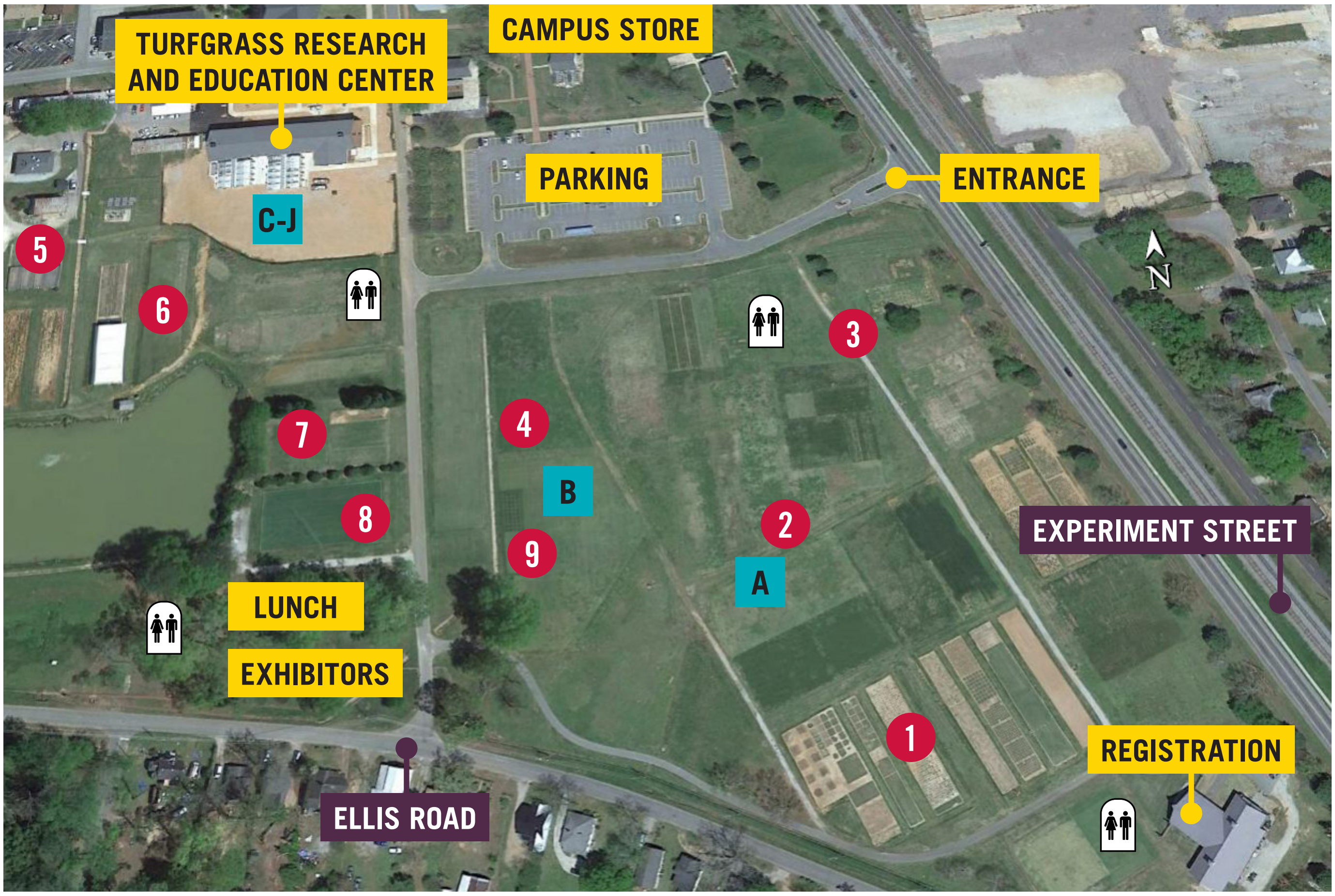
2018 Turfgrass Research FIELD DAY

ONE DAY, ACRES OF INFORMATION

Thursday, August 9, 2018 | UGA Griffin Campus

MAP and Field Day TOUR STOPS



Guided morning tour stops: 1-9

Self-guided afternoon tour venues: A-J

Restrooms

University of Georgia 2018 Turfgrass Field Day Program Guide editors:

David Jespersen, Department of Crop and Soil Sciences

Shimat Joseph, Department of Entomology

Mary Flynn, Department of Crop and Soil Sciences

2018 UGA Turfgrass Research Field Day PROGRAM

THURSDAY, AUGUST 9

8:00 a.m. to 8:45 a.m. **REGISTRATION**

8:50 a.m. to 9:15 a.m. **INTRODUCTION**

Welcome – *Clint Waltz*
UGA Griffin Campus Welcome – *Lew Hunnicutt*
UGA College of Agricultural and Environmental Sciences (CAES) Welcome – *Sam Pardue*

9:15 a.m. to 11:30 a.m. **GUIDED RESEARCH TOUR***

1. Breeding Better Turfgrasses for the Southeast — *Paul Raymer*
2. New Herbicides for Turf — *Patrick McCullough*
3. What are NDVI Images? Applied Applications in Turf — *Brian Schwartz & Jing Zhang*
4. Collection and Submission of Turf Insect Samples — *Shimat Joseph*
5. Mechanisms of Drought Tolerance in Bermudagrasses — *David Jespersen & Brian Schwartz*
6. Wetting Agents: An Added Bonus — *Gerald Henry*
7. Warm-season Turf Disease Management — *Alfredo Martinez-Espinoza*
8. Biological Products and Soil Health — *Mussie Habteselassie & Paul Raymer*
9. Overseeding: Site Prep and Grasses — *Clint Waltz*

