. Mitchell
Ohio State University

Objectives:

1. Transform *Ophiosphaerella korrae* to express green (GFP) and red fluorescent (tdTom) proteins.
2. Compare and contrast infection and colonization of roots and stolons/rhizomes of resistant and susceptible interspecific hybrid, common, and African bermudagrasses by *O. herpotricha* and *O. korrae* that express fluorescent proteins.

Start Date: 2010
Project Duration: 3 years
Total Funding: $57,657

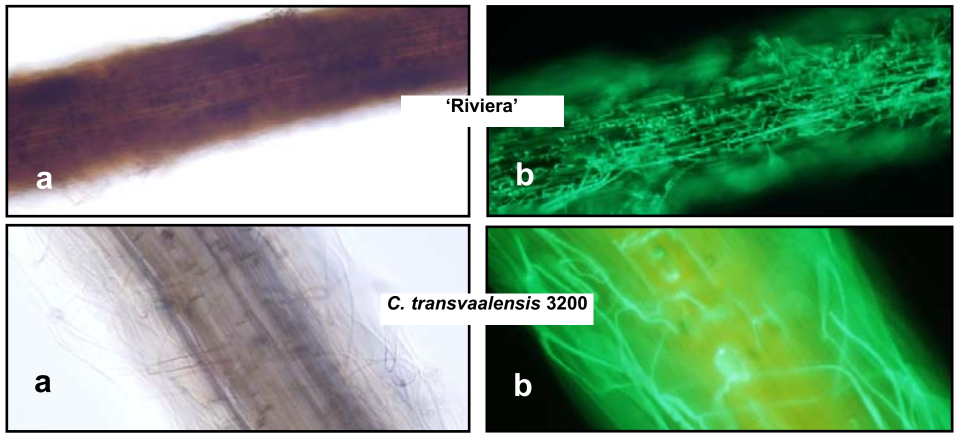
Bermudagrasses in the transition region of the U.S. will undergo cool-temperature induced dormancy during winter months. In this region, spring dead spot is the most devastating and important disease of bermudagrass. The disease is caused by any one of three fungal species in the genus *Ophiosphaerella* (*O. herpotricha, O. korrae,* or *O. narmari*). The disease results in unsightly dead patches in the spring on bermudagrass fairways, tees, and greens and the patches can persist for months. A critical limitation to the study of turfgrass root diseases, such as spring dead spot, is the inability of researchers to rapidly and easily study the plant-fungus disease interaction because it happens below ground and often inside of roots. The overall goal of this study is to enhance our understanding of the interaction between *Ophiosphaerella* species and different bermudagrass hosts.

In earlier studies, we inserted two different fluorescent reporter genes (red and green) into *O. herpotricha* and examined root and stolon infection of various bermudagrasses. Studies examined the fungal interactions with two interspecific hybrid bermudagrass (*Cynodon dactylon* × *C. transvaalensis*) cultivars, 'Tifway' and 'Midlawn' and a *C. transvaalensis* accession. Current studies with *O. herpotricha* have been expanded to include two *C. dactylon* cultivars, 'Riviera' and 'Jackpot' and an additional *C. transvaalensis* accession (3200). Differences in infection response have been observed for these grasses. Infected 'Riviera' roots had a more extensive and dark necrotic response to the fungus in contrast to accession 3200.

To genetically transform *O. korrae* to express fluorescent protein genes, an *Agrobacterium tumefaciens*- mediated transformation system that we optimized for *O. herpotricha* is being utilized. Using this system, the genes for green fluorescent protein (GFP) under the control of the ToxA constitutive promoter with a hygromycin-selectable marker are being incorporated into the genome of the fungus.

A second cassette encoding the red fluorescent protein gene, tdTomato, driven by the ToxA constitutive promoter, is also being used to generate red transformants. We have repeatedly tried to transform *O. korrae* to express both these cassettes. While positive control fungi have been readily transformed, the several strains of *O. korrae* used have remained recalcitrant to transformation, and no fluorescent transformants have been obtained. The failure of these efforts demonstrates the inherent difficulty in transforming this group of fungi. We will adjust transformation conditions to transform this fungus with both proteins. As soon as we obtain green or red fluorescing transformants, their phenotypes will be tested and the growth and colonization of roots evaluated.

Studies using the confocal scanning laser microscope have produced numerous 2 and 3-dimentional still images and video of the fungus in and on bermudagrasses. Images are not possible through conventional microscopy techniques. For example, we can look underneath fungal colonization of bermudagrass stolons to evaluate the plant-fungus interaction. This basic information on how the cultivars react to the fungus will improve our ability to enhance and deploy host plant resistance through traditional breeding efforts at Oklahoma State University.



Differing plant reactions to root infection by O. herpotricha *for two species of bermudagrass.* ***Top:*** *'Riviera' illustrating a dark necrotic reaction through bright field microscopy (a), the identical fluorescent image (b) revealing presence of the fungus.* ***Bottom:*** Cynodon transvaalensis *accession 3200 illustrating much less necrosis through bright field microscopy (a), the identical fluorescent image (b) revealing presence of the fungus.*

Summary Points

- Plant responses to fungal colonization appear variable across species and hybrids of bermudagrass, which is promising for the identification of resistant germplasm.
- Efforts to transform *O. korrae* are underway; but the correct conditions to transform the fungus have yet to be identified.
- Confocal microscopy has revealed details of plant-fungus interactions not obtainable through traditional microscopy.
- This information will be used to enhance host-plant resistance through traditional breeding efforts at Oklahoma State University.

Salinity Management in Turfgrass Systems Irrigated with Effluent Water

Yaling Qian and David Skiles
Colorado State University

Objectives:

1. Determine spatial and temporal salinity accumulation patterns in soil profiles on golf course fairways with effluent water irrigation.
2. Evaluate different management practices for reducing sodium and salt accumulation in the soil.

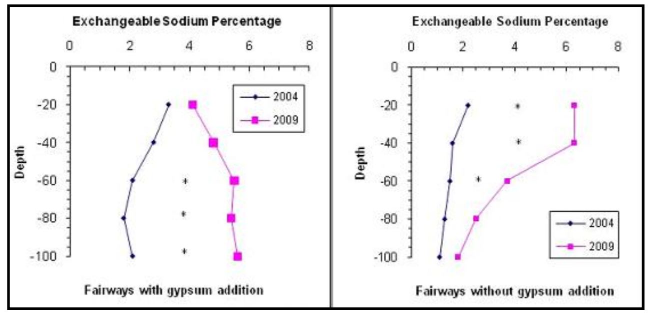
Start Date: 2008
Project Duration: 3 years
Total Funding: $82,459

The main constituents of effluent water include total dissolved salts, nutrient elements, and organic compounds. Salinity and sodicity issues associated with its use continue to be of great concern to the golf course industry. Real-time soil salinity and soil water content information would provide turf professionals with insight when trying to manage turf under effluent irrigation.

We have studied salinity accumulation patterns on four fairways of two effluent water irrigated golf courses using two different types of sensors: 5TE sensor (manufactured by Decagon Devices) and Toro Turf Guard Dual Level (TG2) sensor. Temporal and spatial accumulation patterns were measured using a network of *in situ* soil sensors located at two depths [15 and 30 cm for 5TE sensor and 8 and 19 cm for Turf Guard sensor (TG2)].

Sensors measured electrical conductivity (EC), volumetric soil water content (SWC), and soil temperature data were collected continuously during the 2008 and 2010 growing seasons. Correlation was observed between 5TE sensor-measured soil salinity vs. saturated paste extracted soil salinity ($r = 0.77$). A significant exponential relationship was observed between TG2 sensor-measured soil salinity vs. saturated paste extracted soil salinity.

In-ground measurements indicated that salinity can vary widely across a seemingly homogenous golf course fairway. Plots exhibiting low and high salinities presented opposite seasonal trends at Heritage Golf Course. Strong correlation was observed between average soil salinity and mean soil water content ($r = 0.76$), soil salinity and the percentage of sand in the soil texture composition ($r = -0.63$) for Heritage fairway 1. High salinity was found on fairway 19 at Common Ground Golf Course. However, the salinity level as high as 10.6 dS/m is not a result of water reuse, but a historical geological contribution. Drainage appears to be vital in maintaining low soil salinity levels under effluent irrigation in clay soils. Slow to infiltrate, percolate and difficult to leach, predominately clay soils irrigated with effluent water can accumulate soil salinity over time.



Exchangeable sodium percentage at five soil depths at the initiation (2004) and 5 years after effluent water irrigation (2009). Each data point is the mean of four replications. Asterisks denote a significant difference between 2004 and 2009 samples at P < 0.05.

We collected soil baseline information in 2004 from three golf courses that had just started to use effluent water. In 2009, 5 years after the initiation of effluent water irrigation, soil samples were collected 30 cm from the original sampling spots and analyzed for soil characteristics. Samples were taken at 0 to 20, 20 to 40, 40 to 60, 60 to 80, and 80 to 100-cm depths.

Results from this study suggest that soil salinity and soil organic matter content did not increase at most of the sample sites over the 5-year period. The average soil exchangeable sodium percentage (ESP) increased from 2.65% in 2004 to 5.35% in 2009. Samples collected from all sites showed a significant increase in soil pH (~0.3 units). Our results suggested that sodicity is the primary concern on these landscape soils when effluent water is used for irrigation.

Four golf course fairways were subjected to gypsum application following aerification (aerify once or twice per year and apply gypsum at 50 lb/1,000 ft^2/year). Another four fairways were control with no gypsum addition. For gypsum treated fairways, the increase in ESP from 2004 to 2009 at 0-20 cm and 20-40 cm depths were not statistically significant. The increase became significant from 40-60 cm, 60-80 cm, and 80-100 cm. The changes along the soil profile reflect sodium leaching that effectively prevented a significant increase in soil ESP at the shallow soil depths (0-40 cm) where most of the turfgrass roots are.

For control sites, the increases in ESP from 2004 to 2009 were significant at 0-60 cm depths, demonstrated by an ESP at the 0-20 and 20-40 cm depths that had approximately tripled. The ESP increase became nonsignificant at 60-80 cm and 80-100 cm. High levels of sodium relative to calcium and magnesium in effluent water resulted in increased soil ESP, especially at the shallow soil depths .

Summary Points

- At the experiment conditions, sodicity is the primary concern when effluent water is used for irrigation. The average soil ESP and SAR values approximately doubled over the 5-year period.
- Fairways irrigated with effluent water exhibited an increased soil pH.
- Significant linear correlation was observed between 5TE salinity sensor-measured soil salinity and Turf Guard measured soil salinity vs. saturated paste extracted soil salinity.
- Accumulation of salts appears to relate to soil water content (drainage effectiveness), soil texture, and soil compaction level.
- Soil aerification and gypsum addition effectively prevented a significant increase in soil ESP at the shallow soil depths (0-40 cm).

Cultural Practices, Environment, and Pathogen Biology: Studies for Improved Management of Large Patch of Zoysiagrass

Megan Kennelly, Jack Fry, Rodney St. John, and Dale Bremer
Kansas State University

Objectives:

1. Determine the effects of aeration, verticutting, and sand topdressing on large patch (*Rhizoctonia solani* AG 2-2 and investigate the biology of the interaction of cultural practices and disease.
2. Determine the effects of nitrogen source and time of application on disease development.
3. Study the environmental conditions associated with disease development in the field.
4. Compare large patch susceptibility of 34 new freeze-tolerant zoysiagrass genotypes.
5. Study the effects of different preventive fungicide application timing and correlate with weather conditions to develop better guidelines for fungicide deployment.

Start Date: 2008
Project Duration: 3 years
Total Funding: $46,806

Large patch, caused by *Rhizoctonia solani* AG 2-2, is the most common and severe disease of zoysiagrass in the transition zone. Knowledge is lacking about the interaction of cultural techniques, weather, and disease development. We are conducting field experiments at several sites to elucidate the influence of cultivation practices on large patch, and we will monitor the effects of weather on disease development.

Another key goal is to determine the large patch susceptibility of new zoysiagrass progeny (*Z. japonica* x *Z. matrella*) that may be alternatives to 'Meyer', the most commonly used cultivar in the northern transition zone. We are also investigating fungicide application timing and will correlate it with environmental data to develop a model for optimal fungicide deployment.

In 2010, we carried out the third year of cultural and fertility practices for objectives 1 and 2. Plots were established at three sites (Manhattan, Olathe, and Haysville, KS) in 2008. At all three sites, the experiments are set up as a split-plot with four replications. The main treatment plots are 12 x 20 feet. The main treatments are cultivation (aerification + verticutting + topdressing) versus noncultivated. The subplot (12 x 10 feet) is fertility, either spring + fall or summer fertilization. For the spring + fall treatment, plots were treated with 1 lb N/1,000 ft^2 as urea (46-0-0), in both spring and fall.

The summer treatment was 2.0 lb N/1,000 ft^2 as polymer-coated urea. To induce disease development, all plot areas were inoculated in September 2008 by taking out small turf cores, inserting *R. solani*-infested oats, and replacing the cores. Patch size was determined in spring 2010 by measuring patch size and by using digital image analysis to determine the amount of blighted tissue within the patch. The cultivated/summer fertility plots had slightly smaller patch sizes, but the spring/fall fertilized plots tended to recover faster (faster return to green tissue in the digital analysis).

We deployed temperature and wetness sensors in several experimental plots. There were no differences in thatch-level temperature between cultivated and noncultivated plots. Water content was slightly lower in the cultivated plots on some dates.

Thirty-four zoysiagrass lines were propagated in the greenhouse. Due to ongoing progress in another study by Dr. Fry, the lines of interest (primarily *Z. japonica* x *Z. matrella*) were narrowed down to 20. Inoculations were performed once the turf was established for 5 months after propagation from stolons. The inoculations were conducted in a growth chamber, and sheath blight symptoms were rated for disease severity. In addition, the new progeny were evaluated in field plots in Manhattan by measuring patch size and through digital analysis.

Seven of the lines evaluated in the growth chamber had disease severity value less than that obtained for 'Meyer', the most commonly used zoysiagrass cultivar in our region. Unfortunately, results in the growth chamber did not correlate to results in the field. One promising result is that the new progeny, which have a *Z. matrella* parent, were not significantly worse than 'Meyer' (*Z. japonica*), as is the case with some cultivars of *Z. matrella*. Some progeny appear to recover from symptoms more quickly than 'Meyer'. The field study is being repeated in Olathe. Plots were inoculated in September, 2010 and will be evaluated in May, 2011.

Patch size was determined in spring 2010 by measuring patch size and by using digital image analysis to determine the amount of blighted tissue within the patch.

Summary Points

- Increase of patch size was highest in noncultivated plots with spring + fall fertility.
- However, patches recovered slightly faster in the spring/fall fertility.
- Water content was slightly lower in cultivated plots, possibly reducing disease severity.
- Unfortunately, growth chamber testing does not appear to be a strong indicator of field susceptibility to large patch.
- In the field, some of the progeny recovered from symptoms more quickly than 'Meyer'.

Influence of Nitrogen Fertility and Mowing Height on Zoysiagrass Management

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University of Arkansas

Objectives:

1. Characterize a general response (color, density, turf quality, thatch accumulation, and disease incidence) to nitrogen fertilization, mowing, and their interactions among zoysiagrass cultivars.
2. Determine how nitrogen source affects the turf quality, density, and color of zoysiagrass cultivars.
3. Establish appropriate mowing height and fertility recommendations for each of the cultivars studied.

Start Date: 2008
Project Duration: 3 years
Total Funding: $24,000

Zoysiagrass (*Zoysia japonica* or *Z. matrella*) is increasing in popularity and availability with over 30 cultivars now commercially available. Zoysiagrass has historically been more widely utilized on golf courses in the upper transition zone. However, due to better performance of newer cultivars, there has been a recent trend to plant zoysiagrass on golf courses in the lower transition zone and further south. Knowledge regarding the management of these new cultivars is critical as they are marketed and recommended for use.

Nitrogen source influences growth of creeping bentgrass (*Agrostis stolonifera*) and annual bluegrass *(Poa annua*), but no one has examined the effect of nitrogen source on zoysiagrass growth. Fertilizing zoysiagrass with the appropriate N source could lead to improved growth with reduced N inputs.

Experimental areas were sprigged in 2001 at the Arkansas Agricultural Research and Extension Center, Fayetteville, AR with 'El Toro', 'Meyer', and 'Cavalier' zoysiagrass. Plots were maintained from 2002 to 2007 using 1-2 lb N/1000ft^2/year. Fertilization treatments were initiated in May, 2008 using sulfur-coated urea at 0, 2, 4, and 6 lb N/1000 ft^2/year applied on May 1, June 1, July 1, August 1, and September 1. Response was evaluated as turf quality, density, green-up, and scalping.

Three nitrogen sources (urea, ammonium nitrate, and calcium nitrate) were applied as 2 and 4 lb N/1000ft^2/year with each source. Application timings were the same as previously stated. Response was evaluated as turf color, quality, density, green-up, and scalping.

Results of these studies indicate that there is no advantage to using more than 2 lb N/1000 ft^2/year for zoysiagrass, and spring green-up was fastest for 0.5-inch mown plots. In addition, spring green-up of zoysiagrass was delayed by N rates of 4 lb/1000 ft^2/year.

Results after three years indicate that turf density is improved through cultivar selection and N fertility. 'Cavalier' consistently had greater turf density than 'Meyer' and 'El Toro'. Increasing annual nitrogen applications ≥2 lb N/1000 ft^2 also improved turf density. In the spring of 2009 (after 1 year of fertility treatments), N rates ≥4 lb N/1000 ft^2/year were observed to cause a delay in spring green-up and a decline in turf quality at the 1.5-inch mowing height. In 2010, this delay in spring green-up was more pronounced in 'El Toro' than in 'Meyer' or 'Cavalier'.

Large patch (*Rhizoctonia solani*) was present in some plots, but there was no clear relationship to cultivar, mowing height, or nitrogen rate. Dollar spot (*Sclerotinia homoeocarpa)* was present in 'Cavalier' plots but not in 'El Toro' or 'Meyer'. There was little scalping in our study, but on two collection dates, mowing at 0.5-inch and fertilizing with 6 lb N/1000 ft^2/year resulted in increased scalping. Turf quality was generally highest for 'Meyer' and 'Cavalier'. Turf quality was highest in the summer for plots receiving ≥2 lb N/1000 ft^2/year, but turf quality was never unacceptable (<6) for the unfertilized check plots. Nitrogen source did not impact turf quality, turf density, or turf color in the field trial.

These results are in agreement with previous results that zoysiagrass requires little N fertility to produce an acceptable quality turf. One exception might be when growing zoysiagrass on sandy soils with a longer growing season, such as Florida. In Arkansas, this study has helped to influence nitrogen fertilization practices among golf course superintendents maintaining zoysiagrass.

Results for this study indicate that there is no advantage to using more than 2 lb N/1000 ft^2/year. Hopefully, these results along with similar research in other states will provide necessary information to help fine tune zoysiagrass management programs and reduce N inputs.

Summary Points

- Turf density was greatest for 'Meyer' and 'Cavalier' compared to 'El Toro'. Turf density was improved when fertilizing ≥2 lb N/1000 ft^2/year.
- Spring green-up was fastest for 0.5-inch mown plots. Among 1.5-inch mown plots, higher nitrogen rates (≥4 lb N/1000 ft^2/year) decreased spring green-up.
- Scalping was greatest when mowing at 0.5-inch and fertilizing with 6 lb N/1000 ft^2/year.
- Turf quality was generally highest for 'Meyer' and 'Cavalier'. Turf quality was highest in the spring among 1.5-inch mown plots, when receiving less than 4 lb N/1000 ft^2/year.
- There was no advantage to fertilizing more than 2 lb N/1000 ft^2/year. Turf quality was never unacceptable for the unfertilized check plots.
- Nitrogen source did not affect turf quality in the field.

Correlation and Calibration of the Illinois Soil Nitrogen Test for Use as a Nitrogen Fertility Management Tool

David Gardner
The Ohio State University

Brian Horgan
University of Minnesota

Kevin Frank
Michigan State University

Objectives:

1. Evaluate the production of mineral N during incubation of soils differing in N fertilizer responsiveness.
2. Refine the critical amino sugar-N levels for turfgrass quality responsiveness.
3. Determine the impact of long term fertility management practices on soil amino sugar-N values and nitrate leaching potential and to evaluate amino sugar-N concentration changes over time using the long-term N leaching plots at Michigan State University.

Start Date: 2010 (current cycle)
Project Duration: 2 years
Total Funding: $46,962

Although a majority of research has indicated that turfgrass fertilization with nitrogen poses little risk to the environment, results of recent studies suggest that over time, mineralization will exceed immobilization on fertilized turf which may lead to potential nitrate leaching. Previous nitrate-N tests have not accurately predicted the potential of organic N fractions that will become available to the plant over the growing season.

Our research is attempting to correlate and calibrate the Illinois Soil Nitrogen Test which was developed to identify sites in production agriculture that are not responsive to N fertilizer. The test measures amino sugar-N fractions in the soil organic N pool, which supplies the plant with N through mineralization. This fraction is relatively stable compared to NO_3^- and NH_4^+, and thus may provide an accurate measure of nitrogen fertility on managed turfgrass. A test for soil N status in turfgrass would allow superintendents to reduce excess time and money spent on unnecessary fertilizer applications and may predict the impact of our fertility practices that could reduce environmental contamination associated with nitrate leaching.

Soils have been collected from North Dakota, Illinois, Indiana, Ohio, Michigan, Wisconsin and Minnesota and are being tested in laboratory experiments. We hypothesize that North Central region soils with amino sugar-N values greater than 325 ppm and are deemed nonresponsive sites will mineralize significantly more N than those soils with amino sugar-N values less than 325 ppm.

The test measures amino sugar-N fractions in the soil organic N pool which supplies the plant with N through mineralization.

We have conducted several experiments that investigate the yield response of turfgrass to added nitrogen in soils with various amino N levels. Results of these trials suggest turfgrass clipping yield response to added nitrogen may be lower on soils with higher amino sugar-N levels. However, the results are not as conclusive as what has been found in production agriculture. We are conducting studies on soils with more extreme values of amino N while also examining other characteristics of the turf, such as turfgrass quality and color.