11:30 a.m. to 1:00 p.m. **TURFGRASS EQUIPMENT AND PRODUCT EXHIBITS**

11:30 a.m. to 1:15 p.m. **BARBECUE LUNCH (ribs and chicken)**

1:15 p.m. to 2:30 p.m. **SELF-GUIDED RESEARCH TOUR****

A. Problem Weed Control in Turf — *Patrick McCullough*
B. Agronomic Applications of UAS — *Clint Waltz & Clay Bennett*
C. Carbon Dynamics of Warm-season Turfgrass Measured Using the Eddy-Covariance Technique — *Monique Leclerc, Roshani Pahari, G. Zhang, Hafsah bin Hahrawi, & Paul Raymer*
D. Research Facility Tour
E. Athlete Injuries in Response to Sports Field Conditions — *Gerald Henry*
F. Macroscopic and Microscopic Turf Disease Identification — *Alfredo Martinez-Espinoza*
G. Billbug Identification and Control in Zoysiagrass — *Shimat Joseph*
H. Improving Salt Tolerance in Warm-season Grasses — *Paul Raymer*
I. Tools for Understanding Turfgrass Plant Health — *David Jespersen*
J. Graduate Student Research at UGA

**A Spanish translation will be made available for the Guided Research Tour.*
***Other research plots will be marked and labeled for individual observation.*

Pesticide recertification credits will be available at registration no earlier than 2:15 p.m.

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TIM MURPHY

1951 to 2018

Tim was born in Knoxville, Tennessee, on August 12, 1951.
On April 13, 2018, he died unexpectedly from a home accident. Tim was 66.

In 1985, Tim began his career at the University of Georgia as a Cooperative Extension weed scientist for turf, aquatics, soybeans, canola, non-cropland, forages, and ornamentals. He formally retired in 2007, but continued as a rehire until 2010. Throughout his career, Tim's stations were popular stops at UGA Turfgrass Research Field Days, and practitioners were entertained and educated by his wit and wisdom.

Tim was fortunate to have many passions, including family, friends, church, travel, and the outdoors. Many in this audience knew him for his passion for weeds—their control and biology, too—and for his willingness to help. It was Tim's servant mentality that made him an accomplished scientist and a model Extension specialist. He prided himself on his availability to whomever sought his expertise and knowledge. His research had the end-user in mind; he truly wanted to help turfgrass managers be the best they could be.

Research and Education Contributors

The turfgrass research and education program at the University of Georgia is supported by: (a) state and federal support, and (b) various entities of the turfgrass industry. Without the active direct and indirect support of the turfgrass industry, our research and education efforts would be severely curtailed. We wish to thank the various contributors who, in recent years, have helped the turfgrass industry by supporting our research and education programs:

Air2G2
Akins Feed and Seed
A.M. Buckler & Associates, Inc.
Aquatrols
Aqua-Yield
Amvac Chemicals
Atlanta Athletic Club
Atlanta Braves
Atlanta Country Club
Auburn University
Augusta National Golf Club
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Beck's Turf
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Bethel Farms
Bricko Farms
Brightview
Bulk Aggregate Golf, Inc.
Butler Sand
Buy Sod
Carolina Fresh Farms
Central Garden and Pet
Compost Wizard
Corbin Turf & Ornamental Supply
Corteva (Dow AgroSciences)
DuPont
East Lake Golf Club
Embroidery Works
Evergreen Turf Farms
Ewing Irrigation
FMC
Foothills Compost
Foskey Turf Farm
Georgia Agribusiness Council
Georgia Department of Agriculture
Georgia Center for Urban Agriculture
Georgia Certified Landscape Professionals
Georgia Crop Improvement Association
Georgia Golf Course Superintendents Association
Georgia Golf Environmental Foundation
Georgia Master Gardeners
Georgia PGA
Georgia Recreation and Park Association
Georgia Seed Development Commission
Georgia State Golf Association
Georgia Turfgrass Foundation Trust
Georgia Urban Ag Council
Golf Agronomics
Golf Course Superintendents Assn. of America
Gowan
Greenville Turf and Tractor
Griffin City Golf Course
Harrell's
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Helena Chemical
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NG Turf
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Patten Seed
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Plant the Future, Inc.
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The Scotts Co.
The Toro Company Center of Advanced Turf Technology
The Turfgrass Group
The Turner Foundation
TriEst Ag. Group
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Turfnology
Turfpro USA
Turf Seed
University of Georgia Golf Course
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UGARF Technology Commercialization Office
USDA-ARS
USDA-NIFA
U.S. Golf Association (USGA)
Valent U.S.A.
Valley Irrigation
Wright Turf

Thank you! If we have inadvertently omitted a contributor, we apologize.