Part of our hypothesis is that as amino N levels increase in soil, the N needs of the turf are increasingly met by mineralized organic N. On high amino-N soils there may be an increased chance that added fertilizer N would be more susceptible to leaching. In order to test this hypothesis, soil samples have been gathered from microplot lysimeters at Michigan State University for the years 2000-2010. Our goal with the analysis of these samples is to determine if the nitrate leaching events observed on the lysimeters at Michigan State can be correlated to changes in the amino N level in the soil.

We expect to develop sampling procedure guidelines and interpretation of the ISNT results based on amino sugar-N and mineralization rates in order to make fertility reduction management recommendations on golf courses. We also expect to demonstrate that the ISNT can be utilized to explain nitrate leaching events, such as those reported by Frank in 2005. Since Frank reports that a 50% reduction in added fertilizer effectively eliminates nitrate leaching potential, we believe the ISNT may serve as an appropriate test to assist superintendents in reducing nitrate leaching from golf courses.

Summary Points

- Our field studies suggest that the relationship between amino sugar-N and response of turfgrass to added fertilizer nitrogen is not as consistent as what has been reported in production agriculture. Additional studies are being conducted to analyze if a relationship between amino sugar N levels and turfgrass fertility response exists.
- Laboratory experiments are determining if the Illinois Soil Nitrogen Test value can be correlated to a soil's nitrogen mineralization potential.
- Analysis of soils gathered from lysimeters at Michigan State University from 2000-2010 will determine if the ISNT has any utility for predicting soils with the potential to leach nitrate due to fertilizer nitrogen.

Interpreting and Forecasting Phenology of the Annual Bluegrass Weevil in Golf Course Landscapes

Daniel C. Peck, Masanori Seto, Maria Diaz
Cornell University

Objectives:

1. Describe patterns of variation in population fluctuations and phenology of annual bluegrass weevils.
2. Describe the overwintering strategy by establishing the factors that affect site selection and success.
3. Document the relationship between overwintering sites and developmental sites.
4. Develop and validate a degree-day model to forecast phenology.

Start Date: 2006
Project Duration: 4 years
Total Funding: $100,000

The annual bluegrass weevil (ABW), *Listronotus maculicollis*, is a major insect pest on short-mown *Poa annua* turf throughout the Northeast and Mid-Atlantic regions. Small larvae feed within the stem and large larvae feed on crowns, causing highly visible damage on prominent areas of the course, such as fairway edges and putting green collars. Until recently, management options were largely limited to pyrethroids, and applications may be made two to five times a season. More effective control will depend on better targeting the insect.

We are defining the association between ABW and the golf course landscape. Our goal is to better understand the spatial, temporal, and dynamic aspects of the relationship between overwintering and developmental sites, and how this might be exploited to improve integrated pest management. We surveyed populations over three years on two fairways in upstate New York. Data were collected weekly by extracting larvae from soil cores and flushing adults with a soapy disclosing solution. All larvae were identified to instar, and all adults were identified as male and female, callow and mature.

Most population parameters (e.g., fluctuation curves, abundance, synchrony, number and timing of generations) varied more between years than between sites. In terms of insect load, larvae and adults were eight to nine times more abundant on the fairway than the rough. Across the fairway itself, abundance was consistently greater near the edge at one site, but insects were evenly distributed across the fairway at the other site. Therefore, insect distribution does not fully explain the prevalence of damage on fairway edges.

Field surveys showed that overwintering adults tend to settle along the tree line adjacent to the fairway, establishing up to 60 m from the fairway and 10 m into the woods. Little or no overwintering occurs on the fairway or adjacent rough. In a choice experiment, we showed that white pine litter is not a preferred overwintering substrate. Given a choice, adults preferred to settle in rough-mown grass and a combination of pine and deciduous litter over fairway-mown grass and pine litter alone.

We used linear pitfall traps to document the activity and directionality of adult movement. Captures were greatest in spring, coinciding with the emergence of overwintered adults and their dispersal toward short-mown turf. In the fall, however, there was no indication of movement back toward overwintering sites. We proposed that adults largely fly toward overwintering sites in the fall, orienting to and settling along defined tree lines away from fairways.

We are developing predictive models to test the linkage between insect development and degree-day accumulations. The fit of several models was tested on 3 years of population data. Overall, degree-day was a statistically better predictor than calendar date. The resultant model described population accumulations of overwintered adults and larvae of the first generation well, but not the second generation.

In 2008 and 2009, we partnered with collaborators across New York to validate the applicability of this model for other populations of the insect in different climate areas. Data were gathered from each site to construct fluctuation curves showing the progression of the five larval instars over the course of the spring generation in relation to local temperature. The model must be further refined and adjusted before it can be considered a sufficiently robust tool for ABW management across its geographic range.

Populations were surveyed over 3 years on two fairways in upstate New York. Data were collected weekly by extracting larvae from soil cores and flushing adults with a soapy disclosing solution.

Summary Points

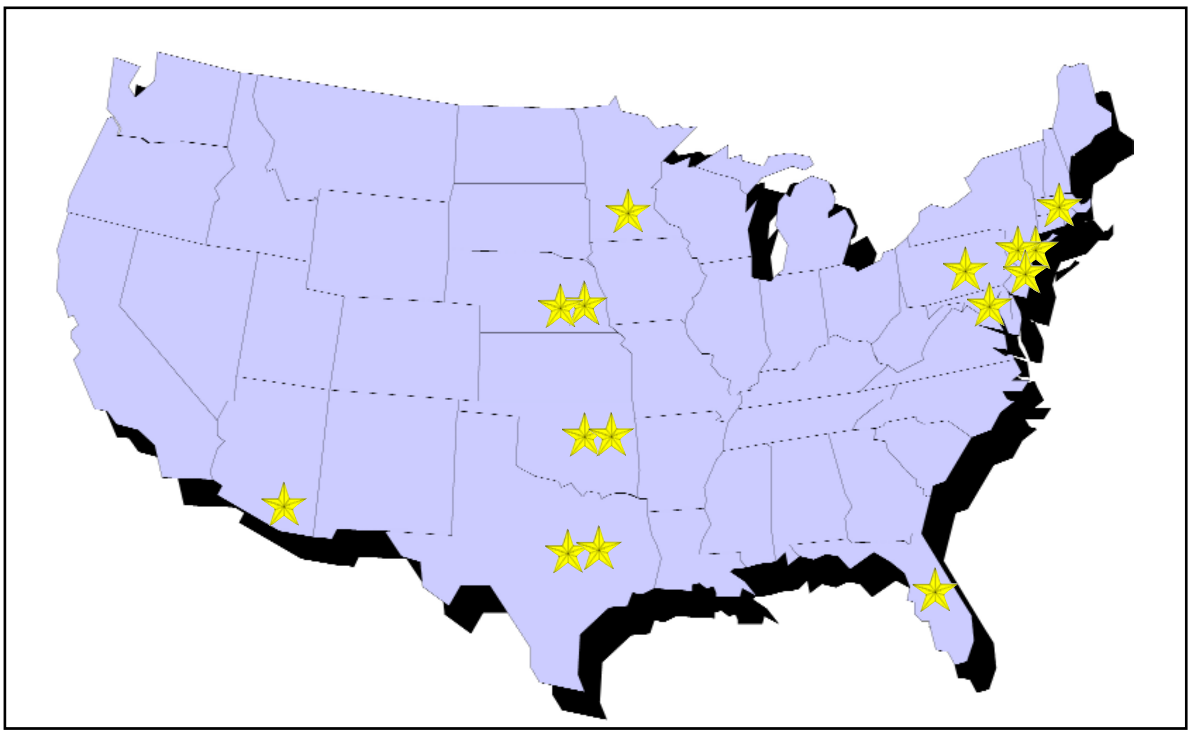
- Studies on the biology of ABW in overwintering and developmental habitats have refined our understanding of how this insect pest exploits and damages susceptible golf course playing surfaces.
- It is hypothesized that adults immigrate to fairways in spring largely by walking with orientation to low-cut turf, but they emigrate in fall largely by flying with orientation to defined tree lines where they settle into preferred overwintering substrates.
- On short-mowed *P. annua* turf, there is more variation from year to year than from site to site in terms of population parameters such as shape of the fluctuation curve, number of generations, and generation time.
- Degree day is a statistically better predictor for ABW phenology than calendar date, and a preliminary model has high predictive power for the first generation.
- With further refinement, a nonlinear degree-day model has the capacity to predict the timing of ABW developmental stages across a wide geographic area.

Breeding, Genetics, and Physiology

The quality and stress tolerance of turf is a product of the environment, management practices, and genetic potential of the grass plant. In many cases, major limitations to turf quality are stress effects, many of which can be modified or controlled through plant improvement. Projects are directed toward the development of turf cultivars that conserve natural resources by requiring less water, pesticides and fertilizers. Research projects that apply new biotechnological methods toward turfgrass improvement are considered. Among the characteristics most desirable in the new turfgrasses are:

1. Reduced need for pesticides by increasing resistance to disease, insects, nematodes, and weed encroachment
2. Increased shade tolerance
3. Reduced requirements for mowing, irrigation, and fertilization
4. Tolerance of non-potable water
5. Ability to survive high- and low-temperature extremes
6. Increased drought tolerance
7. Tolerance of intensive traffic
8. Tolerance of poor quality soils.

Research in the fields of biotechnology, genetics, cytogenetics, cytology, entomology, genetics, microbiology, nematology, pathology, physiology, and other sciences that support the project objectives and provide improved techniques for improving golf turf species will be considered.



Locations of projects funded in 2010 by the USGA Turfgrass and Environmental Research Program under the category of Breeding, Genetics, and Physiology

Breeding and Evaluation of Kentucky Bluegrass, Tall Fescue, Perennial Ryegrass, and Bentgrass for Turf

William A. Meyer and Stacy A. Bonos
Rutgers University

Objectives:

1. Collect and evaluate potentially useful turfgrass germplasm and associated endophytes.
2. Continue population improvement programs to develop improved cool-season turfgrass cultivars and breeding synthetics.
3. Develop and utilize advanced technologies to make current breeding programs more effective.

Start Date: 1982
Project Duration: Continuous
Total Funding: $10,000 per year

As of October 30, 2010, more than 1,678 promising turfgrasses and associated endophytes were collected in Italy, the Atlas Mountains in Morocco, and Latvia. These have had seed produced in The Netherlands and will be evaluated in New Jersey. More than 9,450 new turf evaluation plots, 118,000 spaced-plant nurseries and 19,500 mowed single-clone selections were established in 2010.

More than 350,000 seedlings from intra- and inter-specific crosses of Kentucky bluegrass were screened for promising hybrids under winter greenhouse conditions, and the superior plants were put into spaced-plant nurseries in the spring. More than 25,000 tall fescues, 8,000 Chewings fescues, 9,600 hard fescues, 70,000 perennial ryegrasses, and 10,000 bentgrasses were also screened during the winter in greenhouses, and superior plants were put in spaced-plant nurseries. More than 350 new inter- and intra-specific Kentucky bluegrasses were harvested in 2010.

The following crossing blocks were moved in the spring of 2010: 6 hard fescues (206 plants), 1 Chewings fescue (25 plants), 16 perennial ryegrasses (1,524 plants), 7 strong creeping red fescues (269 plants), 10 tall fescues (237 plants), 4 velvet bentgrasses (93 plants) 4 creeping bentgrasses (80 plants), and 6 colonial bentgrasses (131 plants).

Over 9,450 new turf evaluation plots, 118,000 spaced-plant nurseries and 19,500 mowed single-clone selections were established in 2010.

To enhance our breeding for resistance to gray leaf spot, an early July 2010 planting of 860 perennial ryegrasses were seeded. Excellent *Pythium* blight control was attained, and a good gray leaf spot epidemic occurred. These data will be used to select future varieties of perennial ryegrass. More than 18,000 perennial ryegrasses were planted in the spring of 2010 as space plants. They were allowed to develop seedheads in the late spring, and selections were made for stem and crown rust resistance. A total of 1,180 clones were identified.

The breeding program continues to make progress breeding for disease resistance and improved turf performance. New promising varieties named and released in 2010 were 'Empire' and 'Godiva' Kentucky bluegrasses; 'Side Winder', 'Fesnova', 'Rebel Advance' and 'Rebel XLR' tall fescues; 'Shademaster II' and 'Miser' strong creeping red fescues; and 'Rio Vista', 'Octane', 'Bonneville', and 'Rinova' perennial ryegrasses.

Summary Points

- Continued progress was made in obtaining new sources of turfgrass germplasm. These sources are being used to enhance the Rutgers breeding program.
- Modified population backcrossing and continued cycles of phenotypic and genotypic selection combined with increasing sources of genetic diversity in turfgrass germplasm have resulted in the continued development and release of top performing varieties in the NTEP.
- Fifteen new tall fescues, three fine fescues, five Kentucky bluegrasses, two bentgrasses, and three perennial ryegrasses were released in 2009.
- 'Capri' colonial bentgrass is an improved variety with better brown patch resistance, and 'Pinup' creeping bentgrass has improved dollar spot resistance.
- Published or have in press more than 10 referred journal articles in 2009.

Breeding and Evaluation of Turf Bermudagrass Varieties

Yanqi Wu, Dennis L. Martin, and Charles M. Taliaferro
Oklahoma State University

Objectives:

1. Assemble, evaluate, and maintain *Cynodon* germplasm with potential for contributing to the breeding of improved turf cultivars.
2. Develop and use simple sequence repeat molecular markers.
3. Improve bermudagrass germplasm for seed production potential, cold tolerance, leaf-firing resistance, and other traits that influence turf performance.
4. Develop, evaluate, and release seeded and vegetatively propagated turf bermudagrass varieties.

Start Date: 2010 (current cycle)
Project Duration: 3 years
Total Funding: $90,000

Breeding programs in bermudagrass [*Cynodon dactylon* (L.) Pers., *C. transvaalensis* Burtt-Davy, and their hybrids *C. dactylon* x *C. transvaalensis*] continue to provide genetically improved cultivars for the turf industry in the southern U.S. and throughout tropical and warmer temperate regions of the world. The OSU turf bermudagrass genetic improvement program made progress in the development and evaluation of experimental cultivars, development and utilization of simple sequence repeat (SSR) markers for bermudagrass, and release of two superior clonal turf bermudagrass genotypes as new cultivars in 2010.

OKC 1119 was released as a new cultivar by Oklahoma Agricultural Experiment Station in July 2010, but an official name has not been selected yet. OKC 1119 is a clonally propagated F_1 hybrid from a cross of *C. dactylon* x *C. transvaalensis*. The genotype has been evaluated in several OSU experiments, and more comprehensively and extensively in the National Turfgrass Evaluation Program (NTEP) 2007 National Bermudagrass Test (http://www.ntep.org/bg.htm).

The major strengths of OKC 1119 are its exceptional turf quality, fine texture, improved winter hardiness, high sod density, and very good sod tensile strength. The combined performance data indicate it has less risk of winter injury than ‘Tifway’, while providing higher or equal turf quality. Compared to ‘Midlawn’, its turf quality is much improved. OKC 1119 is also better than ‘Midlawn’ in sod tensile strength, a major consideration for sod growers.

OKC 1134 was released as a new clonal bermudagrass turf cultivar by OAES at the same time as OKC 1119.

A large C. dactylon x C. transvaalensis *putative F1 progeny population was evaluated in 2010 for selection of superior vegetatively propagated plants at Oklahoma State University.*

OKC 1134 is a clonally propagated interspecific F_1 hybrid that exhibited superior performance in 2007 NTEP National Turf Bermudagrass Test (http://www.ntep.org/bg.htm). The major strengths of OKC 1134 are its high turf quality, fine texture, improved winter hardiness, early green-up, high sod density, and very high sod tensile strength. The combined performance data indicate it has less risk of winter injury than ‘Tifway’, while providing equal turf quality. Compared to ‘Midlawn’, its turf quality is much improved. OKC 1134 is much better than ‘Midlawn’ in sod tensile strength, a major consideration for sod growers. An official name for OKC 1134 is to be selected.

Screening of more than 1,500 putative F_1 progeny plants (*C. dactylon* x *C. transvaalensis*) was performed in 2010 by selecting 10 superior progeny plants after evaluating winter color retention, spring green-up, winterkill, foliage color, texture, sod density, seedhead abundance, and overall turf quality for 3 years.

We developed SSR markers in bermudagrass by transferring sorghum genomic SSR primers and by exploring bermudagrass expressed sequence tags (ESTs) from the National Center for Biotechnology Information database. Transferability of 354 tested sorghum SSRs was 57% to *C. transvaalensis* ‘T577’, 27% to *C. dactylon* ‘Tifton 10’,and 22% to ‘Zebra’. From 20,237 *Cynodon* ESTs at NCBI, 303 designed SSR primer pairs amplified target bands in at least one of *C. dactylon* var. *aridus*, *C. transvaalensis* ‘T577’, *C. dactylon* cv. ‘Tifton 10’, and *C. dactylon* var. *dactylon* ‘Zebra’.

Eleven SSR markers were selected on the basis of their polymorphisms to amplify respective DNA samples of 32 commercial and experimental clonal turf bermudagrass cultivars. The study revealed one highly polymorphic marker, and any one of the remaining 10 markers are able to identify all non-mutation cultivars.

Summary Points

- OKC 1119 and OKC 1134 were released as new clonal turf bermudagrass cultivars by OAES in 2010.
- A set of 10 superior clonal bermudagrass putative hybrids were selected in 2010 from a screening nursery for next-step in-house comprehensive evaluation.
- A large set of SSR markers were developed from bermudagrass EST sequences and pre-existing sorghum SSR markers.
- Eleven polymorphic SSR markers were selected to amplify 32 clonal turf bermudagrass cultivars.

Buffalograss Germplasm Improvement and Management

Robert (Bob) C. Shearman and Bekele G. Abeyo
University of Nebraska

Objectives:

1. Breed, select, and evaluate seeded and vegetative genotypes with improved turfgrass quality, pest resistance, and stress tolerance.
2. Improve our basic knowledge of the genetics of buffalograss through modern molecular marker technologies.
3. Expand understanding and use of efficient management practices for best genotypic performance.
4. Develop protocols for best turfgrass establishment.

Start Date: 2006
Project Duration: Continuous
Total Funding: $30,000 annually

We evaluated 1,629 selections obtained from hybridization and plant collection were evaluated for turfgrass quality, gender, and inflorescence height.

A study of advanced lines and standard entries was evaluated for spring green-up, stand density, and turfgrass color and quality in 2010. Differences among genotypes were observed for all of these traits. Similarly, 1,629 selections that were obtained from hybridization and plant collection were evaluated for turfgrass quality, gender, and inflorescence height. Differences were observed among these selections for these characteristics. Evaluation of these selections will continue in an effort to identify and promote genotypes with superior turfgrass performance characteristics for future advanced-line replicated trials.

Selected genotypes (54) were placed in a shade evaluation trial. These selections were found growing in light-limiting conditions and were selected for their potential adaptation to shade. The trial includes the selections and standards, which are replicated under 30% and 60% shading and compared to the same entries growing in open sunlight. The trial was initiated in 2009 and repeated in 2010. Entries are being evaluated for establishment, lateral spread, turfgrass quality, color, and density. In addition, NDVI and chlorophyll meter readings are being made on a regular basis. Genotypes have demonstrated differences in establishment and lateral spread under shaded conditions.

Ninety-four F_1 progeny generated by crossing two heterozygous diploid parents were genotyped using polymorphic SRAP and SSR markers for the parents.

Application of molecular tools, such as marker-assisted selection (MAS), is of considerable interest to enhance our breeding program's progress for turfgrass quality and chinch bug resistance. This study was conducted to a framework genetic linkage map of diploid buffalograsses as a prelude for the application of MAS, and to study the organization of the buffalograss genome. Ninety-four F_1 progeny generated by crossing two heterozygous diploid parents were genotyped using polymorphic SRAP and SSR markers for the parents. Co-segregation analysis placed 42 markers into nine discrete linkage groups covering 355.10 cM, with linkage group sizes ranging from 10 cM to 119.78 cM.

A range of 2 to 18 loci per linkage group were mapped with an average map distance between two consecutive markers of 12.68 cM. This is the first linkage map of buffalograss and would be a logical starting point for further delineation of the buffalograss linkage map with more markers. Results from this study provide a foundation for a new direction for our buffalograss breeding research that will aid further study and improvement of turfgrass quality and pest resistance.

A study was conducted to determine the impact of sprig type and node age on root initiation from buffalograss sprigs. Sprig types consisted of intact stolons and single node sprigs. Node age was based on phenological observations of the nodes and classifying them as juvenile, mature, and post-mature nodes. Sprigs of 'Prestige' buffalograss were planted in a clay loam soil (fine smectitic mesic Pachic Agriudolls), and roots were collected at 10 and 20 days after planting (DAP).

Days after planting, sprig type, and node age influenced root mass. Root mass increased 40% from 10 to 20 DAP. Whole stolons produced 24% more root mass than single-node sprigs. Juvenile and mature nodes produced 22% and 20% more root mass than post-mature nodes, respectively. Results from this study indicate that using multiple-node sprigs and sprigs with juvenile to mature nodes for buffalograss sprig establishment are more effective than single-node sprigs.

Summary Points

- Advance lines and selections differed for stand density, turfgrass color and quality, and spring green-up.
- Selected genotypes demonstrated differences in establishment and lateral spread under light-limiting conditions.
- Initiated the first framework genetic linkage map for buffalograss.
- Buffalograss sprig establishment can be enhanced by using sprigs with multiple nodes and sprigs with juvenile to mature nodes.

Genetic Improvement of Prairie Junegrass

Eric Watkins
University of Minnesota

Objective:

1. Determine the genetic potential of native prairie junegrass (*Koeleria macrantha)* germplasm for use as low-input turfgrass.

Start Date: 2007
Project Duration: 4 years
Total Funding: $40,000

Grass species that are native to North America should be better able to cope with our environment and could lead to overall reductions in inputs such as fertilizers, pesticides, and water. Prairie junegrass (*Koeleria macrantha*), which is native to the Great Plains of the United States, has shown the potential to be successfully used as a turfgrass in low-input environments. The species is widely distributed throughout much of the western United States, and it can also be found throughout much of Europe and Asia.

Prairie junegrass has several attributes that would make it a useful low-input turfgrass in Minnesota, including tolerance of droughty and alkaline soils, tolerance of sandy areas, survival of low- and high-temperature extremes, and reduced growth rate. 'Barkoel' was the first cultivar of this species specifically developed for use as a turfgrass. However, this cultivar was developed with ecotypes from Europe. We are proposing the development of a cultivar primarily derived from germplasm native to North America.

Developing a high-quality turfgrass is not, by itself, adequate. In order to be used by consumers, an economically viable turfgrass cultivar must be able to produce sufficient quantities of seed. Non-selected populations of the species can produce seed for 4-5 years. Collections of natural ecotypes made in 2005 suggest that individual genotypes may possess the ability to be highly productive. However, it is unknown if it can produce economically adequate amounts of seed.

Turf plot evaluations of Koeleria macrantha *accessions and breeding material in St. Paul, MN showing differences in color retention during a summer stress period.*

We have collected native prairie junegrass germplasm from Minnesota, South Dakota, North Dakota, Colorado, and Nebraska. These germplasm collections have been established in breeding nurseries, and in some cases, experienced one cycle of selection. We have established several spaced-plant evaluations that will be used to determine the genetic variation present in our populations for various turfgrass and seed production characteristics.

The USDA National Plant Germplasm Resources Network (NPGRN) maintains a number of accessions of *Koeleria macrantha* originating from locations throughout world. We completed research trials that evaluated the turfgrass quality characteristics of 48 USDA-NPGS accessions. Under low-input management, accessions varied greatly for overall turf performance with several accessions showing acceptable turf quality and mowing quality at two research locations in Minnesota (Becker and St. Paul). Conversely, factors such as summer dormancy, leaf rust incidence, and leaf shredding played a role in decreased quality of several other accessions. Most of the accessions that exhibited superior turf quality originated from Asia and Europe.

Concurrent research trials found that native germplasm collected in the United States does not typically possess the turfgrass quality characteristics necessary for a useful cultivar. However, the native germplasm does provide some other low-input characteristics that can be useful in cultivar development such as slow vertical growth rate, adequate seed production, early spring green-up, ability to survive severe water deficit, and resistance to some important turfgrass diseases. In particular, we found that germplasm collected in Minnesota showed improved resistance to leaf rust.

Koeleria macrantha *accessions differing in seedhead morphology.*

These studies have shown that the characteristics necessary for a low-input turfgrass cultivar of this species do exist in available germplasm. Ultimately, a combination of native and nonnative populations will need to be used in our breeding program. Combining the higher turfgrass quality of the nonnative collections with the superior seed production potential and greater stress tolerance of the native germplasm should result in a cultivar that can be used effectively throughout the northern United States on low-input turf areas such as golf course roughs.

Summary Points

- Nonnative germplasm generally exhibits superior turfgrass quality.
- Native germplasm has shown greater seed production potential and resistance to severe stresses common in low-input environments.
- Integration of traits from diverse germplasm should be effective in the development of a low-input cultivar.

Selection of Bermudagrass Germplasm that Exhibits Potential Shade Tolerance and Identification of Techniques for Rapid Selection of Potential Shade-Tolerant Cultivars

Gregory E. Bell and Yanqi Wu
Oklahoma State University

Objectives:

1. Screen bermudagrass germplasm collections and selections for their effectiveness in shaded environments.
2. Determine turfgrass characteristics that may useful for screening future selections for potential shade tolerance.
3. Create one or two genetic populations by physiological and molecular selections of shade tolerant and susceptible parents for future research.

Start Date: 2008
Project Duration: 3 years
Total Funding: $90,000

A research site was assigned and planted using greenhouse-grown bermudagrass plugs on June 22, 2007 at the Oklahoma State University Turfgrass Research Center, Stillwater. The site was specifically constructed to host this and future shade selection projects. The research site receives mid- to late afternoon shade, depending on season, from a dense, mature evergreen canopy on the west side of the site. These conifers also provide root competition and reduce the predominately westerly airflow. Maple trees have been planted along the south side of the site and redbud trees along the east side to increase the duration of vegetative shade.

We attempted to increase the duration of shade at the site in 2008 by planting vines along a hoop structure, but we had limited success. We had more success with the vines in 2009 and also added a 75% black woven shade cloth above the plots to provide shade in the middle of the day. In April, 2010, additional 75% black woven shade cloth was added to provide extended shade.

The study consists of 45 bermudagrass selections and four standards, 'Celebration', 'Patriot', 'TifGrand', and 'Tifton 10'. 'Celebration', 'TifGrand', and 'Tifton 10' were chosen for their potential shade tolerance, and 'Patriot' was chosen for its likely poor shade tolerance. The bermudagrass selections were collected primarily from China, Africa, Australia, and other nations. Plot size was 61 x 61cm with a 23-cm border between plots. Each bermudagrass was replicated five times on the shade site that is in full sun for about 33% of each day and on an adjacent site that is in full sun for about 90% of each day. Visual turf quality (TQ) and normalized difference vegetative index (NDVI) were assessed every two weeks in 2010, and results are reported for five rating dates from June 1 to Sept. 30, 2010.

In 2008, shade stress occurred on the shade site for 12% longer each day than on the sun site. This short duration of shade stress caused an average 4.9% decline in TQ and a 3.4% decline in NDVI. On May 7, 2009, a black woven shade cloth with 75% light reduction (10 ft x 160 ft) was installed on a hoop structure overhead to provide longer and more uniform shade for the shade site. Consequently, the shade duration increased from 12% in 2008 to 52% in 2009. The additional shade caused an increased decline in TQ from 4.9% in 2008 to 7.5% in 2009 and a decline in NDVI of 3.4% in 2008 to 5.2% in 2009.

An additional black woven shade cloth (75% light reduction) has been added to the shade site in April, 2010.

A second significant decline in TQ was observed by adding additional 75% black woven shade cloth in 2010. TQ decline increased from 7.5% in 2009 to 38.9% in 2010, and NDVI decline also deepened from 5.2% to 23.9% in 2010. The bermudagrass selections differed significantly in TQ and in NDVI both in full sun and in shade in both 2009 and 2010.

In 2010, photosynthesis rates were measured in spring, summer, and fall from five best, five worst, and the four standard bermudagrass selections. CO_2 gas exchange rate was the highest in summer and the lowest in spring for plants both in full sun and shade.

No changes in shade duration will be made to the shade block in 2011. However, a 75% black woven shade cloth (10 ft x 160 ft) will be added over the current full-sun block moderate shade. A third block established in June 2009 will become the full-sun block in 2011.

Shade stress was severe in 2010 and provided adequate stress for selecting resistant grasses and measuring differences in photosynthesis rates. By adding a moderate shade block in 2011, we hope to develop a relationship between shade stress and CO_2 gas exchange. Photosynthesis will again be measured from the five best selections, five worst selections and four standards in May, July, and September. From this data, we may be able to roughly estimate the amount of shade that each selection can tolerate.

Summary Points

- In 2010, the shade site received 33% of the solar irradiance received on the sun site.
- Turfgrass visual quality ratings and NDVI indicated significant diversity among selections.
- The mean visual turf quality decline between like selections in full sun to shade was 39% and the mean decline in NDVI quality was 24%.

Identification of Quantitative Trait Loci (QTL) Associated with Drought and Heat Tolerance in Creeping Bentgrass

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Rutgers University

Objectives:

1. Evaluate variations in drought and heat tolerance for two mapping populations of bentgrass segregating for disease resistance.
2. Identify phenotypic traits associated with drought and heat tolerance.
3. Identify QTL markers associated with drought and heat tolerance utilizing the available linkage maps.

Start Date: 2008
Project Duration: 3 years
Total Funding: $89,912

A creeping bentgrass mapping population (L93-10 x 7418-3) and a hybrid bentgrass population (creeping x colonial), both segregating for dollar spot resistance, were evaluated for variation in drought and heat tolerance and for QTL localization. The creeping population consisted of a pseudo F_2 mapping population (180 individuals) that was generated from the intraspecific cross of a dollar spot-resistant (L93-10) and a susceptible (7418-3) genotype in the spring of 2003. For all QTL analysis described here, a subset of the population (100 individuals, F_2 progeny) and the parents were evaluated for heat and drought tolerance. The population was evaluated four times for phenotypic variation in drought tolerance in three different environments (greenhouse, growth chamber, and field).

The hybrid bentgrass population was originally developed by crossing creeping (*Agrostis stolonifera* L.) and colonial bentgrass (*A. capillaris* L.) by interspecific hybridization for the introgression of colonial genes for dollar spot (*Sclerotinia homoeocarpa*) resistance into creeping bentgrass and for development of a colonial linkage map. The F_2 population, progeny of a creeping/colonial (Hybrid 15) x creeping (9188) cross, was used for drought screening.

Several drought-stress indicators were used to evaluate physiological responses to stress and to determine the genotypic variation and phenotypic traits in the mapping populations. Turf quality (TQ) was rated visually based on a scale of 1-9 (1 = dessicated, brown; 9 = healthy, green). Several commonly used parameters for phenotypic analysis of stress tolerance were measured, including relative water content (RWC), electrolyte leakage (EL), osmotic adjustment (OA), photochemical efficiency (FvFm), carbon-to-nitrogen ratio, water-use efficiency (WUE), green leaf biomass (NDVI), and leaf area index (LAI) as determined by a multispectral radiometer (MSR).

In response to drought stress, both populations portrayed significant variation in most physiological parameters evaluated. The creeping population visual TQ ratings ranged from 3 to 6 following 7 days of drought. RWC varied from 60% to 94%, and OA ranged from 0 to 0.50. The hybrid population exhibited variation after 5 days of drought, ranging from 3 to 9 for TQ, 13% to 77% for RWC, and 0.4 to 0.8 for FvFm.

Several possible QTLs were identified during heat, drought, and recovery from stress within the creeping bentgrass population. Under drought stress, from the results of both the field and greenhouse studies, possible QTLs were identified on chromosomes 2, 3, 4, 5, 6 8, 9, 10, 11, 12, and 13. Of these, four chromosomes, groups 3, 5, 9, 10, 11, and 13, had multiple regions that could be possible QTLs or had overlapping regions for multiple traits. The QTL on group 3 was identified for both MSR and RWC in years 2007 and 2008.

The possible QTL region on group 11 was for TQ and carbon-to-nitrogen ratio, MSR, and TQ. TQ on this group mapped to the 70-80 cM region in both 2007 and 2008 during recovery from drought. Group 5 may be a location determining TQ characteristics under stress conditions, since the same region was consistent across all years. Groups 5, 11, and 12 may be the most important groups for drought-tolerance traits.

During heat stress analysis, potentially important regions of the genome include chromosome groups 2, 3, 6, 9, 10, 11, 12, and 13 identified for the traits TQ, NDVI, LAI, and FvFm. QTLs on groups 2, 3, 9, 11, and 12 accounted for traits over multiple years, indicating that these could also be important chromosomal locations to look at for future use in marker-assisted selection. In the field studies of 2008 and 2009, groups 2, 9, 11, and 12 may have important regions controlling visual quality during heat stress as measured by TQ ratings and MSR readings.

Important linkage groups including possible QTLs for drought tolerance were chromosomes 3, 5, 9, 10, and 14. Greenhouse evaluation of variation in drought tolerance in 2009 resulted in significant QTLs on three different chromosomes, groups 4, 5 and 10. The location of the QTL on group 5 overlapped for the two traits EL and CTD. TQ mapped to three locations, two on group 10 and one on group 4. In 2010, the greenhouse and growth chamber evaluations revealed possible QTLs on groups 1, 3, 5, 9, 10, and 14. Since the most consistent QTLs across years and environments were groups 5 and 10, traits in these regions may contribute greatly to the variation in drought tolerance seen within the hybrid population.

Summary Points

- Phenotypic variation in drought and heat tolerance in both the creeping and hybrid bentgrass populations allowed for identification of potentially important QTL regions.
- QTL regions that were consistent across years and environments such as group 5 and 11 for the bentgrass population and 5 and 10 for the hybrid population may be important chromosomal regions governing stress tolerance traits.
- Regions of chromosomes groups 3 and 11 in the creeping population were significant for both heat and drought tolerance. The importance of these groups in tolerance to multiple stresses may be the most useful in future studies for development of marker-assisted selection procedures.

Evaluation of the New England Velvet Bentgrass Collection

Rebecca Nelson Brown
University of Rhode Island

Geunhwa Jung and Loreto Araneda
University of Massachusetts

Objectives:

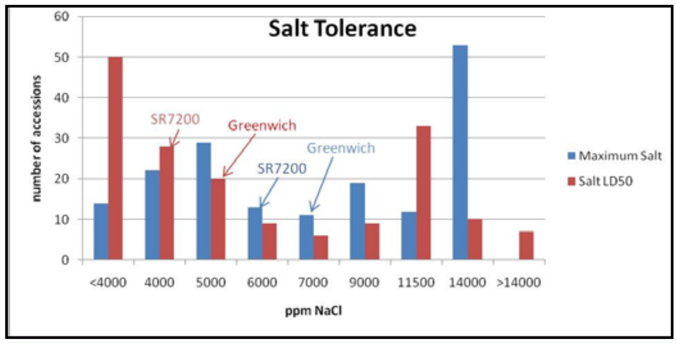
1. Collect velvet bentgrass (*Agrostis canina* L.) germplasm accessions.
2. Identify and group accessions based on their genetic similarities for analysis and breeding.
3. Evaluate accessions for improved resistance to biotic and abiotic stresses.

Start Date: 2007
Project Duration: three years
Total Funding: $90,217

The New England velvet bentgrass germplasm collection is a collaborative effort by researchers at the University of Rhode Island and the University of Massachusetts. More then 250 accessions have been collected from old golf courses throughout New England. In 2009, the entire collection was evaluated for salt tolerance in the greenhouse at URI, and for genetic color, growth rate, and dollar spot in the field at URI. Copper spot resistant accessions identified in 2008 were re-screened to confirm resistance.

Velvet bentgrass (*Agrostis canina*) has two ploidy levels, diploid (2n = 14) and tetraploid (2n = 28) referred to subspecies *canina* and subspecies *montana*. A flow cytometry analysis was carried out in the velvet bentgrass collection to clarify the ploidy level of the accessions. After the analysis, 74% (159 individuals) of the accessions were found diploid supported with velvet phenotypes, and 26% (56 individuals) were found tetraploid. Out of 83 EST-SSR primers previously screened, 10 pairs were selected because of their polymorphism and quality of amplification.

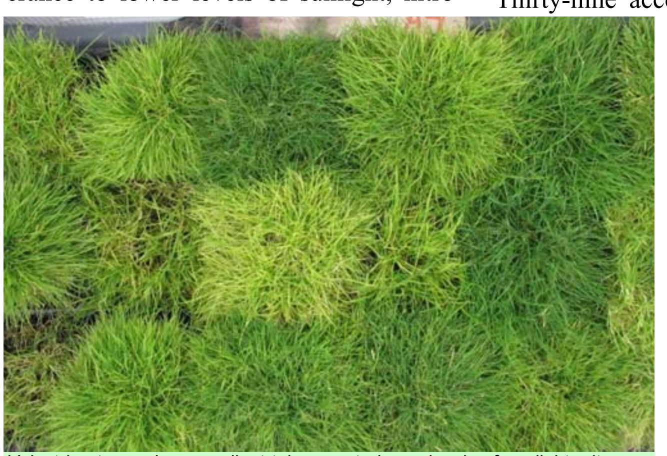
Velvet bentgrass has excellent tolerance to lower levels of sunlight, nitrogen, and water. Velvet bentgrass is considered native to New England and coastal regions as far south as Maryland. The stress tolerance genes found in velvet bentgrass need to be preserved as potentially irreplaceable genetic resources.



Thirty-nine accessions were significantly more salt tolerant than 'SR7200' and 'Greenwich', and an additional seven were more tolerant than 'SR7200'.

The entire collection was evaluated for salt tolerance in the greenhouse at URI from February until June 2009. Three clones of each accession were transferred to pots filled with sand and placed in an ebb-and-flow hydroponics system. The plants were irrigated with a nutrient solution amended with sodium chloride. The salt concentration was increased every 2 weeks from 1,000 ppm to 8,000 ppm.

At the end of each 2-week period, all the plants were photographed using a digital camera and a portable light box. SigmaScan software was used to measure retention of green foliage by calculating the number of green pixels in each image. At 8,000 ppm salt, 'SR7200' retained 4% green cover, and 'Greenwich' retained 10%. The velvet bentgrass accessions ranged from 0% green cover to 80% cover. Thirty-nine accessions were significantly more salt tolerant than either cultivar, and an additional seven were more tolerant than 'SR7200'. Thirty-one of these accessions retained more than 50% green cover.



Velvet bentgrass has excellent tolerance to lower levels of sunlight, nitrogen, and water. Velvet bentgrass is considered native to New England and coastal regions as far south as Maryland.

Three replications of the germplasm collection were established in the field at URI as spaced plants on 18-inch centers and mowed at fairway height. This field trial is being used to evaluate genetic color, turf growth, and disease resistance. Each accession was photographed in September 2008 and July and November 2009 using a digital camera and controlled lighting. The digital green color index has been calculated for each accession, producing quantitative data for color comparisons.

The collection was transplanted to the field in June 2008 as 5.5-cm plugs. Holes were cut into an established chewings fescue turf using a standard cup cutter, so each plug was surrounded by a 2.6 cm-wide ring of bare soil. The diameter of each plant was measured in July 2009. Four accessions failed to survive. Diameters for the others ranged from 6 cm to 23 cm. Most of the accessions more than doubled in size; 42 accessions more than tripled in size despite competition from the chewings fescue.

The field trial was visually evaluated for dollar spot resistance in August 2009 following a severe natural disease outbreak. Accessions were rated from 1 to 9, with 9 indicating no disease. Eighty-seven of 233 accessions (37%) showed no sign of disease.

Summary Points

- Collaborative studies continue with several researchers in New England.
- Significant progress has been made to identify germplasm that have enhanced resistance to biotic and abiotic stresses.

Genetic Enhancement of Turfgrass Germplasm for Reduced-input Sustainability

Kevin Morris
National Turfgrass Federation, Inc.

Scott Warnke
USDA-ARS

Objectives:

1. Use genetic and biotechnology approaches to identify and develop turfgrass germplasm with improved biotic and abiotic stress resistance.
2. Identify molecular markers associated with desirable traits and to combine useful traits into germplasm able to grow with reduced inputs.

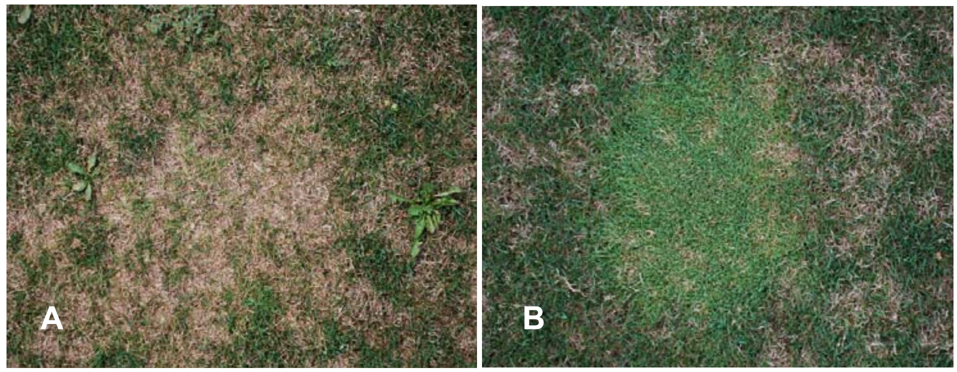
Start Date: 2007
Project Duration: three years
Total Funding: $50,000

There is a tremendous need to improve the stress tolerance of turfgrass. In the past year, our focus has been on identifying and improving disease and heat tolerance in bentgrass (*Agrostis* spp).

A major effort of ours is to improve dollar spot (*Sclerotinia homoeocarpa*) and brown patch (*Rhizoctonia solani*) disease resistance. Dollar spot and brown patch are the most widespread fungal diseases of highly managed turfgrass species such as creeping bentgrass (*A. stolonifera*). More money is spent to manage these diseases than all other turfgrass diseases combined. Dollar spot and brown patch are widespread throughout the summer months in warm humid areas of the United States, and spray programs are generally scheduled at regular intervals to safeguard against disease establishment. However, these spray strategies can lead to the fungi developing fungicide resistance, and this has become a major issue in certain regions of the country.

ARS researchers at Beltsville, MD are using new high-throughput DNA sequencing technologies to determine the genes that are important in the interaction of these important fungal pathogens with turfgrass plants. The identification of the genes involved in this interaction has the potential to significantly reduce the amount of fungicides needed to maintain disease-free turfgrasses.

A new type of bentgrass genetic marker was developed using sequence data obtained as part of a bentgrass DNA sequencing collaboration with Rutgers University. The new markers are based on Miniature Inverted Transposable Elements (MITEs). MITEs appear to be common in *Agrostis* and the markers were used to evaluate the genetic diversity of germplasm.



Susceptible creeping bentgrass clone showing low levels of dollar spot resistance (A) and creeping bentgrass clone showing resistance to dollar spot infection (B) in Maryland.

Critical to the development of improved cultivars is an understanding of the underlying genetic structure. Important to this understanding is knowledge of chromosome numbers and their arrangement. However, very little research on bentgrass chromosome identification is reported in the scientific literature. Therefore, 25 accessions of *Agrostis* from the USDA National Plant Germplasm System were selected for analysis. Previously exhibited DNA content values based on flow cytometry indicated that the accessions were diploids.

Plants from an experimental creeping bentgrass mapping population were established and inoculated with the dollar spot fungus at the University of Maryland turfgrass research center, College Park. Extensive disease development occurred for the second year, and clones with the highest levels of resistance were selected for further evaluation. The most resistant and some selected susceptible clones are being inoculated with *S. homoeocarpa* and *Rhizoctonia zeae*. Infected tissue is being harvested to evaluate gene expression that takes place during infection by these two important turfgrass fungal pathogens. The goal is to determine the genes that control resistance and make this information available to breeders for development of improved, disease-resistant cultivars.

Besides improving disease resistance, we are investigating genes for heat tolerance. Field data from 2008 and 2009, as well as growth chamber data from 2008, was used to search for regions of the bentgrass chromosomes that contribute to heat and drought tolerance in experimental populations. Recent analysis identified seven linkage groups that provide some level of tolerance to these important stresses. Future work will further refine these chromosome locations and the level of importance each plays in heat and drought tolerance. The goal is to improve the speed and accuracy of selection for these important traits.