Breeding Better Turfgrasses for the Southeast

Paul L. Raymer, Professor, Crop and Soil Sciences
UGA-Griffin

Brian M. Schwartz, Associate Professor, Crop and Soil Sciences
UGA-Tifton

ABSTRACT

The University of Georgia has two turfgrass breeding programs and both are focused on developing improved and more sustainable turfgrass varieties for the Southeast. These programs are part of a federally funded, multi-institutional effort to develop new warm-season turfgrass varieties that require less water or tolerate the use of alternative sources of water. This regional collaboration has led to the release of two drought-tolerantcultivars—'TamStar' St. Augustinegrass and 'TifTuf' bermudagrass—and the identification of 140 advanced lines with improved drought and/or salinity tolerance across four warm-season species. Efforts are now underway across the Southern U.S. to better characterize these lines in terms of their response to drought and persistence as well as their tolerance to shade, high salinity, common herbicides, and sod production traits. In addition, our breeding programs work closely with other UGA turf team members to improve other important traits such as disease and insect resistance of our future varieties.

INTRODUCTION

Turfgrass is a primary recreational surface that provides great aesthetic value. Turfgrass enhances our environment by protecting our soils from erosion, providing cooling, and reducing glare, noise, and pollution. The turfgrass industry has a multibillion-dollar impact nationally, but is now being threatened by limited water resources due to water demands associated with population growth. Lower water availability as well as environmental and economic concerns now dictate that we reduce the amounts of water and pesticides used by our industry. Improved and more sustainable turfgrass varieties are needed to ensure our future success.

UGA has two turfgrass breeding programs and both are focused on the development of more sustainable turfgrass varieties that require less water and fewer management inputs. The turfgrass breeding program at the Tifton campus is developing new varieties of bermudagrass, zoysiagrass, and centipedegrass, while the breeding program at the Griffin campus is developing new varieties of seashore paspalum, tall fescue, zoysiagrass, and bentgrass.

Federal funding through the USDA-NIFA Specialty Crops Research Initiative (SCRI) has provided an opportunity for the two UGA breeding programs to work in collaboration with other public turfgrass breeders in the Southern U.S. to address turfgrass water-use-related issues. Six Southern breeding programs are now working together to identify bermudagrass, zoysiagrass, St. Augustinegrass, and seashore paspalum germplasm with improved drought and salinity tolerance. The initial 5-year USDA-NIFA SCRI project identified 140 advanced lines with improved drought and salinity tolerance. Our current SCRI project goals are to better characterize these lines for their long-term drought tolerance, persistence, and other important traits before they are commercialized and to identify new breeding lines with improved drought and persistence traits.

MATERIALS AND METHODS

A second SCRI project is now underway and focused on better characterizing the 140 advanced lines identified by our earlier work. In this new project, extensive irrigation/drought assessments of these advanced lines are underway at Citra, Florida; Bixby, Oklahoma; and College Station, Texas, using three different approaches. In addition, these advanced lines are being evaluated at multiple locations for their tolerance to shade, irrigation with high salinity water, common herbicides, and sod production traits such as sod strength and rate of regrowth.

Breeding Better Turfgrasses for the Southeast, *continued*

We are also working to identify new breeding lines with superior drought tolerance traits through a multilocation screening program. Each of the six breeding programs involved contributed 100 germplasm lines across the four warm-season species (Table 1). This collection of diverse germplasm is being evaluated by each of the participating five institutions. These trials were established during the summer of 2016 and are managed with minimum fertility and pesticide inputs. Irrigation was only used during year one for establishment.

RESULTS

Almost all germplasm lines in this evaluation became well-established and fully grown in during the 2016 growing season. Irrigation of all plot areas was discontinued beginning June 1, 2017. This location had adequate rainfall throughout most of the 2017 growing season with only a brief period of moisture stress during late July. As a result, we were unable to determine major differences among lines in terms of drought tolerance last season. The 2017-2018 winter was colder than normal and followed by repeated frost during the spring. As a result, many plots in these evaluations were injured or were killed by the winter weather. Spring green-up ratings for the four species are summarized in Table 2. Bermudagrass and seashore paspalum were the earliest to green up in 2018 with only a few lines showing extensive winter damage. However, zoysiagrass and St. Augustinegrass lines were slow to green up. Winter kill was most dramatic among St. Augustinegrass lines with more than one-third of the lines tested showing severe winter injury as evidenced by low green-up ratings in late May (Figure 1).

CONCLUSIONS

Collaborative breeding efforts, such as the SCRI project, have helped to focus turfgrass breeding programs in the Southern U.S. to the development of more sustainable turfgrasses. These efforts have already contributed to the release and commercial availability of ‘TifTuf’ bermudagrass (Schwartz *et al.*, 2018) and ‘TamStar’ St. Augustinegrass (Chandra, *et al.*, 2015). Continued efforts with this project and with our own turfgrass research team should ensure that future Georgia turfgrass variety releases will meet future industry demands for more sustainable turfgrasses.

ACKNOWLEDGEMENTS

We gratefully acknowledge the technical support provided by Lewayne White, Rodney Connell, Daniel Nordstrom, and Somer Rowe.

REFERENCES

Chandra, A., Genovesi, A. D., Wherley, B. G., Metz, S. P., Reinert, J. A., Wu, Y-Z., Skulkaew, P., Engelke, M. C., Hargey, D., Nelson, L. R., Schwartz, B. M., Raymer, P. L., Wu, Y. Q., Martin, D. L., Milla-Lewis, S. R., Miller, G., Kenworthy, K. E., & Munoz, P. (2015). Registration of ‘DALSA 0605’ St. Augustinegrass. *J. Plant Reg.* 9:27-34

Schwartz, B. M., Hanna, W. W., Baxter, L. L., Raymer, P. L., Waltz, F. C., Kowalewski, A. R., Chandra, A., Genovesi, A. D., Wherley, B. G., Miller, G. L., Milla-Lewis, S. R., Reynolds, W. C., Wu, Y., Martin, D. L., Moss, J. Q., Kenna, M. P., Unruh, J. B., Kenworthy, K. E., & Zhang, J. (2018). ‘DT-1’, a Drought-Tolerant Triploid Turf bermudagrass. *Hort. Sci.* (in press)

Table 1. Summary of germplasm evaluated for drought tolerance/persistence.

Species	UF	OSU	NCSU	TAMU	UGAG	UGAT	Totals
Bermudagrass	9	100	2	0	0	54	165
Seashore Paspalum	3	0	0	0	80	0	83
St. Augustinegrass	20	0	48	60	0	0	128
Zoysiagrass	68	0	50	60	20	46	244
Totals	100	100	100	120	100	100	620

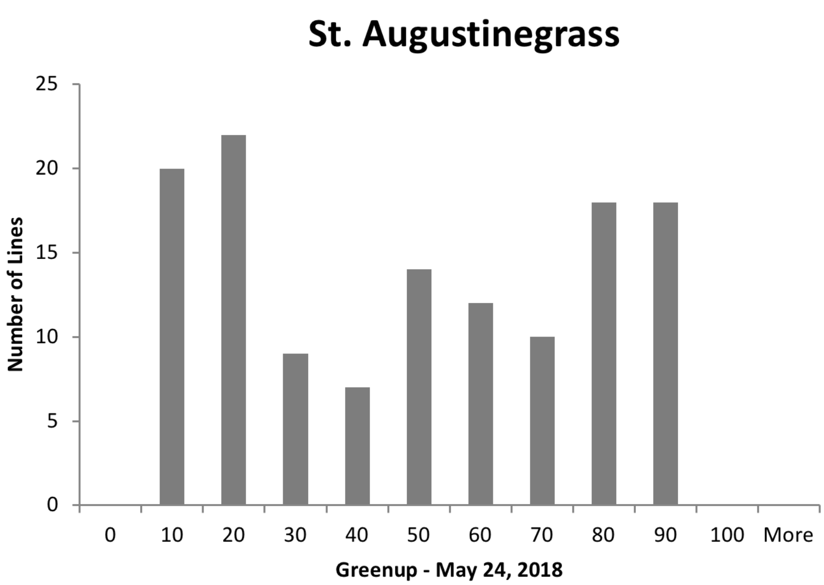
UF = University of Florida, OSU = Oklahoma State University, NCSU = North Carolina State University, TAMU = Texas A&M University, UGAG = University of Georgia-Griffin, UGAT = University of Georgia-Tifton

Data collected included percent coverage during the grow-in period, periodic measurements of turf quality during the growing season, NDVI during periods of drought stress, and spring green-up data.

Table 2. Green-up ratings of germplasm from warm-season turfgrass species, 2018.

Species	March 5 %	April 5 %	May 24 %
Bermudagrass	10.6	44.7	–
Seashore Paspalum	12.5	37.1	–
St. Augustinegrass	–	9.2	44.5
Zoysiagrass	–	28.6	59.9

Figure 1. Histogram showing the green-up distribution of St. Augustinegrass germplasm lines.



Enhancing the Selectivity of Herbicides for Annual Bluegrass Control in Bermudagrass with Growing Degree-Day Timings

Patrick McCullough, Associate Professor and Extension Weed Scientist, Crop and Soil Sciences
UGA-Griffin

INTRODUCTION

Annual bluegrass (*Poa annua*) is a prolific winter annual weed in turfgrass. It germinates in fall, overwinters in a vegetative state, and resumes active growth in spring. Annual bluegrass is unsightly and significantly reduces the quality of turfgrass. The decline of annual bluegrass in late spring causes thinning and stand loss in polyculture with bermudagrass. Summer annual weeds often replace annual bluegrass from voids created in turf after populations decline.

There has been an exponential rise in annual bluegrass resistance to many postemergence herbicides. In Georgia, resistance to inhibitors of acetolactate synthase and photosystem II are common on many bermudagrass golf courses. Rotating modes of action can be difficult due to unacceptable injury from herbicide alternatives like glyphosate and flumioxazin. Application timings that optimize turf safety and provide acceptable control of annual bluegrass may be critical in spring. Calendar-based recommendations for maximizing selectivity for some of these herbicides are inappropriate due to the variability in growing conditions for bermudagrass over years.

A potential method for refining annual bluegrass control recommendations is to use growing degree-day timings to enhance herbicide selectivity. Growing degree-day models use cumulative temperature tracking to time management programs. Superintendents often use this system to time growth regulator applications for annual bluegrass seedhead control. A similar approach could be used to optimize bermudagrass safety to herbicides with injury potential during spring transition. The objectives of this research were to evaluate the potential for growing degree-day timings to enhance the selectivity of herbicides for annual bluegrass control in bermudagrass.