Summary Points

- A new type of bentgrass genetic marker was developed using sequence data based on Miniature Inverted Transposable Elements (MITEs). MITEs appear to be common in *Agrostis* and the markers are useful in evaluating the genetic diversity of germplasm.
- Dollar spot resistant and susceptible plants are now being investigated to identify which genes are expressed, and potentially confer resistance in bentgrass.
- Analysis of bentgrass chromosomes identified seven linkage groups that contribute some level of heat and drought tolerance. These chromosome locations will more intensively studied to better understand the role each plays in conferring stress tolerance.

Collection and Evaluation of Native Grasses from Grazed Arid Environments for Turfgrass Development

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University of Arizona

Objectives:

1. Collect and evaluate native grasses grazed rangelands for potential use as turfs in Arizona.
2. Determine species survival performance of mowed clones in the field.
3. Identify superior clones for future breeding.

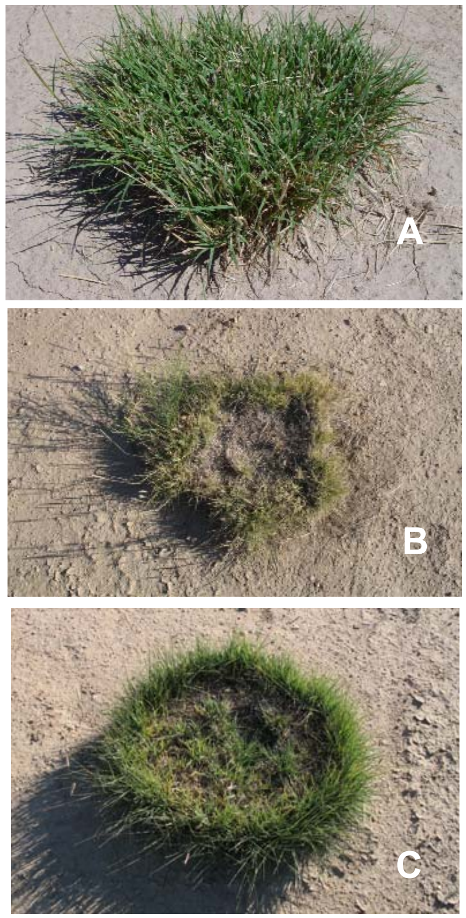
Start Date: 2008
Project Duration: 3 years
Total Funding: $29,993

The nationwide effort to use native grasses is spurred by concerns regarding species diversification and invasive habits of some commonly used turf species.

In 2008, clones of the bunchgrasses sprucetop grama, black grama, hairy grama, and wolfstail, which had the best color, density, and general turf quality in a greenhouse trial were propagated into multiple plant copies for field evaluation. One hundred clones from the 2007-2008 greenhouse tests were placed in a mowed spaced-plant nursery. Each of the clones appeared four times in the spaced-plant nursery, which numbered 400 plants in total. After transplanting into the field in July 2008, plants were mowed 3x weekly at 3.0 inches starting in August 2008, and from May through October in 2009 and 2010.

In the first year, wolfstail produced close spreading robust plants with high shoot densities, as did blue grama clones. Toward the end of the summer of 2009, the inner tillers began to die en masse in a concentric ring on wolfstail, and to a lesser extent on most blue grama plants, as well. Hairy grama plants developed coarse open stemmy plants and had poor density, regardless of plant size.

Sprucetop grama plots, however , did not die out with inner concentric rings, as did blue grama and wolfstail grasses. Instead, they produced bunch-type tillers from the center of the plant outward, with almost full viability of each separate tiller. Most plants of sprucetop grama maintained full green color leaves with a minimal amount of white leaves present. The shoot density was not as great as that of the wolfstails, before they fell apart, nor were the plants as large as the blue grama plants, but their appearance was clearly the best, and most plants were acceptable as a low maintenance turf.



Shown above are sprucetop grama (A), wolfstail (B), and blue grama (C). Sprucetop grama produced the best quality plants. Both blue grama and wolfstail did not persist under the desert heat of Tucson, .

All plants in the mowed spaced plant nursery were rated for turfgrass quality using a 1-5 scale (1 = straggly or dead plant, 5= excellent quality). On June 21, 2010, there are almost equal amounts of plants in each "quality" score class (1-5) for sprucetop grama. Several plants reside in the highest turfgrass quality score class (quality = 5). This means that after 2 years of mowing with minimal irrigation, 10%, or so, of the sprucetop grama plants selected as the better plants from the greenhouse study produced and maintained very good quality, and the phenotypic variation is distributed as a normal bell curve. This suggests that traits for improving turf-type habit are probably polygenic in nature, and plant improvement for the turf-type habit is possible through standard breeding techniques.

The vast majority of wolfstail plants had extremely poor turf quality. One hairy grama and two blue grama clones had good turf quality, but generally, blue grama plants did not hold-up in the heat of the long Tucson summer. They eventually produced an inner concentric ring of straw resulting from dead tillers within the center of the plant.

Although blue grama is used in many northern states as a low-maintenance turf, the total heat load in Tucson was overwhelming, and the clones selected from Arizona rangelands clones proved generally unacceptable under mowed conditions. Likewise, wolfstail on the range maintains good color and turgid leaves for several weeks of natural drought after a nominal rainfall, but when mowed consistently, the grass cannot survive adequately.

Sprucetop grama produced the best (and acceptable) quality plants. The next logical step is to screen a larger sample of this species, and cross the best with the best. Seed from such crosses will go into mowed turf plots.

Summary Points

- We collected 300 clones from seven species of perennial range grasses were collected from a 150-mile radius of Tucson. One hundred bunchgrass and 100 stoloniferous grasses were selected for field evaluation under regular mowing.
- The vast majority of wolfstail plants had extremely poor turf quality.
- The blue grama and wolfstail clones selected from Arizona rangelands clones proved generally unacceptable under mowed conditions.

Bermudagrass and Seashore Paspalum Cultivar Response to the Sting Nematode

Wenjing Pang, William T. (Billy) Crow, and Kevin E. Kenworthy
University of Florida

Objectives:

1. Determine the range of response (resistance or tolerance) of bermudagrass and seashore paspalum cultivars to the sting nematode and identify the best performing cultivars.
2. Investigate if a proposed alternative method for assessing sting nematode response is as effective, or more efficient, than traditional methods.

Start Date: 2008
Project Duration: 3 years
Total Funding: $31,407

A major limitation of planting turfgrasses in the sandy soils of Florida is the destruction of roots by the sting nematode (*Belonolaimus longicaudatus*). Spiral nematodes (*Helicotylenchus* spp.) are also frequently found in high numbers (>500 nematodes/cm^3 soil) on seashore paspalum in Florida. Utilization of resistant and tolerant turfgrass cultivars is one of the most environmentally safe nematode management practices. Several commercial cultivars of bermudagrass and seashore paspalum have been tested for their responses to *B. longicaudatus* or *H. pseudorobustus* under greenhouse conditions. However, information is lacking with respect to their responses under field conditions or multiple nematode species in the field.

In May 2008 and April 2009, two field studies were conducted separately through 2010. Nematode population densities in each plot were assayed on the same day the plots were planted. Soil samples were subsequently collected every 90 days after planting. Turfgrass health was determined by evaluating root lengths and turf density every three months throughout the turf growing season.

Population densities of *B. longicaudatus* exhibited variable changes from 2008 to 2010 for the bermudagrass cultivars studied. *Belonolaimus longicaudatus* populations increased in 'Champion' (37%) and 'Mini Verde' (40%); and dropped in 'Tifgreen' (4%), 'TifEagle' (18%), and 'Celebration' (27%), 'Floradwarf' (32%), 'Tifway' (33%), and 'TifSport' (93%). Population densities of *B. longicaudatus* were not different among dwarf bermudagrass cultivars, but remained the lowest in 'TifSport'.

Population densities of *B. longicaudatus* in 'TifSport' continuously declined from 102 to 7 nematodes/cm^3 soil, which indicated resistance to *B. longicaudatus*. However, 'TifSport' was a good host to *H. pseudorobustus*, whose population densities increased from 6 to 744 nematodes/cm^3 soil (124 fold) from 2008 to 2010. Nematode densities of other bermudagrass cultivars remained below 180 nematodes/cm^3 soil. 'TifSport' appeared to be more effective at suppressing the reproduction of *B. longicaudatus* in field.

Utilization of resistant and tolerant turfgrass cultivars is one of the most environmentally safe nematode management practices.

Seashore paspalum was a better host to *H. pseudorobustus* than *B. longicaudatus*. The population densities of *H. pseudorobustus* increased 177-, 106-, and 214-fold, while population densities of *B. longicaudatus* decreased by 69, 96, and 86%, respectively, in the seashore paspalum cultivars, 'Aloha', 'SeaDwarf', and 'Sea Isle I' within the two years. 'SeaDwarf' was the most effective seashore paspalum cultivar at suppressing the reproductive capabilities of *B. longicaudatus* in field.

Interactions were found between *B. longicaudatus* and *H. pseudorobustus*. *H. pseudorobustus* had a suppressive effect on the reproduction of *B. longicaudatus* in all seashore paspalum cultivars studied and for 'TifSport' and 'Celebration' bermudagrass. The interaction between the two nematode species was not apparent for other bermudagrass cultivars. This effect may be host-dependent and could vary with different species and cultivars.

Nematodes affected the total root length and turf density of the turfgrass cultivars. A negative linear relationship was found between the population density of *B. longicaudatus* and the total root length as well as turf density of 'Celebration' bermudagrass. A negative relationship between the population density of *B. longicaudatus* and the turf density of 'Aloha' was also identified. A negative linear relationship between the population densities of *H. pseudorobustus* and the total root length, as well as turf density, was found in 'Floradwarf' bermudagrass, and for total root length of 'Tifgreen' and turf density of 'TifEagle'. Regression analysis indicated that 'Celebration' bermudagrass and 'Aloha' seashore paspalum may be intolerant to *B. longicaudatus*, while 'Floradwarf', 'Tifgreen', and 'TifEagle' bermudagrasses could be intolerant to *H. pseudorobustus.*

Summary Points

- Bermudagrass is a better host to *B. longicaudatus*, and seashore paspalum is a better host to *H. pseudorobustus*.
- *Belonolaimus. longicaudatus* was a better competitor than *H. pseudorobustus* in bermudagrass cultivars other than 'TifSport', and *H. pseudorobustus* was a better competitor than *B. longicaudatus* in seashore paspalum cultivars.
- Population densities of *B. longicaudatus* were not different among dwarf bermudagrass cultivars, but remained the lowest in 'TifSport' among the non-dwarf cultivars.
- 'TifSport' bermudagrass and 'SeaDwarf' seashore paspalum were best for suppression of *B. longicaudatus* densities in the field.
- 'Celebration' bermudagrass and 'Aloha' seashore paspalum showed intolerance to *B. longicaudatus*, and 'Floradwarf', 'Tifgreen', and 'TifEagle' bermudagrasses were intolerant to *H. pseudorobustus*.

Breeding Turf-type Annual Ryegrass for Salinity Tolerance

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Objectives:

1. Identify improved salt- and sodium-tolerant genotypes and introgress the tolerance into adapted turf-type genotypes of annual ryegrass and increase seed of these populations for experimental testing.
2. Test new experimental lines of annual ryegrass under greenhouse and field conditions of highly saline and sodici soil and water, and release the line as a salt-tolerant variety.

Start Date: 2008
Project Duration: 3 years
Total Funding: $88,276

Annual and perennial ryegrass are considered to be susceptible to high salinity. Genetic selection for tolerance to high salinity was carried out by two methods. First, a salt-tank greenhouse screening method was utilized to select salt-tolerant plants at Overton, Texas. Secondly, a screening procedure was utilized under high salt field conditions at Pecos, Texas.

The methods for selection of genotypes with improved salt tolerance were planting seed in the field in a high salinity soil and irrigating with highly saline water. Seed (300 g) was broadcast over a 30- x 30-ft area. Sprinkler irrigation was used to germinate and establish a stand. During the 2008-09 season, almost no rainfall occurred at Pecos. Irrigation was the only source of moisture for the growing season. Selection of seedheads of the best plants took place in May 2009.

In 2009-10, a second cycle of selection was conducted at Pecos using germplasm from the earlier selection. In the greenhouse procedure in 2009-10, two gemplasms were selected. One was from Pecos, the second from the previous year's greenhouse selection. When plants were in the two to three-leaf stage, entire flats were immersed in water with a salt concentration of 3,100 ppm (4.9 dS/m).

Thereafter, flats were immersed every 3 to 4 days. Salt concentration was increased gradually over 60 days until a water salt concentration of 19,500 ppm (31.2 dS/m) was reached at selection period. At that time, 75% of plants were dead. Remaining plants (250 plants) cross-pollinated and produce seed in the spring of 2010. This seed, as well as the seed from Pecos, will be tested for salt tolerance in 2010-11 in both greenhouse and field studies.

Ryegrass plant at Pecos started in high-salt soil.

In addition to the above trials, 20 genotypes were tested in a field trial at Pecos and in a greenhouse study at Overton. At Pecos, ratings were made at two dates. On the first date, February 2, all genotypes were evaluated in an overseeded turf environment. The three lines that had highest salinity tolerance ratings were Pecos Salt Blk, Pecos Blk. 07-08, and TXR2009-SS-Blk. Each of these lines had been selected at either Pecos or Overton. These results indicate the ryegrass selected at Pecos is either more adapted to the Pecos environment and/or more tolerant to the high-salinity conditions at Pecos. Two intermediate entries, LH-08 and 66B-08, also showed above-average tolerance to salinity at Pecos.

In the greenhouse trial, plants were grown in flats in an organic mix and later immersed in high salt concentrations in a tank. Significant differences were measured between entries. However, results were not positively correlated with all the Pecos salt-tolerant selections. SS3 (07-08), a greenhouse salinity section, and 'Intercross' (an intermediate ryegrass not selected for salt tolerance) appeared to have slightly more salt tolerance than other entries.

Seed from the most salt tolerant breeding lines as described from the Pecos screening trial will be increased in Oregon during the 2010-11 growing season. This increase is made up of 50% TXR2010-SS3G, 33.3% TXR2009-SSBlk, 8.3% Salt S-10, and 8.3% Pecos Blk 2010. Three pounds of seed will be planted on approximately 1 acre and should produce approximately 1,500 lb of seed in the summer of 2011.

This seed will then be returned to Texas for evaluation under field studies on high salt problem areas on golf courses in Texas. It will be compared to control varieties such as 'Panterra', 'Axcella 2', and 'Intercross' to determine if it is improved for salinity tolerance.

Summary Points

- Differences for salt tolerance between genotypes were obtained in both greenhouse and field experiments.
- Elite salt-tolerant germplasm selected at Pecos, Texas, was rated as most tolerant in a Pecos salinity trial in 2010.
- Seed of the elite salt-tolerant germplasm will be increased in Oregon in 2010-11 for further testing in 2011-12.

Evaluating Methods for Vegetative Propagation and Enhancement of Seed Production of Greens-Type Poa annua *Cultivars*

David R. Huff
Pennsylvania State University

Objectives:

1. Establish efficient vegetative propagation methods of greens-type *Poa annua* for sod production and for establish ing/renovating golf course putting greens.
2. Scale-up our results for greens-type cultivar production to a larger commercial level by collaborating with sod producers.
3. Release a genetically stable, vegetative greens-type cultivar exhibiting superior putting green quality and stress tolerance.

Start Date: 2008
Project Duration: 3 years
Total Funding: $20,000

Poa annua is widely recognized for providing a large portion of high-quality putting surfaces in many regions of North America, Europe, and Australasia. However, despite repeated attempts in the U.S. to develop improved cultivars of greens-type *P. annua* for the golf course industry, there currently are no commercially available sources suitable for use in new construction or renovation of putting green surfaces.

Our previous genetic research suggests that the dwarf, perennial greens-type phenotypes result from the action of mowing which causes a repression of the plant growth hormone gibberellic acid signaling pathway through a non-Mendelian epigenetic mechanism involving the auxin biosynthesis pathway. Greens-type *P. annua* is an unstable phenotype which, in the absence of mowing pressure, will relatively quickly revert back to its wild annual form. The purpose of this research is to determine if the genetic stability of perennial greens-type *P. annua* is capable of being maintained through vegetative propagation during sod production of cultivars.

Poa annua is an allotetraploid species which means it originated from a whole genome duplication of an F_1 hybrid between two diploid parents. The parental species of *P. annua* have long been believed to be *P. supina*, a perennial, stoloniferous species that is native to the mountainous regions of central Europe and *P. infirma*, a bunch-type annual that inhabits the Mediterranean regions of Western Europe. Typically, an allotetraploid has the complete complement of chromosomes that each of the diploid parents contains.

Poa annua's set of chromosomes has a vastly different structure than either of its two parental species. The mechanism that has rearranged the chromosomal structure of *P. annua* most likely involves the action of class II transposable genetic elements, or "jumping genes." It is well known that once such jumping genes have been mobilized, often the resulting genomic reshuffling is accompanied by a wide variety of non-Mendelian epigenetic factors that differentially regulate gene expression.

Dr. Dave Huff and his colleagues have successfully propagated phenotypically stable greens-type Poa annua *across several replicated trials in various regions of the U.S.*

The ability of *P. annua* to become so widely distributed and to inhabit such a wide range of environments is likely the result of the same mechanism that has enabled it to evolve an ability to tolerate the close mowing heights of golf green putting surfaces. Gaining additional information and knowledge of exactly how these transposable elements have restructured the chromosomes of *P. annua* and how these elements affect genetic stability will help us in the future to potentially manipulate the breeding and genomics of *P. annua*.

We have demonstrated that genetic integrity and resulting phenotypic stability is achievable through vegetative propagation in combination with the action of mowing as the most critical factor to maintaining the greens-type phenotype. Using these methods, we have successfully propagated phenotypically stable greens-type *P. annua* across several replicated trials in various regions of the U.S. In order to rapidly establish these sod production fields, we have carefully produced 5 lb of phenotypically stable seed to provide the necessary planting stock for an evaluation of scaled-up production.

After the initial establishment, cores will be harvested from these sod fields to expand production and supply of our greens-type *P. annua* cultivar. The cultivar chosen for this sod production has repeatedly demonstrated high turf quality and excellent field resistance to anthracnose and dollar spot.

Summary Points

- Our research has successfully demonstrated the potential to maintain the phenotypic stability of greens-type *Poa annua* cultivars through vegetative propagation in combination with mowing.
- We have successfully produced enough stock material to initiate testing of large-scale sod production of one our top-performing cultivars.
- We have begun collaborating with commercial sod producers in Pennsylvania and Illinios to begin scaling up our vegetative propagation techniques of greens-type *P. annua*.

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

Bingru Huang, Yan Zhang, Faith Belanger, Stacy Bonos
Rutgers University

Scott Warnke
USDA-ARS

Objectives:

1. Develop PCR-based markers from heat-responsive genes.
2. Map heat-responsive candidate genes on the present bentgrass genetic linkage maps.
3. Test for co-localization of candidate genes with mapped heat tolerance QTLs.
4. Confirm candidate gene markers for use in marker-assisted breeding of creeping bentgrass for improved heat tolerance.

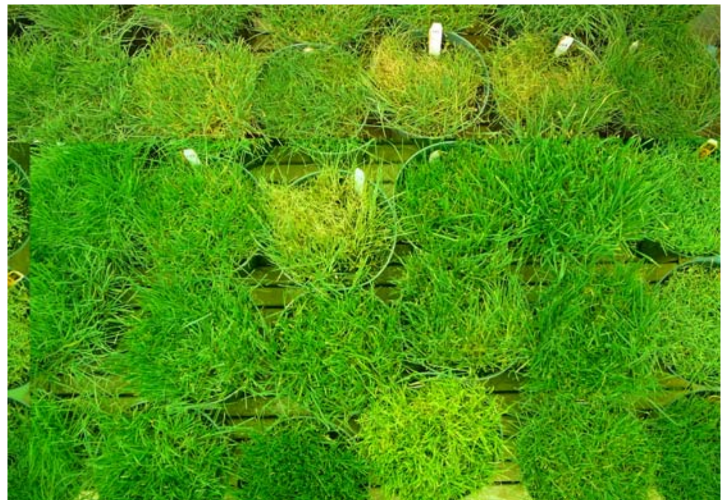
Start Date: 2010
Project Duration: 3 years
Total Funding: $89,713

Heat stress is a major abiotic stress affecting creeping bentgrass growth, leading to quality decline during periods of prolonged heat in many turf areas. Improving heat tolerance in creeping bentgrass is critical for maintaining high quality turf during summer months. By identifying important genes controlling heat tolerance and developing markers to assist in selection, the severity of summer bentgrass decline could be significantly reduced.

Several potentially important genes associated with heat tolerance were identified using suppression subtraction hybridization method and proteomic profiling, including fructose 1,6-bisphosphate aldolase, inducible phenylalanine ammonia-lyase, protein disulfide isomerase, putative glutathione S-transferase, cysteine protease, HSP16 and expansin. Potential markers for these genes are being tested in a hybrid mapping population which consists of a creeping x colonial hybrid (TH15) crossed with another creeping line (9188).

Several methods of developing useful markers to detect polymorphisms are being employed. Using EST sequences in the NCBI database, allele-specific PCR-based markers have been tested for inducible glutathione S-transferase, protein disulfide isomerase, cysteine protease, HSP16, and expansin. This method has successfully uncovered polymorphisms in the cysteine protease gene that controls protein degradation. The mapping population is currently being scored to potentially add this gene to the linkage map. Unfortunately, this method did not work for the other genes, so other means are being explored.

Cleavage amplified polymorphism (CAP) markers have been tested on fructose 1,6-bisphosphate aldolase as well as HSP16. Previous experiments have shown that the HSP16 and expansin genes are important for heat tolerance. These genes from the parents of this mapping population are being sequenced to uncover useful polymorphisms for marker development.



Plants exposed to 20 days of heat stress (38^{O} C), showing genetic variations in heat tolerance.

Concurrent with marker development, heat stress trials on the mapping population are being carried out. Turf quality, normalized difference vegetative index (NDVI), chlorophyll fluorescence, chlorophyll content, and electrolyte leakage are being used to evaluate the heat tolerance of individuals in the population. Tissue samples are also being collected to confirm expression levels of key genes.