MATERIALS AND METHODS

Field experiments were conducted from 2015 to 2017 at the University of Georgia Griffin campus. The turf was a 'Tifway' bermudagrass fairway grown on a Cecil sandy loam with 6.0 pH and 2.5% organic matter. The field was irrigated as needed to reduce turf wilting. Treatments were the factorial combination of four herbicides applied at four growing degree-day (GDD) timings. Herbicides applied included Sureguard 51% (flumioxazin) at 12 oz/acre, Roundup Pro (glyphosate) at 16 oz/acre, Aatrex 4L (atrazine) at 1 qt/acre, and Ronstar Flo (oxadiazon) at 3 lb a.i./acre. These herbicides were applied at 50, 100, 200, and 300 GDD using a base model of 50 °F on January 1. Daily temperature data was used to calculate cumulative GDD with the following formula: GDD = (Tmax + Tmin)/2 – Tbase, where Tmax is the daily high temperature, Tmin is the daily low temperature, and Tbase is the base temperature for the model (50 °F). Application dates are presented in Table 1.

Table 1. Application dates for treatments across years based on growing degree-day (GDD) timings.

GDD	2015	2016	2017
50	Mar. 4	Feb. 17	Jan. 13
100	Mar. 12	Feb. 29	Jan. 19
200	Mar. 23	Mar. 25	Feb. 8
300	Apr. 3	Apr. 2	Feb. 27

Visual ratings were made weekly on a percent scale including annual bluegrass cover and control and turf injury. The experimental design was a randomized complete block with four replications of 3 ft x 10 ft plots. Separate plots were used each year. Data were subjected to analysis of variance and means were separated with Fisher's LSD test at a = 0.05.

RESULTS AND DISCUSSION

Bermudagrass injury was acceptable (less than 20%) in all three years when herbicides were applied at 50 and 100 GDD. Sureguard, Roundup, and Ronstar applied at 200 and 300 GDD caused unacceptable injury in all three years (Figures 1 and 2). Injury persisted for several weeks from these treatments (data not shown). Atrazine applied at 200 GDD caused acceptable injury to bermudagrass on all evaluations, but treatments at 300 GDD caused unacceptable injury in one of three years (Figure 2). Bermudagrass injury was expressed as stunted growth and discoloration relative to the nontreated.

Figure 1. 'Tifway' bermudagrass injury from herbicides applied at 200 growing degree-days when rated at around 50% green-up.

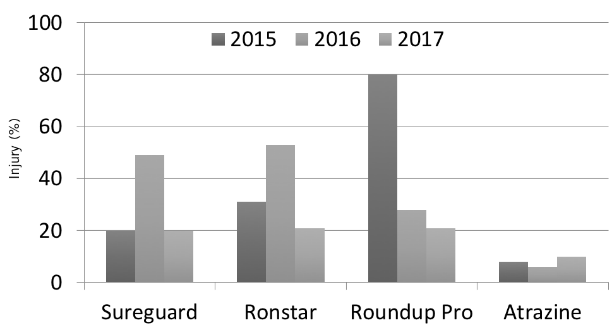
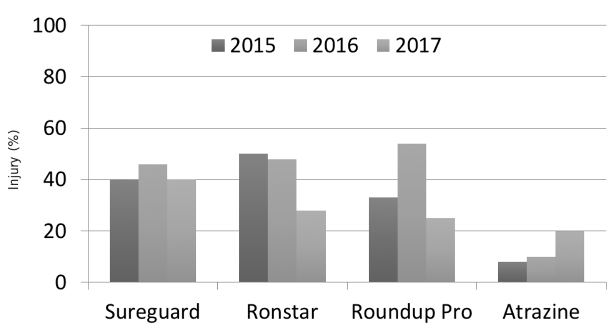


Figure 2. 'Tifway' bermudagrass injury from herbicides applied at 300 growing degree-days when rated at around 90% green-up.



Annual bluegrass control was only evaluated in two of three years (Table 2). Acceptable control (>70%) was achieved with Sureguard at 50 and 100 GDD in one of two years, Roundup and atrazine at 50, 100, and 200 GDD in both years, Sureguard at 200 and 300 GDD in both years, and atrazine at 300 GDD in one year. Ronstar treatments caused suppression of annual bluegrass but generally gave about 50% control.

Table 2. Annual bluegrass control in 'Tifway' bermudagrass from herbicides applied at four growing degree-day (GDD) timings.

GDD	Herbicides	2016	2017
50	Sureguard at 12 oz/acre	61	80
	Ronstar at 3 lb a.i./acre	26	33
	Roundup Pro at 16 oz/acre	91	98
	Atrazine at 1 qt/acre	84	91
100	Sureguard at 12 oz/acre	50	88
	Ronstar at 3 lb a.i./acre	35	28
	Roundup Pro at 16 oz/acre	73	95
	Atrazine at 1 qt/acre	96	85
200	Sureguard at 12 oz/acre	83	91
	Ronstar at 3 lb a.i./acre	74	50
	Roundup Pro at 16 oz/acre	94	85
	Atrazine at 1 qt/acre	89	95
300	Sureguard at 12 oz/acre	73	93
	Ronstar at 3 lb a.i./acre	55	48
	Roundup Pro at 16 oz/acre	84	95
	Atrazine at 1 qt/acre	53	98
	$LSD_{0.05}$	21	33

Overall, the best selectivity for bermudagrass safety and annual bluegrass control were with the following treatments: Roundup and Sureguard applied at 50 and 100 GDD and atrazine applied at 50, 100, or 200 GDD. Ronstar is not a postemergence herbicide for annual bluegrass control but turf managers may be able optimize the safety of sprayable formulations when treating bermudagrass no later than 100 GDD with our model. The use of GDD will enhance selectivity of herbicide application timing to help rotate modes of action in spray programs. Further research is needed to look at the interaction of photoperiod with GDD on turf tolerance and annual bluegrass control.