Initial heat stress results show significant variation for a number of physiological parameters. Turf quality and NDVI, which both indicate overall turf health, as well as electrolyte leakage, a measurement of membrane stability previously found to be correlated with heat tolerance, are among the preliminary results analyzed. These parameters demonstrate that there is phenotypic variation in heat tolerance within the population.

In the near future, potential marker development for several of the key genes will be finished, marker development for genes discovered to be of potential importance based on current proteomic research will begin. Markers will be screened and confirmed using the mapping population, and successful markers will be added to the linkage map expanding its coverage.

Confirmation of these genes' roles in heat tolerance will also help develop our understanding of heat stress on the molecular level. Eventually, these will result in quick and efficient methods to screen populations for heat tolerance and select tolerant individuals for cultivar development.

Summary Points

- Several methods of detecting polymorphism have been tested.
- A potential marker for cysteine protease has been developed and is being scored to be added to the map.
- Parental DNA is being sequenced to uncover polymorphisms in two important heat tolerance genes, HSP16 and expansin.
- Heat stress trials are underway to confirm candidate genes importance and expand QTL maps
- Initial heat stress results show there are significant phenotypic variations within the population.

Development of Seeded Zoysiagrass Cultivars with Improved Turf Quality and High Seed Yields

A. Dennis Genovesi and Ambika Chandra
Texas A&M University

Objectives:

1. Develop seeded type zoysiagrass germplasm/cultivar(s) with high seed yields that offer an economical alternative to vegetative types with the potential for rapid turf establishment.
2. Breed improved characteristics such as turf quality, competitive ability, and persistence under biotic and abiotic stresses.

Start Date: 2010
Project Duration: 3 years
Total Funding: $89,434

Zoysiagrass is most often vegetatively propagated by plugging, sprigging, or solid sodding. Vegetatively produced grasses provide considerably higher quality turf, however, marketing and distribution is easier with seeded cultivars. Our research focuses on the development of seeded cultivars of zoysiagrass that are genetically stable with improved turf quality, high seed yields, persistence, and competitive ability.

Initial breeding efforts to develop seeded type zoysiagrass were carried out at Texas AgriLife Research Center – Dallas from 2000 to 2002. Preliminary breeding work utilized cycles of genetic recombination followed by selection of 53 out of approximately 1,600 experimental lines that exhibited high seed-yield potential and turf quality. This group of 53 advanced lines includes interspecific hybrids resulting from crosses between *Zoysia japonica* and Z. *matrella*.

Current funding is directed toward the evaluation of these selected experimental lines for possible commercialization, as well as the initiation of additional breeding cycles of recombination and selection of germplasm to generate new seeded families. Evaluation of the 53 selected experimental lines will be performed through a series of isolation/crossing blocks, spaced-plant nurseries (SPN), and replicated field trials. Isolation blocks will promote open pollination and recombination among entries and SPN will allow selection of individuals with the best seed production potential. Selected individuals from a SPN cycle will be allowed to recombine the following year in a crossing block cycle for further population improvement by stacking genes that enhance seed yields. In addition to scoring

Fine-textured isolation block planted on July 2, 2009 and photographed May 24, 2010 just prior to seed harvest.

for seedhead production in the SPN, we will also evaluate each seeded family for turf quality and performance characteristics in a replicated field trial.

In 2009, 19 of the 53 selected experimental lines were classified as fine textured, 18 as medium coarse, and 16 as coarse. Three isolation blocks were planted representing each texture class on July 2, 2009. A total of 17 clones of each entry were planted in a randomized manner within their respective crossing block. The intent was to maximize open pollination among members of the same texture class. Seed was collected during late May and early June, 2010 from each individual entry.

This winter, we will focus on the germination of seed harvested from the isolation block nurseries. Because resources are limited, we are going to focus solely on the fine texture class and place seed from the medium coarse and coarse texture classes into cold storage. Seed from 15 of 19 fine-textured genotypes will be germinated in the greenhouse during the winter with the goal of producing around 54 progeny per genotype.

Since zoysiagrass has hard seeds, it must be scarified to enable quick germination. The preferred way to scarify zoysia seed is chemically with a strong base (40% KOH). Three reps of 50 seeds each will be chemically treated and germinated on filter paper in petri plates to determine percent germination for each genotype. Another three reps of 50 seeds each will be planted directly into potting mix to score for seedling vigor.

The resulting seedlings will be transplanted to 4-inch pots for grow-out prior to field planting in 2011. This effort should produce a population of more than 1,000 progeny which will be planted on 4-ft centers in the 2011 SPN. The progeny population will be evaluated for seedhead production and turf-quality characteristics in 2011 and 2012. The best seed parents will be selected for another cycle of cross pollination in isolation blocks in 2013.

We will introgress new germplasm identified from other sources with the potential for good seed production in the 2013 isolation block to ensure a broad genetic base and minimize inbreeding. A replicated field trial with will be planted in 2011 for all 15 fine-textured, seeded families to determine their turf quality.

Summary Points

- Fifty-three advanced lines with the potential for good seed production were planted in field isolation blocks July 2, 2009 in order to allow open pollination within texture classes.
- Seed was harvested from the isolation blocks which represent each of three texture classes in late May and early June of 2010.
- This winter, seed harvested from 15 fine-textured entries will be germinated in the greenhouse to generate a progeny population of over 1,000 individuals and planted in a spaced-plant nursery in 2011.

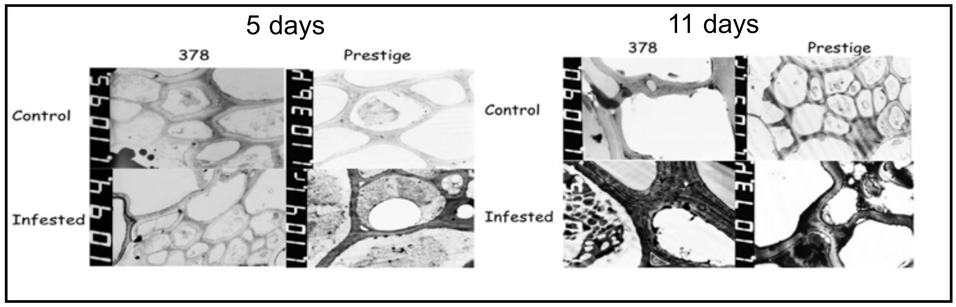
Molecular Characterization of Chinch Bug-Resistant Buffalograsses

T. Heng-Moss, R. Shearman, F. Baxendale, P. Twigg, B. Abeyo, L. Baird, and G. Lu
University of Nebraska

Objectives:

1. Assess the role of oxidative enzymes, specifically peroxidases, in the defense response of buffalograsses resistant to the western chinch bug.
2. Increase the genomic resources available for buffalograss using next generation sequencing technology.
3. Identify genes differentially expressed between chinch bug-infested and noninfested buffalograsses through the use of normalized and subtracted cDNA libraries for susceptible and resistant plants.

Start Date: 2010
Project Duration: threee years
Total Funding: $79,423



Peroxide accumulation at 5 and 11 days after initiation of chinch bug feeding on ‘Prestige’ and ‘378’ buffalograss.

Turfgrass resistance (specifically tolerance) to insects, when used as part of an integrated pest management program, offers the opportunity to effectively and economically reduce chinch bug infestations while dramatically reducing pesticide inputs. Unfortunately, deployment of chinch bug-resistant turfgrasses has been seriously hampered by insufficient knowledge of plant resistance mechanisms and genes contributing to the resistance.

This information is fundamentally important for formulating plant breeding strategies, and subsequently developing chinch bug-resistant germplasm. In addition, knowledge of specific resistance mechanisms would be valuable for identifying biochemical and physiological markers for use in germplasm enhancement programs, and for characterizing plant defense strategies to insect feeding.

Plants have developed defense strategies to overcome the abiotic and biotic stresses to which they are exposed. One component of this defense system uses a wide array of stress-related proteins which can be elevated or repressed in response to specific or general stress conditions. Changes in the expression of these proteins can play direct or indirect role(s) in the plant’s defense response to stress. Reactive oxygen species (ROS), such as hydrogen peroxide, are known to be important early signals for altering gene expression patterns in plant cells.

Despite the benefits gained from molecules like hydrogen peroxide as defense signals, accumulation of these ROS can be toxic to cells. To protect themselves from the effects of ROS accumulation, plants have developed defense-related enzymes (peroxidases and catalases) that break down the ROS.

Previous research by our group has documented increased levels of peroxidases following chinch bug feeding in the resistant (tolerant) buffalograss, ‘Prestige’, and a loss of catalase activity in the susceptible buffalograss, ‘378’. These findings support our working hypothesis that a primary plant defense response to chinch bug feeding is to elevate the levels of specific oxidative enzymes, such as peroxidase, to help detoxify peroxides that accumulate as a result of plant stress.

We are documenting the accumulation of peroxides in both resistant (‘Prestige’) and susceptible (‘378’) buffalograsses in response to chinch bug feeding. Buffalograss plant tissue was fixed, sectioned, and stained for microscopy. Preliminary results indicate a greater accumulation of peroxides in ‘Prestige’ infested plants compared to ‘Prestige’ control plants starting at day 5 and continuing through day 8. Infested ‘378’ plants had similar levels of peroxide accumulation compared to control plants at both day 5 and 8. Both infested ‘378’ and ‘Prestige’ plants exhibited greater peroxide accumulation compared with their respective control plants at day 11.

These findings suggest that peroxides are playing multiple roles in the plant. Peroxides are likely accumulating in susceptible infested plants in response to the plant’s inability to detoxify the ROS. On the other hand, the peroxides in the resistant infested plants are likely activating plant defense pathways and/or detoxifying ROS.

Research efforts are also underway to increase the genomic resources available for buffalograss using next generation sequencing technology and identify candidate transcripts that may serve as markers for selecting buffalograsses with improved chinch bug resistance. A final objective of this research is to identify specific genes conferring resistance to western chinch bug through the development of cDNA subtractive libraries for resistant and susceptible buffalograsses and gene expression studies.

Summary Points

- This research will (1) allow comparison of gene expression between resistant and susceptible buffalograsses and serve to identify genes differentially expressed in response to chinch bug feeding, (2) provide insights into the biological pathways impacted by chinch bug feeding and help elucidate plant tolerance mechanisms, and (3) facilitate development of improved buffalograsses with tolerance to chinch bugs through marker-assisted selection.
- This research will also shorten the timeframe needed to identify and improve buffalograsses with superior chinch bug resistance, and, because of shared genomics among members of the grass family, may contribute to similar improvements in other grasses species.

Environmental Impact

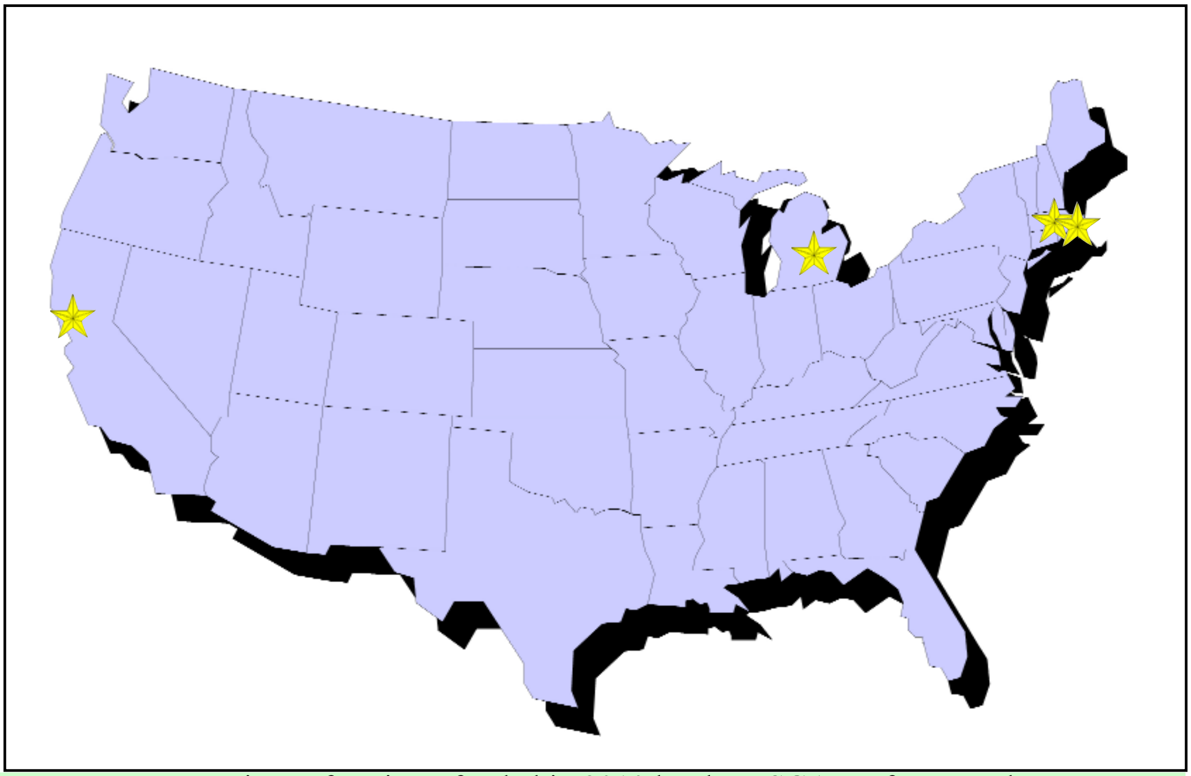
The public is concerned about the effects of golf courses on the environment. In response to this concern, the USGA has conducted research examining the fate of pesticides and fertilizers since 1991. The USGA continues to support scientifically based investigations on the environmental impact of golf courses. The focus remains on research to understand the effects of turfgrass pest management and fertilization on water quality and the environment.

Research on best management practices evaluates pesticide and fertilizer programs for golf courses in order to make turfgrass management recommendations that protect environmental quality. The research is conducted on university experiment stations and golf courses. The projects evaluate pesticides or nutrients that pose an environmental risk, and identify cultural practices that minimize volatilization, surface runoff, and groundwater contamination.

Pesticide and nutrient fate models are used to predict the environmental impact of turfgrass pesticides and fertilizers. From 1991 through 1997, research sponsored by the USGA demonstrated:

1. Measured nitrogen and pesticide leaching was minimal, and surface transport (runoff) posed a greater problem for golf courses, especially on heavy-textured soils in high rainfall areas of the country.
2. The turf/soil ecosystem enhances pesticide adsorption and degradation that greatly reduces the amount of chemical that moves below the rootzone.
3. Current agricultural fate models need modification to predict the fate of pesticides and fertilizers applied to turfgrasses grown under golf course conditions.

The results of USGA-sponsored pesticide and fertilizer fate research is being used to calibrate and validate existing pesticide fate models for turfgrasses managed under golf course conditions.



Locations of projects funded in 2010 by the USGA Turfgrass and Environmental Research Program under the category of Environmental Impact

Optimization of Vegetative Filter Strips for Mitigation of Runoff from Golf Course Turf

B. DeFlorio, J. Marshall Clark, Jeffery J. Doherty and Guy R. Lanza
University of Massachusetts

Objectives:

1. Use selected plant species in a field study to evaluate the efficacy of vegetative filter strips (VFS) and their most effective arrangement.
2. Determine the fate of pesticides retained in VFS and the major mechanisms of degradation.

Start Date: 2008
Project Duration: 3 years
Total Funding: $90,000

The loss of pesticides and nutrients into surrounding bodies of water and the resulting decreases in water quality has led to the use of best management practices on golf courses. One such practice is the use of vegetative filter strips (VFS) to intercept runoff water and thus prevent its loss and the loss of any associated pesticides and nutrients to surrounding water bodies.

Joint greenhouse and field studies have been implemented to evaluate selected plants for their effectiveness in removing pesticides and nutrients from turfgrass runoff waters that enter vegetative filter strips. A greenhouse pot study determined five species (big bluestem, blue flag iris, eastern gama grass, prairie cord grass, and woolgrass) most effectively removed the six selected pesticides (two fungicides, two herbicides, and two insecticides) from a silt loam soil.

In 2008, a run-on plot, consisting of 12 VFS planted in replicates of three (unvegetated, random mixture of plants, succession of plants, and turfgrass cut to three heights), was established; and an overhead simulated rainfall system was constructed similar to those used in previous USGA-funded runoff studies in Minnesota.

During the 2009 growing season, we installed additional lysimeters 1 ft underground and conducted two studies using an estimated runoff volume generated during a 1-year storm event of 25.4 gal over the course of 24 hours. The 25.4 gal of run-on was applied to the top edge of each VFS as a water mixture with bromide (15.1 g/gal) via a solvent transfer pump, once using inground irrigation and once using an artificial rainfall system. Runoff water was continuously collected from the bottom of the VFS. There were little differences in runoff volumes from the VFS planted as turfgrass (0.5 gal), mixture of plants (0.2 gal), and succession of plants (0.3 gal) compared to the bare strips (7.1 gal).

Bromide was detected in the runoff from the unvegetated VFS only (average time to bromide detection was 6.5 min). An average of 32.4 mg of chlorothalonil, 10.9 mg chlorpyrifos, 6.3 mg pendimethalin, 11.3 mg propiconazole, and 68.6 µg of imidacloprid were detected in the runoff collected continuously from the unvegetated VFS. Chlorothalonil (0.7 mg), propiconazole (0.1 mg) and imidacloprid (2.0 µg) were detected in two of the three succession of plants VFS. Pesticides were not detected in the runoff from either the random mixture of plants or turfgrass VFS. 2,4-D was not detected in the runoff from any of the VFS. Lysimeter samples and soil core samples are currently being analyzed for pesticide residues.

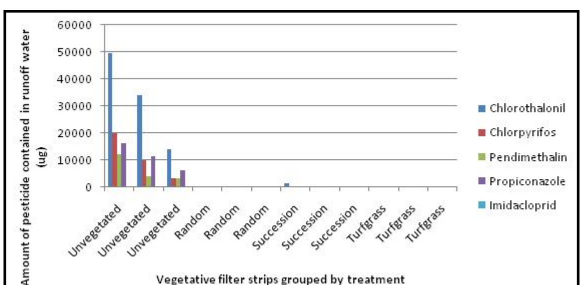


Figure 1. Amount of pesticides contained in runoff water collected from the bottom of vegetative filter strips (VFS) during a simulated 1-year storm event.

We conducted a 5-year storm event which occurred in the presence of overhead simulated rainfall. Soil presaturation was achieved prior to the initiation of the storm event by applying 0.8 inches/hour of rainfall for 9 hours, followed by 15 hours without rainfall. Three hours of overhead rainfall overlapped with the run-on (62.1 gal of water mixed with the six pesticides from the greenhouse study, at 5% their maximum application rate, and bromide at 1.5 g/gal as a tracer) for the last hour only. Overhead rainfall produced a greater distinction between the treatments than was apparent during the 1-yr rain event (3.2, 7.9, 14.9 and 74.94 gal over the course of 2 hours for turfgrass, mixture of plants, succession of plants and unvegetated VFS, respectively).

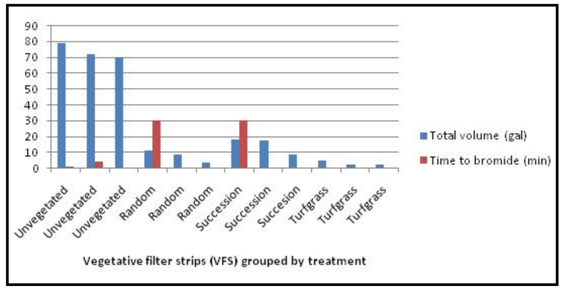


Figure 2. Average total runoff volumes (gal) and time (min) to bromide detection in runoff water from vegetated filter strips (VFS) during a simulated 5-year storm event.

Bromide was detected in the runoff from all the unvegetated VFS at 2 minutes following the initiation of the run-on event. Bromide was detected in the runoff from only two of the vegetative VFS (one succession and one random mixture of plants) at 30 minutes. We collected 60 runoff samples, 84 subsurface water samples from 1-ft lysimeters, 108 subsurface water samples from 5-ft lysimeters, and 648 soil core samples that will be analyzed for pesticides. We collected 132 30-mL samples to be analyzed for bromide. Bromide was detected after 3 minutes for the unvegetated VFS.

Summary Points

- A 1-year storm event has been simulated twice on the VFS, once using irrigation and once using an artificial rainfall system.
- A 5-year storm event has been simulated on the VFS using an artificial rainfall system.
- Preliminary bromide data indicate that bromide (and presumably pesticides) are being intercepted by the vegetative plots.
- We are currently analyzing 1,800 samples for pesticides.

Long-Term Nutrient Fate Research

Kevin W. Frank
Michigan State University

Objectives:

1. Determine nitrate-nitrogen and phosphorus leaching from a turfgrass stand that has been continually fertilized for 20 years.
2. Continue data collection from the Long-Term Nutrient Fate Research Area at MSU; currently we have data collection for 12 consecutive years.

Start Date: 2003
Project Duration: 11 years
Total Funding:
2008-2010: $34,800
2003-2007: $68,886
2000-2002: $64,612

The USGA initially funded research at Michigan State University to determine nitrogen fate and leaching from a Kentucky bluegrass turf in 1991. Like previous research, the initial research at MSU conducted from 1991 through 1993 indicated that there was minimal risk of nitrate-nitrogen (NO_3-N) leaching from Kentucky bluegrass (*Poa pratensis* L.) turfgrass. Since the summer of 1998 percolate samples have been collected from the same monolith lysimeters and analyzed for NO_3-N. As of 2010, the turfgrass area has now been under continual fertilization practices for 20 years with percolate collection for the last 12 years consecutively.

From July, 1998 through 2002, lysimeters were treated annually with urea at a low N rate of 98 kg N/ha (24.5 kg N/ha per application) and a high N rate of 245 kg N/ha (49 kg N/ha per application). From 1998 to 2002 for the high N rate, there was a dramatic increase in NO_3-N leaching from 5 mg/L in 1998 to 25 mg/L in 2002. During the same time frame, there was a modest increase in NO_3-N leaching from 3 mg/L in 1998 to 5 mg/ L in 2002.

The concentration of phosphorus detected in leachate remains very low regardless of treatment. The mean concentration of phosphorus detected in leachate since initiating phosphorus treatments in 2003 has been less than 0.02 mg L^{-1}.

In 2003, the N rate was reduced to 196 kg N/ ha for the high N rate, while the low N rate remained at 98 kg N/ha. Since 2003, phosphorus from triple superphosphate (20% P) has been applied at two rates, 49 and 98 kg P/ha split over two applications. The phosphorus application dates coincide with nitrogen application dates in the spring and autumn.

Since the summer of 1998, percolate samples have been collected from the same monolith lysimeters and analyzed for nitrate-nitrogen (NO_3-N)

In 2003, the concentration of NO_3-N leaching from the high N rate treatment did not decline from the previous years. The average NO_3-N concentration leached from the low and high N rate treatments was 6.3 mg/L and 31.6 mg/L. In 2004, the concentration of NO_3-N leaching from the high N rate treatment declined drastically from previous years.

The average concentration of NO_3-N in leachate for the high N rate was 8.5 mg/L. This was a decrease in NO_3-N concentration of 23.1 mg/L from 2003. For the low N rate, the average concentration of NO_3-N in leachate was 1.2 mg/L.

The average concentration of NO_3-N in leachate for the high N rate from 2004 through 2009 was 8 mg/L. In 2009, the mean NO_3-N concentration in leachate for the high N rate was 3.2 mg/L. This was the lowest mean NO_3-N concentration in leachate for the high N rate since data collection began in 1998. The concentration of phosphorus detected in leachate remains very low regardless of treatment. The mean concentration of phosphorus detected in leachate since initiating phosphorus treatments in 2003 has been less than 0.02 mg/L.

This research indicates that leaching potential from continually fertilized turfgrass sites changes due to the age of turfgrass and annual nitrogen rate.

Summary Points

- From 2004 to 2009, for the high N rate, less than 4% of all samples had NO_3-N concentrations greater than 20 mg/L.
- For the high N rate, most of the sampling dates that had elevated NO_3-N concentrations were during late fall or winter when the turfgrass was dormant.
- For the low N rate, the mean NO_3-N concentration has been 5 mg/L or less for every year except one (2003).
- Results continue to indicate low amounts of phosphorus leaching.

Audubon International

Audubon International strives to educate, assist, and inspire millions of people from all walks of life to protect and sustain the land, water, wildlife, and natural resources around them. In 1991, Audubon International launched the Audubon Cooperative Sanctuary Program for Golf Courses (ACSP), an environmental education program designed to help golf courses play a significant role in enhancing and protecting wildlife habitat and natural resources. The ACSP provides an advisory information service to help golf courses conduct environmental projects and achieve positive recognition for their efforts.

In addition, the Audubon Signature Program works closely with planners, architects, managers, and key stakeholders of new golf course developments to merge wildlife conservation, habitat enhancement, resource conservation, and environmental improvement with the economic agenda associated with the development. Involvement in the developmental stages of a project enables Audubon International to ensure that biodiversity conservation, environmental quality, and sustainable management are built into the project and continue after construction is completed.

Golf courses offer a unique open space in the human landscape for wildlife to exist and thrive. Ongoing stewardship actions and education efforts lead to habitat protection, and natural resource protection, as well as a reduction in the overall impact of golf management practices on the surrounding ecosystem.

Through a coordinated effort by staff and Ktunaxa elders, golfers at the St. Eugene Golf Resort Casino in British Columbia can now learn a few words in Ktunaxa as they play a round of golf. The tee box markers throughout the golf course are being renamed in the Ktunaxa language with phonetic spelling and translation. Ktunaxa names show an intimate knowledge of the environment that developed over 10,000 years of aboriginal history.

Audubon International partnered with FedEx and The First Tee to teach junior golfers about sustainable golf practices while facilitating eco-friendly public golf course improvements in communities that host PGA TOUR FedEx Cup tournaments.

PortAventura Golf Courses became the first Certified Gold Signature Sanctuary in Spain in 2009. By preserving over 65% of the property as green space, the project was able to protect the Sequia Major wetland which is home to at least one endangered fish species.

The Audubon Cooperative Sanctuary Program for Golf Courses

Josh Conway
Audubon International

Objectives:

1. Enhance wildlife habitats on golf courses by working with the golf course superintendent and providing advice for ecologically sound course management.
2. Encourage active participation in conservation programs by golfers, golf course superintendents, golf officials, and the general public.
3. Recognize the people who are actively participating in environmentally responsible projects.
4. Educate the public and golfing community about the benefits of golf courses and the role they play relative to the environment and wildlife.

Start Date: 1991
Project Duration: Ongoing
Total Funding: $75,000/year

Audubon International is a nonprofit environmental organization that envisions communities becoming more sustainable through good stewardship of the natural environment where people live, work, and recreate through responsible management of land, water, wildlife, and other natural resources. Since 1991, it has worked in partnership with the USGA to offer the Audubon Cooperative Sanctuary Program for Golf Courses (ACSP), an award-winning education and certification program that promotes ecologically sound land management and the conservation of natural resources on golf courses. Audubon Signature Programs also provides comprehensive environmental education and planning assistance to new developments.

Today, 2,265 golf courses in 32 countries participate in the ACSP for Golf Courses. More than 80% of those enrolled have developed an environmental plan to guide management of the golf course and more than 800 have achieved certification for their outstanding best practices. We also awarded 875 "Certificates of Achievement" to recognize golf courses for outstanding accomplishments to improve wildlife habitat, save water, conserve energy, and reduce waste.

Audubon International provided environmental planning services to 160 projects (129 golf-related) in 37 U.S. states and in six countries, covering more than 75,000 acres of land, through the Audubon Signature Programs in 2009-10. Five projects achieved certification, bringing the total number of golf courses that have been designated as Certified Audubon Signature Sanctuaries to 89 in 27 states and five countries.

Today, 2,265 golf courses in 32 countries participate in the ACSP for Golf Courses. More than 80% of those enrolled have developed an environmental plan to guide management of the golf course

Conducted first in 2001 and later in 2010, the Managed Lands Survey for Golf, a survey of ACSP for Golf Course members, indicated areas of great success as well as areas for improvement. With a 25% survey return rate, the results are focused on three critical environmental areas: chemical use reduction and safety, wildlife and habitat management, and water quality and conservation, as well as participant attitudes. Once again, the efforts of golf course superintendents, managers, course staff, and golfers themselves have shown to be worthy of praise and recognition.

The survey revealed the following in each of the key research areas:

- In the area of chemical use, reduction and safety, 69% of respondents reduced pesticide costs with an additional 94% reducing pesticide use itself. Additionally, 95% of respondents used pesticides with lower toxicity levels. Fertilizer costs have also been reduced by 66% of respondents, and fuel costs by 44%, decreasing operation overhead.
- Efforts to address wildlife and habitat management have been equally effective, with 89% choosing native plants when landscaping, as compared to 49% before joining the program. Likewise, the average percentage of pond shoreline naturalized, since joining the program, increased more than 40%, creating more habitat.
- When examining water quality and conservation efforts, 68% of courses who responded had improved their irrigation system or the way that water was applied to the site. As a result, these golf courses saved an estimated 2 million gal of water per year per course since joining ACSP—totaling over 500 million gal per year. Likewise, 88% of golf course managers and superintendents have increased mowing heights along the water's edge to slow and filter runoff since joining the program. Additionally, 91% of respondents have implemented primary and secondary spill containment systems.

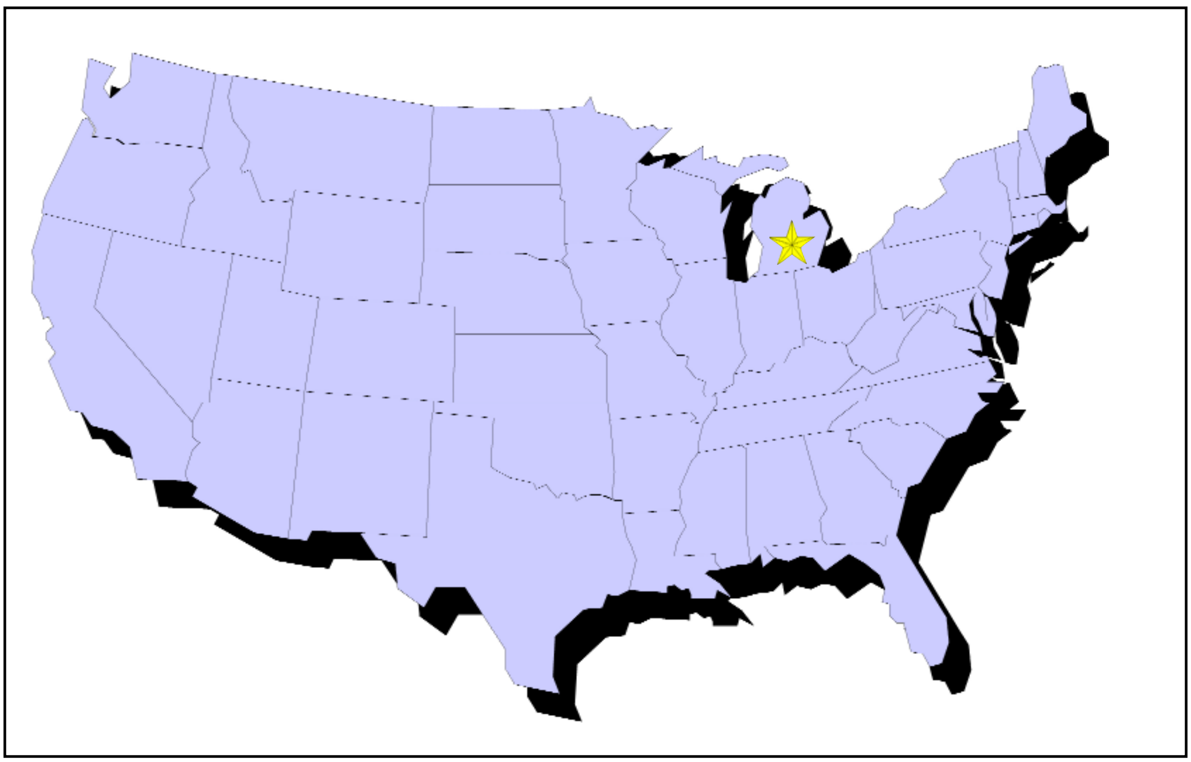
Summary Points

- Number of golf courses enrolled in the Audubon Cooperative Sanctuary Program (ACSP): 2,265
- Number of golf courses enrolled in the Audubon Signature Program: 129
- Total number of acres registered in ACSP for Golf Courses: 477,565
- Number of conservation organizations directly involved with golf courses as a result of their participation in the ACSP: >500
- Number of Certified Audubon Cooperative Sanctuary Golf Courses: 721
- Number of Certified Audubon Signature Golf Courses: 89
- Total number of golf courses certified in Environmental Planning: 1,340
- Number of golf course personnel and others educated by Audubon International in 2009/10 through seminars, conference presentations, and site visits: > 2,000

Turfgrass Information Center

The Turfgrass Information Center (TIC), a specialized unit at the Michigan State University Libraries, contains the most comprehensive publicly available collection of turfgrass education materials in the world. TIC has more than 170,000 records in its primary database, the Turfgrass Information File (TGIF), with over 40% linked to the full-text of the item.

The aim of this ongoing project is to provide exhaustive access to the turfgrass research and management literature, regardless of age or language or format of the source material. With much of that rich heritage previously inaccessible to the majority of even heavily networked turf scientists, TGIF intends to aggressively continue to move toward providing "a turfgrass library on your desktop." And, of course, there has to be a physical turfgrass library behind the virtual one, where the cumulative record of turfgrass science is collected, preserved, and made available.



Location of the Turfgrass Information File housed in the Michgan State University Libraries in East Lansing.

The Turfgrass Information File

Peter Cookingham
Michigan State University

Objectives:

1. Continue to build and expand the online offerings associated with the USGA Turfgrass Information File database.
2. Index all turf-related research and management articles and reports.
3. Continue to digitize and make available additional turf research and management content from both the present and past.
4. Increase both the usability and reach of the database by turfgrass scientists, practitioners, students, and public policy decision-makers worldwide.

Start Date: 1983
Project Duration: Ongoing

Since construction started in 1984, the Turfgrass Information File (TGIF), a cooperative project of the USGA and the Michigan State University Libraries' Turfgrass Information Center, has offered access to the turfgrass literature in support of more effective turfgrass research and management. From initial print-only search results by mail or fax from the database, to dial-up access beginning in 1988, to Internet access in 1993, to World Wide Web access beginning in 1997, TGIF has steadily grown along with turfgrass science and technology advancements.

Today, turfgrass researchers and students at more than 62 subscribing academic institutions worldwide, corporate and individual subscribers, as well as professional members of the following organizations all have access to TGIF via the web:

American Society of Golf Course Architects
Asociación Española de Greenkeepers
Canadian Golf Superintendents Association
Golf Course Superintendents Association of America
Midwest Association of Golf Course Superintendents
Sports Turf Association
Sports Turf Managers Association
Turfgrass Producers International
Wisconsin Golf Course Superintendents Association

Over 171,000 records have been uploaded to the Turfgrass Information File housed at Michigan State University's Libraries.

Online use of TGIF data continues a trend of steady, upward growth, reflecting TGIF's fundamental role in:

- supporting more efficient and thorough support for ongoing turfgrass research,
- expanding golf course superintendents' ability to verify product claims and evaluate documented research,
- permitting students to explore new concepts within the turf industry,
- enabling all users to discover international diversity in turf management practices as reflected in the literature published worldwide.

TGIF indexes academic journals, professional and trade magazines, organizational publications and special reports, annual research reports, government documents, theses and dissertations, book chapters and books, fact sheets, manuscripts, booklets, registration statements, CD-ROM discs, extension bulletins, etc., as well as the increasing galaxy of online materials, such as video clips, podcasts, online presentations, web documents, digitized blueprints, and webinars.

TGIF's digitization efforts began first with and featuring USGA content such as:

USGA Green Section Record (1921-present)
USGA Turfgrass and Environmental Research Online (2002-present)
USGA Turfgrass and Environmental Research Summary (1983-Present)

This work has now expanded to include materials from 18 additional organizational, agency, academic institutions, or individual partners from around the world. In addition, digitization of relevant turf-related theses and dissertations, and out-of-copyright or non-copyrighted classic turfgrass works are undertaken in order to permit direct access to complete content.

The Michigan State University Libraries continue to actively seek support to build the Turfgrass Information Center Endowment to underwrite ongoing operational costs. Contributions from organizations, industry, foundations, other academic institutions, and individual donors to the Endowment have currently surpassed $2.5 million.

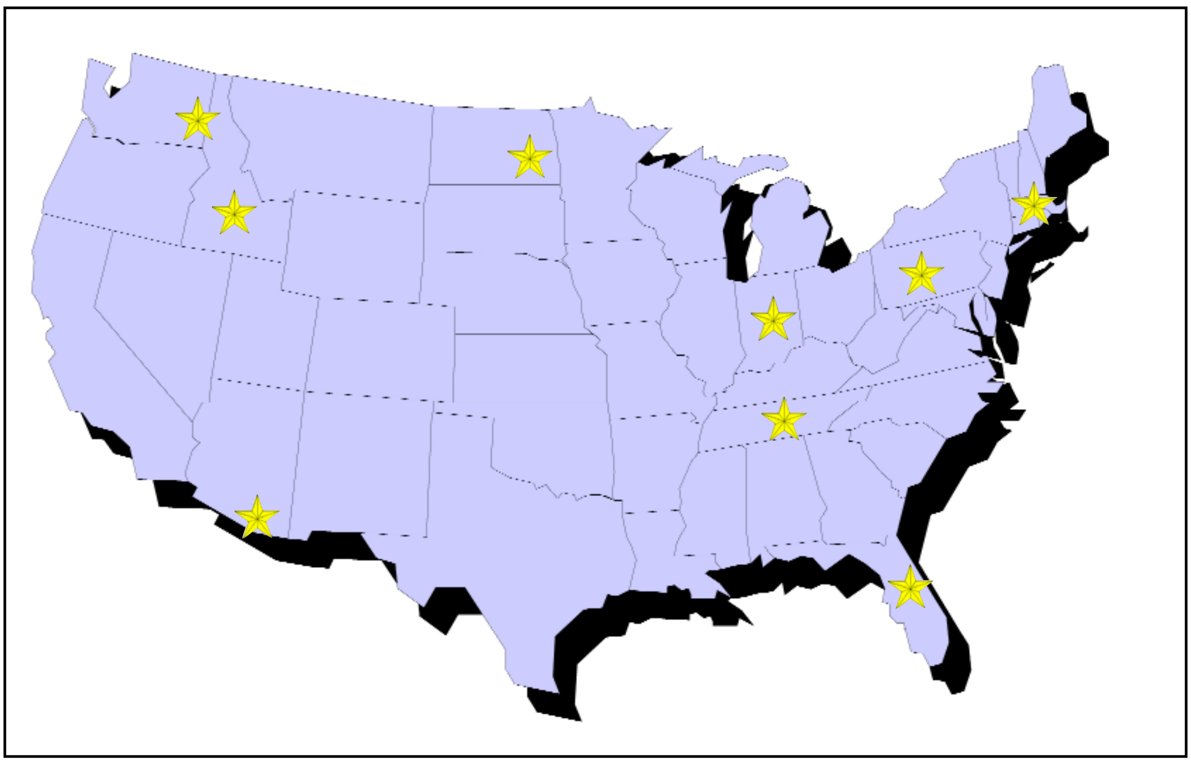
TGIF indexes academic journals, professional and trade magazines, organizational publications and special reports, annual research reports, government documents, theses and dissertations, book chapters and books among other sources of information.

Summary Points

- Number of TGIF records: over 171,000
- Digitized or online periodical projects hosted in cooperation with partners: 11 public websites, with two under construction
- Ten additional TGIF user-accessible websites
- Different periodicals monitored routinely for TGIF inclusion (past or present): 731
- Percentage of TGIF records now linking to full-text content: more than 43%
- Number of 2010 TGIF search result displays: 1 million +

Grant-in-Aid Research Program

USGA's Turfgrass and Environmental Research Program relies on science to attain answers that will help ensure the long-term success of the golf course management industry. Frequently projects may span several years. Many times, however, golf course superintendents need answers to very applied problems to help them meet the many challenges of properly managing golf courses. The Grant-in-Aid Research Program was created to address this need. This program allows directors of all eight USGA Green Section regions to identify applied problems and the appropriate researchers in their regions to solve those problems. Research projects funded under this program most often include cultural aspects of golf course management. Examples include what fungicides work best on a particular disease, or the management of new turfgrass cultivars, renovation techniques, safe and effective use of herbicides, insecticides, or fertilizers. These projects are usually of short duration (1-3 years), but can offer golf course superintendents answers to practical, management-oriented challenges that they can put into use quickly.



Location of projects funded in 2010 by the USGA Turfgrass and Environmental Research Program under the Grant-in-Aid Program

Application Timing Affects the Efficacy of Herbicides Used for Control of Bermudagrass in Zoysiagrass Fairways

James T. Brosnan and Gregory K. Breeden
University of Tennessee

Objective:

1. Determine the effects of application timing on the level of bermudagrass suppression achieved following applications of Fusilade II + Turflon Ester.

Start Date: 2009
Project Duration: 2 years
Total Funding: $6,000

One of the most troublesome weeds to control in zoysiagrass is common bermudagrass (*Cynodon dactylon*), as physiological similarities between these species often render them susceptible to similar herbicide chemistries. Although research has shown that applications of fluazifop (Fusilade II) mixed with triclopyr (Turflon Ester) can provide bermudagrass suppression with minimal zoysiagrass injury, superintendents still struggle to control bermudagrass infestations in zoysiagrass fairways. The objective of this research was to determine points in the growing season in which bermudagrass was most susceptible to applications of fluazifop and triclopyr.

Research was initiated in 2009 at the East Tennessee Research and Education Center in Knoxville, TN on a stand of 'Zenith' zoysiagrass infested with common bermudagrass. Plots measuring 1 m X 1 m were arranged in a 4 X 6 factorial design replicated three times. Herbicide treatment and application timing served as factors in this study. The four herbicide treatments evaluated were: (1) fluazifop at 6 fl oz/A + triclopyr at 32 fl oz/A; (2) fluazifop at 12 fl oz/A + triclopyr at 32 fl oz/A; (3) fluazifop at 18 fl oz/A + triclopyr at 32 fl oz/A; and (4) untreated check.

These treatments were applied at six timings: 200 growing degree days (GDD), 450 GDD, 825 GDD, 1,275 GDD, 1,775 GDD, and 2,250 GDD. Yearly accumulated GDD were calculated beginning on January 1st using a Celsius scale according to the equation,

$$GDD = [(T_{max} - T_{min})/2] - T_{base}$$

where T_{max} represents the daily maximum air temperature, T_{min} represents the daily minimum air temperature, and T_{base} equals 10° C. Bermudagrass suppression and zoysiagrass injury were assessed weekly using a visual scale from 0 (no injury; vigorously growing, green turf) to 100% (severely injured, necrotic, brown turf) until suppression/injury subsided. Bermudagrass suppression and zoysiagrass injury were also assessed quantitatively by collecting relative chlorophyll index data with a hand-held chlorophyll meter.

Although this experiment is still ongoing, current results indicate that bermudagrass is most susceptible to applications of fluazifop and triclopyr surrounding periods of dormancy. The greatest degree of suppression was observed for applications made to bermudagrass transitioning out of winter dormancy in spring and entering winter dormancy in fall in both 2009 and 2010. This response was observed for all fluazifop + triclopyr treatments evaluated. At these timings, increasing the rate of fluazifop from 6 to 18 fl oz/A did not improve efficacy. Increased fluazifop rates resulted in greater efficacy when applied at other summer timings.

Although the maximum labeled use rate of fluazifop for bermudagrass suppression is 6 fl oz/A, 'Zenith' zoysiagrass exhibited tolerance to higher application rates. With the exception of treatments applied in spring (200 GDD), zoysiagrass injury measured less than 13% for all fluazifop rates evaluated. Regardless of fluazifop rate, spring (200 GDD) applications induced greater zoysiagrass injury at 7 days after treatment than any other timing each year.

Relative chlorophyll index data collected on bermudagrass and zoysiagrass were significantly correlated ($P < 0.0001$) with visual assessments of bermudagrass suppression and zoysiagrass injury each year.