ACKNOWLEDGEMENTS

We would like to acknowledge Seth Williams for technical support with this research and Bob Perry for assistance with plot maintenance.

What are NDVI Images? Applied Applications in Turf

Jing Zhang, Postdoc, Agronomy
University of Florida

Brian Schwartz, Associate Professor, Crop and Soil Sciences
UGA-Tifton

ABSTRACT

Noninvasive remote-sensing methods including digital image analysis and spectral reflectance have been widely used for quantifying turfgrass cover and quality. Unmanned aerial vehicle (UAV) imagery has the potential to increase the efficiency in assessing turfgrass health by providing images with higher spatial and temporal resolution than a proximity sensor can. The study was conducted to assess the use of UAV-based imagery on replicated turfgrass field trials. Visual images and multispectral images were acquired with a UAV platform on field trials of bermudagrass (*Cynodon dactylon* L.) with a plot size of 1.8 m x 1.8 m. Ground truth measurements were taken immediately following the flight. Percent green cover (PGC) was calculated from the data extracted from ground-level red-green-blue (RGB) images and the normalized difference vegetation index (NDVI) was calculated from the data extracted from multispectral images. Data collected from UAV-based sensors identified the same, best-performing entries as the ground truth measurements, but provided more precise statistical separation than visual turfgrass quality. Ground PGC in bermudagrass can be predicted using UAV-based NDVI ($R^2 = 0.77$). Further investigation is needed for UAV system optimization and expanded use of these technologies.

INTRODUCTION

For decades, turfgrass color, density, uniformity, quality, and cover have been used to assess turfgrass health and performance (Horst *et al.*, 1984; Morris, 2000). The National Turfgrass Evaluation Program (NTEP) developed protocols for visually assessing turfgrasses, which are widely used and recognized by industry and turf researchers (Morris and Shearman, 2008). In recent years, more quantitative methods (e.g., digital image analysis and spectral reflectance) have been developed to supplement visual ratings to minimize subjectivity. Noninvasive remote-sensing methods including digital image analysis and spectral reflectance have been widely used for quantifying turfgrass cover and quality (Menges *et al.*, 1985; Richardson *et al.*, 2001; Jiang and Carrow, 2007; Xiong *et al.*, 2007).

Spectral reflectance of a turfgrass canopy is a function of absorption of visible light by chlorophyll and carotene content (amount, not type) (Jacquemoud *et al.*, 1996; Daughtry, 2000), whereas reflectance of near-infrared (NIR) light is associated with water and leaf turgor, which attenuate absorbance features associated with lignin and cellulose (Murphy, 1995). These characteristic features of plant reflectance make remote-sensing technologies an ideal method for quantitatively assessing turf-quality attributes. Vegetation indices such as NDVI and ratio vegetation index (RVI), calculated from reflectance at red and NIR bands, have been validated to indicate turfgrass health in previous studies (Fitz–Rodríguez and Choi, 2002; Jiang and Carrow, 2007; Lee *et al.*, 2011; Bremer *et al.*, 2011).

Vegetation indices can be obtained using a proximity multispectral sensor or a sensor carried by a UAV. A UAV-based NDVI map will have higher spatial resolution than that generated using a proximity sensor. Caturegli *et al.* (2016) used UAV-based multispectral imagery to estimate nitrogen (N) status of hybrid bermudagrass (*C. dactylon* L. × *C. transvaalensis* Burtt-Davy), zoysiagrass (*Zoysia matrella* L. Merr.), and seashore paspalum (*Paspalum vaginatum* Swartz). The study concluded that UAV imagery can adequately assess the N status of turfgrass and its spatial variability within a species for large areas such as golf courses and sod farms. To our knowledge, no investigation has been conducted regarding the use of UAV-based imagery on turfgrass variety trials with small plot sizes. Therefore, the objective of the study was to assess the potential use of digital visual (RGB) images and multispectral images collected with UAV platform in replicated turfgrass field trials with small plot sizes of 1.8 m^2.

MATERIALS AND METHODS

A Solo quadrocopter manufactured by platform (Solo 3D Robotics, Berkeley, California) was used to collect a set of aerial images for this study. The whole system consists of the drone, the controller, and a ground station with the software for mission planning, flight control, and telemetry system. Two cameras mounted separately on two similar quadcopters were tested in this study. The first one is the visual camera (GoPro Hero 4, GoPro, Inc., San Mateo, California). The second camera is a multispectral camera (Parrot Sequoia, MicaSense, Seattle, Washington) consisting of four narrow bands (green: 550 nm; red: 660 nm; red edge: 735 nm; NIR: 790 nm).

An advanced breeding trial of bermudagrass was planted using plugs in June 2016 on a loamy sand (Tifton-Urban land complex, pH 5.3) at the University of Georgia Tifton campus. Field plots were arranged as a completely randomized block design with three replicates. The plot size was 1.8 m x 1.8 m. Forty advanced lines from two breeding programs (UGA and Oklahoma State University) and four commercial cultivars (‘Celebration’, ‘Latitude 36’, ‘TifTuf’, and ‘Tifway’) were included. The UAV-based digital and multispectral images were taken on September 28, 2017, at 9:30 a.m. under clear weather. The flight altitude was 30 m for the digital camera, resulting in image resolution of 2.2 cm per pixel. For the multispectral camera, the flight altitude was 46 m and the resulting image resolution was 4.3 cm per pixel. The UAV speed was set to 4.5 ms-1 for all flights.