Preliminary results suggest that bermudagrass is most susceptible to applications of fluazifop and triclopyr when this species is transitioning into or out of winter dormancy. This study will conclude in spring 2011 once all data have been collected for treatments applied at the 2,250 GDD timing in 2010.

The four herbicide treatments evaluated were: (1) fluazifop at 6 fl oz/A + triclopyr at 32 fl oz/A; (2) fluazifop at 12 fl oz/A + triclopyr at 32 fl oz/A; (3) fluazifop at 18 fl oz/A + triclopyr at 32 fl oz/A; and (4) untreated check.

Summary Points

- Preliminary results suggest that bermudagrass is most susceptible to applications of fluazifop and triclopyr when transitioning out of winter dormancy in spring or transitioning into winter dormancy in fall.
- Increasing the rate of fluazifop above 6 fl oz/A did not improve efficacy for treatments applied to bermudagrass transitioning out of winter dormancy in spring or transitioning into winter dormancy in fall. When applied during the summer, increased rates of fluazifop resulted in greater bermudagrass suppression.
- Regardless of application rate, 'Zenith' zoysiagrass injury measured less than 13% for treatments applied after 200 GDD each year

Examination of Cold Deacclimation Characteristics of Creeping Bentgrass and Annual Bluegrass

Michelle DaCosta and Lindsey Hoffman
University of Massachusetts

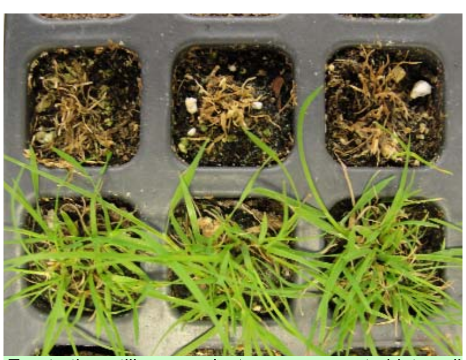
Objective:

1. To determine the temperature degree and duration combinations that result in a loss in freezing tolerance of creeping bentgrass and annual bluegrass.

Start Date: 2009
Project Duration: 1 year
Total Funding: $3,000

Fluctuations in soil temperatures during winter months can negatively impact turfgrass freezing tolerance levels and enhance susceptibility to freezing injury. Some limited research suggests that annual bluegrass (*Poa annua* L.) and creeping bentgrass (*Agrostis stolonifera* L.) may differ in their capacity to resist deacclimation, which can contribute to interspecific differences in winter injury potential. In order to understand the physiological basis of winter deacclimation, we needed to first quantify the critical temperature thresholds leading to deacclimation of annual bluegrass and creeping bentgrass.

Plant material consisted of one annual bluegrass ecotype obtained from researchers at Agriculture and Agri-Food Canada, Quebec, that was previously shown to exhibit sensitivity to freezing temperatures. For comparison, one creeping bentgrass cultivar ('L-93') was obtained from the Joseph Troll Research Center, University of Massachusetts. Two to three tillers per plant were propagated into cell trays (10 x 20 cm) and maintained in a greenhouse under optimal conditions for 3 weeks. Following establishment, plants were moved to a controlled environment growth chamber to initiate treatments.



Two to three tillers per plant were propagated into cell trays (10 x 20 cm) and maintained in a greenhouse under optimal conditions for three weeks.

Before plants were subjected to deacclimation treatments, they were cold acclimated at 2° C for 2 weeks, followed by -2° C for 2 weeks. The baseline freezing tolerance values for annual bluegrass and creeping bentgrass were determined following this cold acclimation period.

Next, plants were exposed to one of six deacclimation treatments which consisted of the following temperature degree and duration combinations: 4° C for 1 or 5 days, 8° C for 1 or 5 days, and 12° C for 1 or 5 days. Changes in freezing tolerance were determined based on controlled freeze tests from -6 to -21° C.

Fluctuations in soil temperatures during winter months can negatively impact turfgrass freezing tolerance levels and enhance susceptibility to freezing injury.

The lethal temperature at which 50% of plants were killed (LT_{50}) was determined by curve fitting percent survival to temperature using a four-parameter sigmoid model. In addition, leaf extension was measured to evaluate changes in growth associated with exposure to deacclimation treatments.

Following cold acclimation, the freezing tolerance of creeping bentgrass (LT_{50} of -19.2° C) was greater than that of annual bluegrass (LT_{50} of -14.3° C). There were no significant changes in freezing tolerance when creeping bentgrass was exposed to 4° C for either 1 or 5 days. However, the freezing tolerance of annual bluegrass declined when exposed to 4° C for either 1 day or 5 days.

For creeping bentgrass, deacclimation was not observed until plants were maintained at 8° C for 5 days. As expected, the greatest change in freezing tolerance occurred when plants were exposed to 12° C, where freezing tolerance of creeping bentgrass and annual bluegrass declined to approximately -8.5° C and -6.1° C, respectively.

In addition to observed changes in freezing tolerance, the deacclimation temperature treatments also influenced leaf growth. In general, leaf growth did not change following exposure to 4° C, whereas increases in leaf growth were detected in response to both 8° C and 12° C. There were no significant differences in leaf extension among the two species, which suggested a lack of strong association between interspecific differences in deacclimation potential and leaf growth rate.

Summary Points

- Fluctuations in soil temperatures following cold acclimation can lead to a decrease or complete loss in freezing tolerance, and therefore predispose plants to freezing injury.
- Deacclimation of annual bluegrass and creeping bentgrass was observed in response to 4° C , 8° C , and 12° C whether exposed to 1 day or 5 days.
- Annual bluegrass deacclimated to a greater extent at a lower temperature, which may account for greater susceptibility to freezing injury for this species.

Preliminary Investigation on the Epidemiology of Fairy Ring in Turfgrass

Michael Fidanza
Pennsylvania State University

Objectives:

1. Develop a technique to facilitate the successful isolation of fairy ring-causing basidiomycete organisms from a turf/soil sample.
2. Develop a technique to induce the vegetative mycelium from fairy ring-causing basidiomycetes to produce a basidiocarp (i.e., fruiting body or mushroom) that could be used to accurately identify the organism.
3. Examine weather conditions associated with the appearance of fairy ring symptoms in turf.

Start Date: 2009
Project Duration: 2 years
Total Funding: $6,000

Visual symptoms of fairy ring in intensively managed turfgrass stands are categorized as type I, type II, or type III, and all three types can occur alone or in various combinations at the same site. Type I is the most severe, characterized by necrotic or dead turf in circle or arc patterns and often accompanied by soil hydrophobicity and localized dry spot conditions. Type II symptoms are easily identified by the appearance of rings or arcs of stimulated, rapidly growing turf that is typically darker green in color than the surrounding turf. Type III symptoms are simply the appearance of the basidiocarps or "fruiting body" (i.e., mushrooms or puffballs). Fairy ring symptoms in turf are attributed to a basidiomycete fungal organism that interacts with the rootzone's biological, chemical, and physical environment, thus indirectly causing turf damage or reduction in turf stand quality and function.

Fairy ring is often confirmed in turf if the fairy ring-causing basidiomycete organism is successfully isolated from the affected area and examined under a microscope. In the field, the basidiocarp is the most accurate way to identify the species. More than 60 species of fairy ring-causing basidiomycetes exist, and their range of susceptibility to fungicides labeled for fairy ring or cultural practices to suppress fairy ring symptoms has not been determined.

Most basidiomycete organisms collected from fairy ring-affected turf sites in the Mid-Atlantic region grew well on either potato dextrose agar or malt extract agar, especially when either growth media was amended with an antibiotic. A total of 20 different growth media recipes were tested for the purpose of facilitating rapid extraction and growth of these fairy ring-causing basidiomycete fungi from turf/soil samples. In addition to standard potato dextrose agar and malt extract agar, oatmeal agar and Leonian media were equally effective at growing *Marasmius* spp., *Coprinus* spp., and *Bovista* spp. during in vitro testing.

Type I fairy ring is the most severe, characterized by necrotic or dead turf in circle or arc patterns and often accompanied by soil hydrophobicity and localized dry spot conditions.

The basidiomycetes grown in pure culture were transferred into a potting soil mix containing wood chips since these fungi are classified as wood-decaying fungi and therefore prefer a diet of lignin, which is also a major component of thatch. The soil mix was subjected to a series of wet/dry cycles to induce fungal colonization of the soil mix and eventually produce a basidiocarp or mushroom. Future research will continue to examine methods to rapidly produce basidiocarps to make rapid and accurate identification of the fairy ring-causing species.

Fairway and green sites with a history of fairy ring activity at Blue Ridge Country Club (Harrisburg, PA) were visually monitored from May through September 2010 for the appearance of fairy ring symptoms. Local weather information was obtained from the Harrisburg International Airport located in close proximity to the golf course. Therefore, airport weather data was chosen to represent environmental conditions within this central Pennsylvania region. Weather data obtained included air temperature, relative humidity, and natural rainfall.

A severe fairy ring outbreak of type I symptoms was observed during the last week of July and persisted into the first week of August, 2010. Although overall weather conditions were not strongly correlated with the severe fairy ring outbreak, an observed trend revealed the onset of type I fairy ring symptoms at this location corresponded to a period of low rainfall (i.e., dry cycle) from June 17 through July 9, higher than normal rain activity (i.e., wet cycle) from July 10 through July 19, then another dry cycle from July 20 through mid-August.

High humidity (i.e., prolonged periods of > 90% maximum relative humidity) and high air temperatures (i.e., several consistent days > 90^{o} F maximum daily air temperature) during the dry cycle in early July and into the wet cycle in mid-July preceeded the onset of severe type I fairy ring symptoms on several golf course fairways at this location. These wet/dry cycles may be the key to understanding fairy ring epidemics in turf.

Summary Points

- Basidiomycete fungi attributed to fairy ring symptoms in turfgrasses are difficult to isolate from the soil and thatch of affected turf areas, although progress is being made in this area.
- Techniques are being tested to develop a reliable and rapid procedure to identify the species of the fairy ring-causing basidiomycete, and thus may lead to improved recommendations for control.
- Destructive, or type I, fairy ring symptoms are often seen during periods of heat/drought stress, often associated with hot/humid weather and may be exacerbated by repeated wet/dry weather patterns.

Aeration Timing and Topdressing Color to Enhance Creeping Bentgrass Green Recovery

William Johnston
Washington State University

Objectives:
1. Determine the effect of date of aeration on recovery time.
2. Establish whether black sand topdressing can enhance recovery.

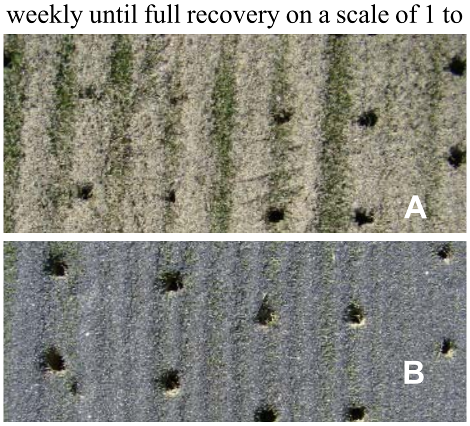
Start Date: 2008
Project Duration: 2 years
Total Funding: $6,000

In the Intermountain Pacific Northwest, golf green aeration often occurs at the extreme ends of the growing season to avoid disruptive aeration practices during the peak golf season. To determine if topdressing timing and sand color could mitigate the effects of aeration, a 'T-1' creeping bentgrass (*Agrostis stolonifera* L.) research green was aerated with 1.27-cm hollow tines every two weeks from April 15 to November 1, 2008 and 2009. Tan sand (TS) or black sand (BS) was applied following aeration and brushed into aeration holes.

Tan sand topdressing treatments were applied at 40,000 kg/ha. Black sand topdressing treatments received TS at 20,000 kg/ha brushed in followed by BS at 20,000 kg/ha to duplicate how BS is commonly used by golf course superintendents in the Pacific Northwest. One week prior to each aeration date, each plot received 293 kg/ha fertilizer (10-4-16) (Micro 10, BEST Fertilizer, Lathrop, CA).

Data collected were days to recovery (DTR) from aeration injury, turfgrass quality, and soil temperature. Aeration injury recovery was rated twice weekly until full recovery on a scale of 1 to 9, where 9 was no detectable damage from cultivation, and 1 was no recovery from treatment. Turfgrass quality was visually rated twice weekly until full recovery on a scale of 1 to 9 where 9 was ideal, dark green uniform turf, 6 was minimum acceptable quality, and 1 was dead turf. Soil temperature was recorded twice weekly until full recovery. Soil temperature was measured at a 7.5-cm depth in 2008 and a 2.5-cm depth in 2009 with a digital thermometer (Spectrum Technologies Inc., East-Plainfield, IL). Full recovery was determined when no visible damage from cultivation was observed in 95% of the plot.

Sand type resulted in turfgrass quality differences in the spring and fall. Black sand had as much as a 25% increase in quality over tan sand.



Tan sand topdressing treatments (A) were applied at 40,000 kg/ha. Black sand topdressing treatments (B) received tan sand at 20,000 kg/ha brushed in followed by black sand at 20,000 kg/ha.

The fastest recovery time ranged from 10 to 18 days and occurred at the June 15, July 1, or August 15, 2008 aeration dates and at six dates between May 15 and September, 15 2009. Black sand was able to reduce recovery by 2 to 9 days compared to TS at nine aeration dates during the study. In addition, BS never resulted in more DTR than TS. Aeration treatments applied after October 1, 2008 and September 15, 2009 did not fully recover within that growing season.

There was a 0.3° C and 0.4° C increase in soil temperature from BS compared to TS when measured 4 days after treatment in 2008 and 2009, respectively. Black sand increased turfgrass quality over TS by as much as 25% and never resulted in lower quality ratings than TS.

Summary Points

- The best time to aerate in the Intermountain Pacific Northwest would be about May 15 and August 15.
- Black sand was able to reduce the number of days to recovery in the late fall.
- Black sand resulted in increased quality and color in the spring and fall.

Fertility and Traffic on Eight Bermudagrass Cultivars in Florida

Jason Kruse and Kevin Kenworthy
University of Florida

Objectives:

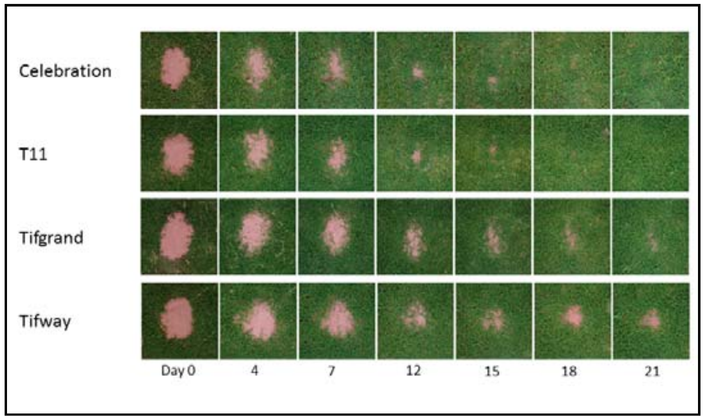
1. Characterize a general response of these bermudagrass genotypes (both seeded and vegetative) to varying combinations of N fertility and traffic.
2. Establish appropriate fertility recommendations for each of the genotypes studied under high- and low-traffic conditions.
3. Identify those cultivars that are best able to maintain quality under conditions of abiotic stress (nutrients and traffic).

Start Date: 2009
Project Duration: 2 years
Total Funding: $10,000

This project compares fertility, traffic tolerance, and divot recovery of eight bermudagrass genotypes. Included genotypes are commercial cultivars 'Tifway', 'TifSport', 'Tifgrand', 'Celebration', 'Floratex'. 'Riviera', and two University of Georgia experimental lines (Hybrid #1 [seeded], and 'T-11'). Plots were evaluated for genetic color, density, turf quality, winter color, and divot recovery. Artificial traffic was applied to a portion of the plot weekly using a modified Cady traffic simulator that was constructed using a John Deere Aercore 800. Divots were removed from the plots using a divot machine constructed from a modified clay pigeon thrower.

Main plots (cultivar) were laid out in a randomized complete block (RCB) design with three replications with each main plot being approximately 14 ft x 14 ft in size. Each cultivar was split into traffic and non-traffic plots 14 ft x 7 ft in size. Traffic treatments were applied weekly during the study period. Each traffic treatment was split into three nitrogen rates (0.5, 0.75, and 1.0 lb/1000 ft^2) applied as a Harrell's 15-5-15 turf fertilizer blend with 50% slow-release nitrogen once every two weeks. Divots were removed from each plot and tracked through recovery on three different dates in 2010.

Not a single cultivar performed the best in every aspect of evaluation. Instead, several cultivars performed well in multiple areas of assessment. 'Celebration', 'Hybrid 1', 'T11', and 'TifGrand' all performed well under both traffic and no-traffic treatments. 'Celebration' produced high visual ratings, consistently above the minimum level of acceptability, and yielded the darkest green color of any of the cultivars evaluated.



'Celebration' was the fastest recovering commercially available cultivar from divot damage in this study, typically reaching 50% recovery by day 7, and by day 15 was 95% recovered in these growing conditions.

When evaluating cultivars for percent cover, all cultivars began the season in the same statistical category. 'Hybrid 1' and 'TifGrand' performed the best in both years of the study while 'Celebration', 'Riviera', and 'T11' performed well in one of the two years. 'Tifway', 'TifSport', and 'Floratex' consistently rated in the lowest statistical category for percent coverage. Once traffic damage began to accumulate, these cultivars could not recover fast enough and percent cover greatly declined. In 2009, plots receiving simulated traffic treatments declined by up to 20%.

Changes in caused by traffic were evaluated by calculating delta values between traffic treatments and comparing cultivar and fertility effects. It was found that in 2009, cultivars 'Hybrid 1', 'Riviera', and 'T11' were affected the least by traffic over all evaluations. The change in percent cover, color, and visual ratings were not greatly affected by traffic treatments in these cultivars. 'Celebration' and 'Tifsport' were affected the most by traffic as shown by their reduction in color, quality, and density of these cultivars as a result of traffic stress.

When evaluated for divot recovery, 'T11' performed the best of all bermudagrass cultivars, and was in the top statistical category on all but one collection date. 'T11' is a promising experimental cultivar, exhibiting a high growth rate even when subjected to traffic stress. 'Celebration' was the fastest recovering commercially available cultivar in this study, typically reaching 50% recovery by day 7, and by day 15 was 95% recovered in these growing conditions. 'Floratex' did well in early and midsummer, but divot recovery slowed in late summer, suggesting a decrease in growth rate. Seeded cultivars 'Riviera' and 'Hybrid 1' performed similarly reaching 50% recovery in an average of 8 to 10 days and 95% recovery in 16 days.

'Tifgrand', 'Tifway', and 'Tifsport' recovered slowly from divot damage, taking an average of 10 days to reach 50% recovery and about 18 days to reach 95% recovery.

Summary Points

- Nitrogen rates of 0.5, 0.75, and 1.0 are too narrow in range to result in N-rate treatment differences
- 'Celebration' has the darkest genetic color as supported by visual ratings.
- 'Celebration', 'ST5', 'Hybrid 1', and 'T11' maintained the highest plant density of the eight cultivars after two seasons of weekly traffic treatments.
- 'Celebration', 'Floratex', and 'T11' consistently recovered from divot injury 3 to 4 days faster than 'Hybrid 1', 'Riviera', 'Tifgrand', 'Tifway', or 'Tifsport'.

Spatial Distribution of Organic Matter and Soil Properties in the Rootzones of Aging Putting Greens

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Objectives:

1. Evaluate the soil chemical properties such as cation exchange capacity (CEC), mineralizable N, and pH as affected by treatments during the grow-in period and age of the putting green.
2. Analyze the decomposition of soil organic matter (lignin and cellulose) and to understand its spatial distribution and the effects on soil chemical properties.

Start Date: 2008
Project Duration: 2 years
Total Funding: $6,000

The chemical and physical properties of a putting green rootzone can be largely altered by the changes of organic matter over time. Meanwhile, spatial distribution and decomposition of organic matter, both quantity and quality, may be reflected from the soil fertility. Not only the turf quality, but also the fate of chemicals is affected by the status of soil properties. Environment and cultural practices influences the dynamics of soil properties. However, little information is available for the soil organic matter with depth-based analysis of putting green rootzone mixtures.

The first part of this study was aimed at investigating space variations of selected soil properties which are used as measures (indicators) of soil organic matter. The second part focused on testing the potential of using Fourier transorm infrared spectroscopy (FTIR) in predicting soil properties.

Soil samples in this study were collected in 2006 from four experimental putting greens that were constructed in sequential years from 1997 to 2000 in University of Nebraska. Putting green age was 6, 7, 8 and 9 years old. Treatments are consisted of two rootzone mixtures: a sand:sphagnum peat mixture at 80:20 (v/v) and a sand:sphagnum peat:soil mixture at 80:15:5 (v/v/v). Two nutritional programs during the year of establishment were also included.

Four-inch deep cores of soil samples were collected from each plot and subdivided evenly into 12 layers. Soil pH, cation exchange capacity (CEC), total C, total N, and mineralizable N were measured for each layer.

The rootzone mixtures and establishment fertilization regimes had no effect on soil chemical properties investigated except for EC which was higher in sand/peat/soil rootzones. Total organic C, total N, CEC, and EC decreased with soil depth, whereas soil pH increased with soil depth. The interaction between putting green age and soil depth was significant for total N, CEC, and EC. The initial differences of soil chemical properties disappeared due to topdressing over a period of 6 years at the top of the rootzones. This was especially apparent in the 0- to 2-cm layer.

The rootzone mixtures and establishment fertilization regimes had no effect on soil chemical properties investigated except for EC which was higher in sand:peat:soil rootzones.

Diffuse reflectance Fourier transform infrared (DRIFT) spectroscopy in the near-infrared (NIR) (4,000-10,000/cm) and mid-infrared (MIR) (600-4,000/cm) region in conjunction with partial least square regression (PLSR) is able to rapidly predict multiple soil properties from a single spectral scanning and is deemed as a promising surrogate for conventional analytical methods.

In the second study, by using samples collected in the first study, calibration models were developed for total organic C, total N, CEC, EC, and pH by regressing spectral results of DRIFT-NIR and DRIFT-MIR with values determined by conventional methods.