Geotagged images were processed in Agisoft PhotoScan Pro (Agisoft LLC, St. Petersburg, Russia) for image stitching and generating an orthomosaic. Georeferenced orthomosaic was exported in TIFF format for further analysis in ArcGIS. For data analysis, a shape file consisting of the individual field plot information was created in ArcMap 10.4.1 (Esri, Redlands, California). Data were extracted within each polygon (each polygon represented a plot) and were presented as table in ArcMap. The vegetation index NDVI was calculated as follows:

NDVI = (NIR-Red)/(NIR+Red)

“NIR” and “Red” refer to the canopy spectral reflectance at NIR and red bands.

Ground truth measurements including turfgrass quality, PGC, and canopy spectral reflectance were taken on the same day. Visual ratings of turfgrass quality were based on the National Turfgrass Evaluation Program (NTEP) using a 1 to 9 scale (9 = excellent performance, 1 = poor performance, 6 = minimum acceptable quality) (Morris and Shearman, 2008).

Percent green cover was estimated from digital images collected using a digital camera (Powershot G5; Canon, Tokyo, Japan) mounted to an enclosed photo box (56 cm x 56 cm) with four 9-W compact fluorescent lamps (TCP; Lighthouse Supply, Bristol, Virginia). Each image was analyzed using SigmaScan Pro (version 5.0; Systat Software, San Jose, California) for PGC (0% to 100%) using a hue range from 60 to 120 and a saturation range from 10 to 100 as outlined by Richardson *et al.*, (2001). Canopy spectral reflectance was measured using a spectral senor (CropCircle, ACS470; Holland Scientific, Lincoln, Nebraska), equipped with a decimeter level GPS (Raven Industries, Sioux Falls, South Dakota). The spectral sensor, with an active light source, measured light reflectance in three spectral bands centered on 550 nm (green), 650 nm (red), and 730 nm (NIR). The system was mounted to a mobile cart at 61 cm (2 ft) above ground with a target area of 35 cm by 6.4 cm. Data were collected and processed using TurfScout platform (TurfScout, Greensboro, North Carolina), and NDVI was calculated.

All data were subjected to analysis of variance using SAS 9.4 (SAS Institute Inc., Cary, North Carolina). For each parameter, Fisher’s protected LSD at 0.05 probability level was used to mark the top statistical group in bermudagrass entries. Pearson correlation and regression were performed between UAV-based measurements and ground measurements using the CORR and REG procedures, respectively. Graphs were generated using SigmaPlot 12.5 (Systat Software, Inc., Point Richmond, California).

RESULTS

The visual digital image and NDVI map are illustrated in Figure 1. Ground truth measurements including PGC, turfgrass quality, and NDVI, were positively correlated with UAV-based measurements PGC (0.79, 0.73, and 0.80, P<0.0001) and NDVI (0.80, 0.84, and 0.83, P<0.0001), respectively (Table 1). The best-performing bermudagrass genotypes as identified using visual turfgrass quality ratings ground PGC were consistent with the top entries found using different parameters measured by the UAV (Table 2). Nine bermudagrass entries entered the top statistical group based on ground PGC, which overlapped when the ranking was based on UAV-based PGC. Both TQ and ground NDVI provided less separation among the entries compared to ground PGC. In addition, five entries (‘TifTuf’, ‘TifB16118’, ‘TifB16116’, ‘TifB16115’, and ‘OSU1406’) were consistently ranked as the top statistical group based on measurements such as UAV-based NDVI. According to regression results, ground PGC in bermudagrass can be predicted using UAV-based NDVI (Table 3, R2 = 0.77).

What are NDVI Images? Applied Applications in Turf, *continued*

Figure 1. UAV images collected on bermudagrass field. Left: Visual digital image; right: Normalized Difference Vegetation Index.

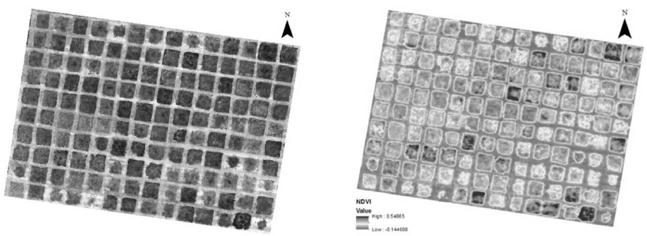


Table 1. Pearson correlation coefficients among ground measurements (PGC: percent green cover; TQ: turfgrass quality; and NDVI.G: normalized difference vegetation index) and UAV-based measurements (PGC.A and NDVI.A) on 1.8 m x 1.8 m field plots of bermudagrass.

GDD	PGC.A	TQ	NDVI.G	NDVI.A
PGC.G	0.79***	0.73***	0.80***	0.86***
PGC.A		0.73***	0.80***	0.86***
TQ			0.78***	0.84***
NDVI.G				0.83***

*, **, *** indicate significant level at 0.05, 0.01, 0.001 P level.