Results for total organic C, total N, CEC, and EC achieved $R^2 > 0.80$. MIR and NIR spectroscopy gave similar calibration accuracy for soil properties investigated. Satisfactory accuracy of MIR calibrations and mutual predictions was achieved with subsets of different rootzone mixtures and putting green ages.

However, subsets separated by soil depth failed to be predictive with sufficient accuracy within the group. Results of the study verified the potential of using DRIFT-NIR and DRIFT-MIR to predict soil chemical properties of sand-based turf soil, however, model robustness may be affected by sampling depth.

Summary Points

- Generally, soil pH increases and soil CEC and mineralizable N decreases from the top to the bottom of the soil profile across years and treatments.
- By the end of six years, sand mixtures and establishment fertilization regime had no effect on soil chemical properties investigated except EC, which was higher in sand/peat/soil rootzones.
- The initial differences of soil chemical properties disappeared due to topdressing practice over a period of 6 years at the top of the rootzones especially in the 0- to 2-cm layer.
- MIR and NIR calibration models for total organic C, total N, CEC and EC resulted in prediction with $R^2 > 0.80$.
- MIR outperformed NIR for total organic C, total N and pH. EC was better calibrated by NIRS.
- MIR and NIR had equal accuracy for CEC.
- Subsets separated by depth failed in calibration and mutual prediction, suggesting that calibration robustness could be largely affected by OM.

Unraveling Billbug Seasonal Ecology to Improve Management: Developing a DNA-Based Larval Identification Tool

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Objectives:

1. Identify key regions in billbug rDNA sequences that can be used to identify and differentiate major billbug pest species.
2. Create species-specific DNA primers for these same rDNA regions that will allow for rapid and dependable identification of field-collected billbug larvae

Start Date: 2009
Project Duration: two years
Total Funding: $10,000

Billbugs are increasingly being recognized as a serious threat to golf course turf across the United States. The larvae of this diverse group of insect species (a species complex) damage both cool- and warm-season turfgrasses by feeding on or inside the stems, crowns, roots, stolons, and rhizomes. Recent expansions in the range of several billbug species, possibly driven by suburban development and increasing interstate movement of turfgrass sod, have resulted in a national collage of billbug species assemblages.

The resulting variation in seasonal life histories, behavior, and ecology that often accompany such novel species interactions have challenged management schemes in many regions. Although adult monitoring can be used to estimate billbug species composition and track adult activity, it is the larvae that are primarily responsible for damage. Unfortunately, the larval stages of these insects cannot presently be identified to species.

The long-term goal of this project is to clarify the seasonal ecology of the billbug species complex and elucidate new management opportunities. The first phase of this research is focused on developing a DNA-based billbug larval identification tool that will facilitate the basic, regional studies of billbug seasonal ecology that are needed to improve management.

The tandemly arrayed ribosomal RNA multigene family is a common target of efforts to differentiate closely related species because of useful features of its sequence organization and evolution. Portions of the rDNA coding sequences are highly conserved even between distantly related species, allowing the application of "universal" primers for amplification from any species. The non-coding rDNA spacer sequences, however, can be highly variable in length and sequence between closely related species making them particularly useful for species-diagnostic assays.

Billbug larvae damage both cool- and warm-season turfgrasses by feeding on or inside the stems, crowns, roots, stolons and rhizomes.

Several hundred billbug adults and larvae were collected from various locations across the U.S. Specimens include all known billbug pest species: bluegrass billbug (*Sphenophorus parvulus*), lesser billbug (*S. minimus*), unequal billbug (*S. ineaqualis*), Denver or rocky mountain billbug (*S. cicatristriatus*), hunting billbug (*S. venatus*), and Phoenix billbug (*S. phoeniciensis*). Adult specimens were identified to species using classic morphological characteristics. After the identity of adult specimens was confirmed, several regions (ITS1, ITS2 and CO1) of ribosomal DNA were extracted, amplified, and sequenced. Sequences were compared to determine which ones were most useful for differentiating billbug species.

The ITS2 region (internal transcribed spacer region 2) between the 5.8s and 18s rDNA sequences was the first target of our investigation. Based on the size and sequence of ITS2, *S. parvulus* and *S. minimus* may be differentiated from each other based on the size (number of base pairs) of the region alone. Furthermore, ITS2 allowed differentiation of these two species from all other species examined. However, ITS2 did not provide the differences in size or sequence necessary to dependably differentiate all of the billbug species examined.

Likewise, CO1, the second rDNA region examined, did not prove at all useful in differentiating billbug species as the size and sequence of this region was identical for all species. ITS1, which is currently being examined, will likely provide further resolution between species as the ITS1 sequence for all species examined to date varies significantly in size.

Summary Points

- A DNA-based billbug larval identification tool could provide researchers with the means to gain a more complete understanding of the seasonal biology of the billbug pest complex and provide a science-based foundation for improving management programs.
- The ITS2 region of the rDNA will allow differentiation between *S. parvulus* and *S. minimus* as well as differentiation of these two species from all other species examined.
- Although CO1 was not useful for differentiating any of the species examined, ITS1 will likely provide further resolution between species as the ITS1 sequence for three of the five species examined to date varies significantly in size.
- When complete, DNA primers can be developed for use in a multiplex PCR system that will allow accurate identification of field collected billbug larvae, facilitate studies of billbug seasonal ecology, and improve billbug management.

Comparison and Evaluation of Cultivation Techniques on Ultradwarf Bermudagrass Greens

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Brian Whitlark
USGA Green Section

Objective:

1. Compare core aeration and aggressive verticutting with sand injection for their abilities to affect organic matter content in the rootzone of ultradwarf bermudagrass greens.

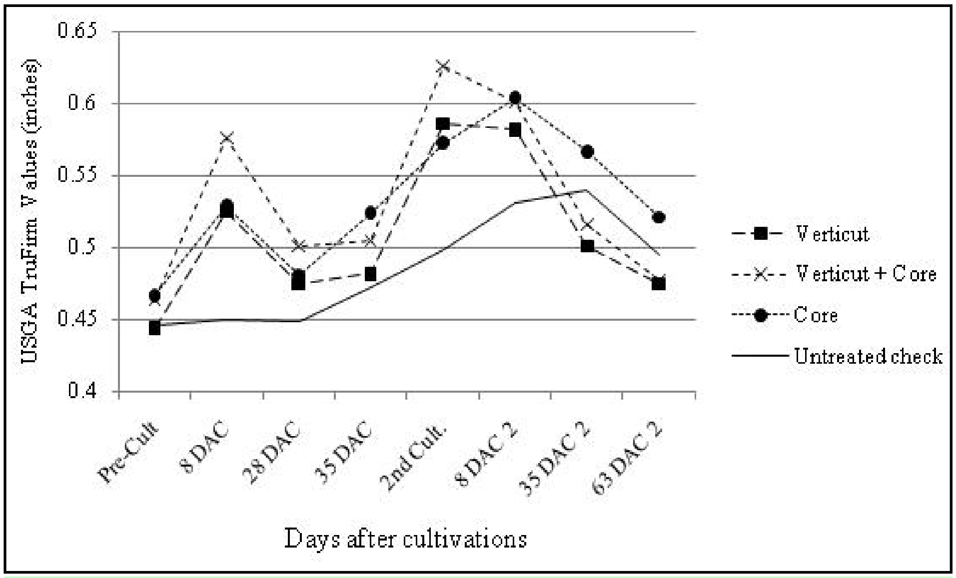
Start Date: 2009
Project Duration: 1 year
Total Funding: $3,000

Two turf cultivation implements were compared in field experiments, a Toro ProCore 648 equipped with 0.5-inch hollow-core top-eject tines on 1.5 by 2.0-inch spacing and a Graden sand-injection machine with 2-mm blades spaced 1.0 inch apart and set to a depth of 1.0 inch on the first pass and 0.5 inch on a second crossing pass. A third treatment combined the core aerifying followed by two passes of the Graden machine (aggressive verticutting).

The single replicate cultivation treatments were performed on a 'MiniVerde' ultradwarf green located in Mesa, AZ on June 7, 2010 and repeated on July 20, 2010. Soil samples were collected from each treatment replicate using a hole-cutter before cultivation on September 30, 2010. Laboratory analysis provided organic matter (OM) content of the samples at increments of 1-inch depth from the surface to 3 inches. Additionally, ball roll was measured by using a stimpmeter, and green surface firmness was measured by using the USGA TruFirm device.

The core-aerifying technique affected 6.5% of the surface area of the green at each event. A total of 13% of the surface area of the green was affected by the two cultivations. The aggressive verticutting implement treated 8% of the green's surface with each pass, and the total was 16% for two passes at each event. The season total was 32% of the surface area affected. The combination treatment affected 48% of the green's surface area.

At approximately 2 months after the second cultivation event, OM in the top 1 inch of the soil-sample core was reduced the most in the combined core removal plus verticutting at 68%. Aggressive verticutting alone reduced OM 55%, and removing cores only reduced OM 36%. The layer between 1 and 2 inches showed OM reduced 74% by core removal, 68% by verticutting, and 35% by combining the two techniques. At a 3-inch depth, verticutting removed OM 58%, the combination removed 42%, and no change was observed for removing cores.



USGA TruFirm values (inches of penetration) before and after two cultivations on a 'MiniVerde' ultradwarf putting green in Arizona.

Ball-roll measurements were the fastest at 3 weeks after the first cultivation event. Ball roll was slightly slower on the treated greens compared to the untreated. Following the second cultivation, ball roll on the treated green exceeded the untreated green. However, there was no consistency for ball-roll measurements among the three treatments. Core-removal treatments tended to have fastest ball roll, and the aggressive verticutting tended to have the slowest ball roll.

The USGA TruFirm data indicated that all of the cultivations softened the green. At about 1 month after the initial cultivation, the green was firmer for all treatments, but not as firm as the untreated plots. At approximately 2 months after the second cultivation event, the aggressive verticutting treatments resulted in a slightly more firm green than the untreated or the core removal only.

Additional visual observations were that the core removal only treatment resulted in a puffy turf that was scalped during regular mowing for approximately 2 months after the second cultivation. The aggressive verticutting treatments had turf infested with rove beetles that pushed up nuisance mounds of soil.

Summary Points

- Cultivation techniques applied twice reduced organic matter content at various depths on a 'MiniVerde' ultradwarf green.
- The greatest OM reduction of 68% at 1-inch depth was observed for the core removal combined with aggressive verticutting.
- Verticutting alone reduced OM 55%, and core removal alone reduced OM 36%.
- Ball roll was not consistent for cultivation treatments.
- USGA TruFirm measurements showed the green was softer soon after cultivation treatments. The green became firm approximately 1 month after cultivations.
- Verticutting treatments resulted in a slightly more firm green than no cultivation or core removal alone.

Selection and Improvement of Idaho Fescue Germplasm for Turf Applications

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Objectives:

1. Evaluate the turf quality and performance of Idaho fescue (*Festuca idahoensis*) accessions collected from the Intermountain West.
2. Evaluate the seed production potential of Idaho fescue accessions to confirm reproductive potential from seed.
3. Select superior individual plants of Idaho fescue and establish them in seed productions blocks for use in development of improved synthetic cultivars with superior turfgrass quality.

Start Date: 2010
Project Duration: 3 years
Total Funding: $9,000

A native of the northern Great Plains and Intermountain West, Idaho fescue (*Festuca idahoensis*) is a member of the *F. ovina* complex. Leaf color ranges from blue to dark green and both colors commonly co-exist in existing releases. Blue, glaucous leaf color has been associated with many plants adapted to high irradiation environments characteristic of the high altitude regions of the Intermountain West. Another key physiological characteristic to Idaho fescue's survival of low precipitation common in the Intermountain West is summer dormancy. These color and growth variations suggest that there is considerable room for Idaho fescue improvements.

In 2009, 42 accessions of Idaho fescue were acquired from industry and USDA seedbank sources. Twenty-six accessions were obtained from the USDA Plant Materials Center at Pullman, WA. Ten accessions were obtained from Benson Farms, two from the NRCS Plant Materials Center at Aberdeen, ID, and one each from Thorn Creek Native Seed, Currans Family Farm, and Seeds Trust. A final accession was a collection made by project personnel in the Island Park region of Idaho. Accessions were chosen specifically to represent ecotypes from a variety of ecological environments. Collection locales included sites in British Columbia, Alberta, Washington, Oregon, Idaho, Montana, and Wyoming.

In March 2010, seed of all 42 accessions were planted in plug trays in a greenhouse. After emergence, seedlings were thinned to a single plant per plug. Field planting occurred on May 17, 2010 when seedlings were approximately 3 inches tall. Of the initial 42 accessions, 36 were established in the field. Two accessions from the USDA seedbank were misidentified and were species other than Idaho fescue. Four additional accessions had poor seed emergence and did not produce enough plants for plot establishment. For the 36 remaining accessions, 100 plants were established in the field. Plants were arranged in a randomized comlete block with four replications of 25 plants.

Field planting occurred on May 17, 2010 when seedlings were approximately 3 inches tall.

The plot area was deep-tilled, packed, and fertilized with urea at 1 lb N/1,000 ft^2. Plugs were irrigated every other day until new growth was evident, and subsequently on demand to avoid drought symptoms. The soil is a loamy-sand (CEC 12.2) with a pH of 8.0. Plots were mowed at 2.5 inches, irrigated to replace 75% to 80% of Kentucky bluegrass ET, and fertilized at 1 lb N/1000 ft^2 in the fall.

Accessions were evaluated on July 26 for growth and color variability, percentage of green individuals, growth habit (upright vs. decumbent), leaf texture and degree of dormancy. Three accessions had 100% green plants, and another six accessions had greater than 50% green plants. Six accessions had zero green plants, and another 12 had less than 10%. Most accessions have the characteristic fine leaves of the *F. ovina* complex, with only one expressing broader than normal texture.

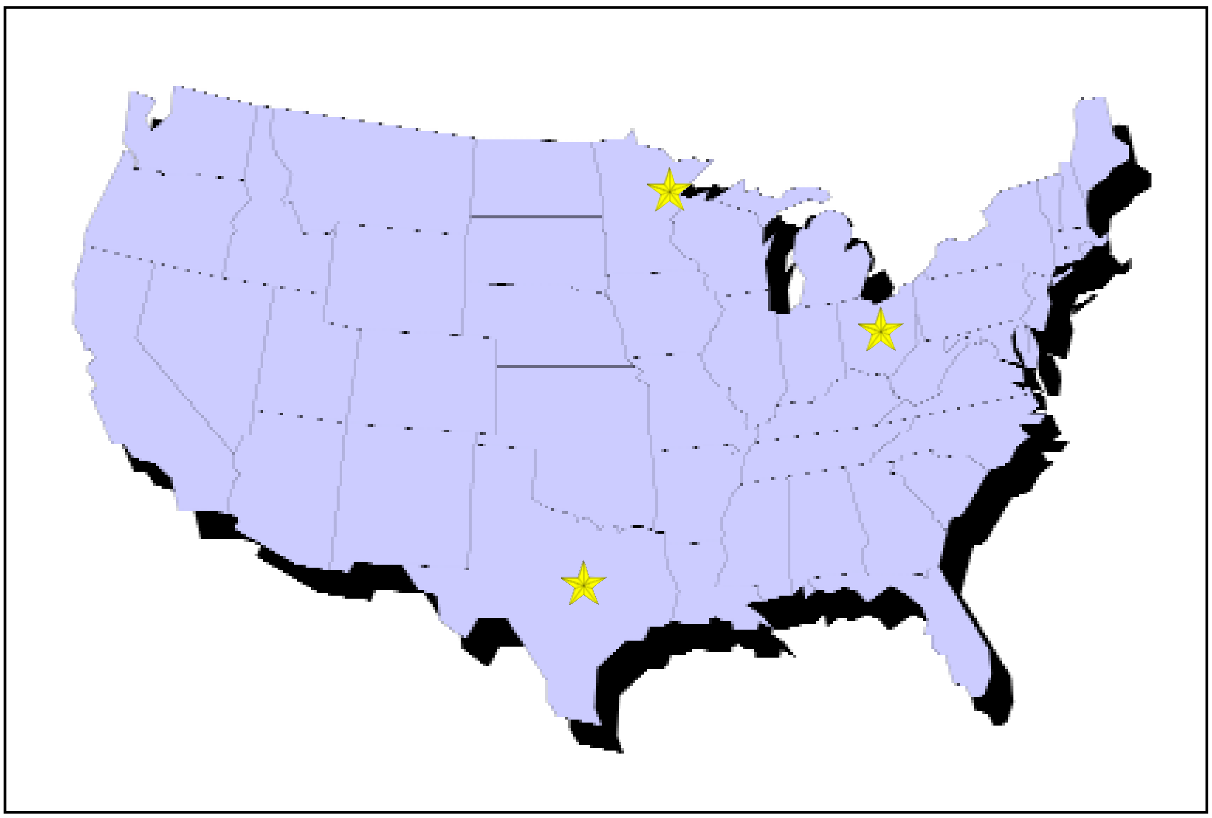
Five accessions showed a low level of summer dormancy with only a few plants showing partial dormancy, and another 17 accessions had plants expressing moderate levels of dormancy.

Summary Points

- Thirty-six Idaho fescue accessions were established in the field.
- Accessions varied in number of green individuals, summer dormancy, and growth habit.
- Accessions showed similar leaf texture characteristic of other fine fescues.
- Field observations suggest good opportunity for turf-type Idaho fescue development.

Product Testing Program

Every year golf course superintendents are introduced to new products in the marketplace. Without results from properly designed, objective research, superintendents are asked to make buying decisions based on word-of-mouth, previous experience from colleagues, or recommendations of the product representation. Several surveys indicate that golf course superintendents desire side-by-side product evaluations to assist them in making product purchases. The result of this desire for this type of information is the Product Testing Program section of USGA's Turfgrass and Environmental Research Program. Currently, USGA is funding one project that falls into this category of USGA-supported research, including cooperators at sites across the country (see map below).



Locations of projects funded in 2010 by the USGA Turfgrass and Environmental Research Program under the category of Product Testing

Use of Industrial By-products and Natural Minerals to Filter Nutrients and Pesticides in Golf Green Drainage Water

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USDA-ARS

James F. Moore
USGA Green Section

Jim C. Balogh
Spectrum Research, Inc.

Objectives:

1. Assess the feasibility and effectiveness of commercially marketed filters designed to strip nutrients (nitrogen and phosphorus) and pesticides (chlorothalonil and metalaxyl) from drainage waters exiting managed turf areas.
2. Identify and demonstrate the efficacy of using both synthetic and natural products in a field-scale application of the end-of-tile filter.

Start Date: 2005
Project Duration: 4 years
Total Funding: $42,200

Subsurface tile drainage is essential to maintain water tables at depths necessary for healthy plant growth, to retain sufficient water and air in soil void space to stimulate microbial activity, to avoid rutting and soil compaction by maintenance equipment, and to allow site use soon after heavy rains. However, subsurface drainage is known to carry elevated levels of phosphorus and pesticides that can ultimately be transported to surface waters. In this way, subsurface drainage bypasses managed and natural filter processes including riparian zones and vegetated buffer strips, and may add to aboveground runoff of contaminants to surface waters.

The goals of this research are to investigate the use of industrial by-products and natural minerals as filter media to significantly reduce the transport of excess phosphorus and three pesticides (chlorothalonil, mefenoxam, and propiconazole) from golf course tile drainage outlets to surface waters. The most recent field study was conducted at the Ridgewood Country Club in Waco, TX using a filter housing designed by KriStar Enterprises, Inc. A different filter design will be assessed in the near future at the Royal American Golf Course located in Galena. OH.

The Texas experiment was conducted on an 8,000-ft^2, split-design, chipping green. The green was originally designed to test alternative materials for the gravel layer used in green construction. In lieu of gravel, the north half of the green was constructed with AirDrain Geocells (polypropylene plastic grid system covered by a geotextile), while the south half used a geogrid (double-layer, polypropylene plastic grid sandwiched between two geotextile layers).

This field site was originally instrumented in 2005 with two different commercial filters (one for each half of the green). For this study, the site was retooled and an additional filter box (which houses three filter cartridges filled with by-products and natural minerals) was installed. Three new filter cartridges were also added to the existing box. Two storm events, which consisted of three, 3,785-L (1,000-gallon), 10-minute irrigations at 2-hour intervals, were simulated on separate days. Each day, phosphorus, mefenoxam, chlorothalonil and propiconazole were applied to the green prior to the first irrigation and according to the manufacturers' specifications.

This research is designed to address the potential for end-of-tile filters to significantly reduce the transport of nutrients and pesticides from golf course tile drainage outlets to surface waters.

On day 1 of experimentation, no filter media were placed into the cartridges to determine the influence of the filter box construction itself on contaminant removal. On day 2, the empty cartridges were swapped out for new ones filled with a 14-L blend of blast furnace slag, cement kiln dust, zeolite, sand, and coconut-shell activated carbon. A total of four Isco 6712 portable samplers were positioned to collect simultaneous water samples at the inflow and outflow of the filter boxes, thus providing a before-and-after assessment. Flow measurements were recorded by two Isco 4230 bubbler flow meters located at the discharge end of the filter boxes, and ranged from 0.0034 L/s (0.05 gal/min) to 0.6433 L/s (10.16 gal/min).

Water samples and flow measurements were collected and recorded at predetermined time intervals throughout the course of the storm simulations. Pre- and post-filter phosphorus, chlorothalonil, mefenoxam, and propiconazole loads were calculated by multiplying sample concentrations measurements by flow rates. Of the four contaminants investigated, only chlorothalonil was removed in statistically significant quantities.

Median chlorothalonil removal was 69%, while the highest was 96%. Interestingly, chlorothalonil removal was very high at peak flows. Phosphate, mefenoxam, and propiconazole were not removed, highlighting the need to optimize the filter blend, as well as the importance of conducting field-scale versus laboratory-scale studies. In a previous laboratory-scale study, these by-products and minerals removed >85% quantities of the investigated contaminants, which was not the case in the field.

Summary Points

- Field and laboratory instrumentation is in place to continue to assess different filter materials and designs.
- Filter blends must be retooled/optimized to achieve significant removal of all contaminants (only chlorolthalonil was significantly removed). This highlights the need for field-scale over laboratory-scale research.
- Preliminary hydrology findings suggest that use of the AirDrain Geocell decreases nutrient and pesticide leaching and the frequency of irrigation compared to a geogrid design.