Table 2. The mean of percent green cover (PGC), TQ, and normalized difference vegetation index (NDVI, ground versus UAV-based) in 44 experimental bermudagrass entries in September 2017.

Entry	PGC.G[y] %	TQ	NDVI.G	NDVI.A
TifTuf	67.42 a[z]	5.67 a	0.42 a	0.36 a
TifB16118	65.94 a	5.50 a	0.46 a	0.38 a
TifB16116	64.76 a	5.50 a	0.42 a	0.35 a
TifB16115	60.41 a	5.33 a	0.42 a	0.38 a
OSU1439	57.46 a	5.17 a	0.41 a	0.29
OSU1406	56.84 a	5.50 a	0.44 a	0.35 a
OSU1337	55.11 a	5.17 a	0.43 a	0.31 a
TifB16110	53.78 a	5.83 a	0.46 a	0.33 a
OSU1433	51.50 a	6.17 a	0.45 a	0.30
TifB16114	49.37	5.00	0.37 a	0.28
TifB16106	45.50	5.33 a	0.43 a	0.32 a
TifB16101	45.49	5.00	0.41 a	0.28
OSU1408	45.45	4.50	0.41 a	0.26
TifB16117	45.36	4.00	0.36 a	0.25
TifB16102	45.08	5.33 a	0.37 a	0.31 a
TifB16104	44.61	5.67 a	0.42 a	0.29
OSU1418	42.72	4.00	0.36 a	0.24
TifB16103	40.73	5.00	0.38 a	0.26
OSU1412	40.65	5.17 a	0.37 a	0.25
TifB16105	40.41	5.33 a	0.37 a	0.29
TifB16113	39.60	4.83	0.34	0.29
TifB16112	38.42	5.00	0.35 a	0.29
OSU1435	37.39	4.50	0.38 a	0.25
TifB16111	36.98	4.00	0.34	0.21
OSU1417	35.54	4.00	0.37 a	0.23
TifB16120	34.52	5.00	0.33	0.27
OSU1403	34.45	4.67	0.39 a	0.23
OSU1402	33.10	4.33	0.35 a	0.21
TifB16119	32.62	5.00	0.36 a	0.28
OSU1257	32.18	4.83	0.37 a	0.23
Latitude36	30.60	4.50	0.38 a	0.23
Tifway	30.06	4.83	0.32	0.25
OSU1425	29.19	5.00	0.36 a	0.24
Celebration	29.05	4.67	0.34	0.24
OSU1414	27.96	4.33	0.32	0.23
OSU1318	26.64	4.67	0.33	0.22
OSU1423	24.25	4.00	0.31	0.20
TifB16109	23.39	3.67	0.28	0.22
OSU1409	22.51	4.33	0.33	0.20
OSU1310	20.29	3.00	0.24	0.12
OSU1415	19.59	4.00	0.28	0.18
TifB16107	16.08	3.67	0.29	0.20
TifB16108	13.24	4.00	0.32	0.23
OSU1420	10.94	3.33	0.23	0.14

Commercial cultivars are highlighted in gray.

[z]Value followed by letter a indicate the top statistical group using Fisher's LSD.

[y]The table was sorted by the first column, PGC.G.

Table 3. Regression between ground measurements (percent green cover, PGC, and normalized different vegetation index, NDVI) and UAV-based NDVI in bermudagrass.

Model	Intercept	Slope	R^2
NDVI_A vs PGC_G	-44.45	227.56	0.77
NDVI_A vs NDVI_G	-0.06	0.89	0.74
NDVI_A vs TQ	1.98	10.59	0.73

CONCLUSIONS

UAV-based imagery can generate a NDVI map with higher spatial resolution than proximity sensor. The study warrants further application of UAV-based imagery in small-plot-size research. Further investigation of more turfgrass species under different weather conditions will be needed if this technology is to be used for more applications.

REFERENCES

Bremer, D. J., Lee, H., Su, K., & Keeley, S. J. (2011). Relationships between normalized difference vegetation index and visual quality in cool-season turfgrass: I. variation among species and cultivars. *Crop Sci.* 51(5): 2212–2218. doi:10.2135/cropsci2010.12.0728.

Caturegli, L., Corniglia, M., Gaetani, M., Grossi, N., Magni, S., Migliazzi, M., Angelini, L., Mazzoncini, M., Silvestri, N., Fontanelli, M., Raffaelli, M., Peruzzi, A., & Volterrani, M. (2016). Unmanned aerial vehicle to estimate nitrogen status of turfgrasses (X Hu, Ed.). *PLoS One* 11(6): e0158268. doi:10.1371/journal.pone.0158268.

Daughtry, C. (2000). Estimating corn leaf chlorophyll concentration from leaf and canopy reflectance. *Remote Sens. Environ.* 74(2): 229–239. doi:10.1016/S0034-4257(00)00113-9.

Fitz–Rodríguez, E., & Choi, C. Y. (2002). Monitoring turfgrass quality using multispctral radiometry. *Trans. ASAE* 45(3): 865. doi:10.13031/2013.8839.

Horst, G. L., Engelke, M. C., & Meyers, W. (1984). Assessment of visual evaluation techniques. *Agron. J.* 76(4): 619–622. doi:10.2134/agronj1984.00021962007600040027x.

Jacquemoud, S., Ustin, S.L., Verdebout, J., Schmuck, G., Andreoli, G., & Hosgood, B. (1996). Estimating leaf biochemistry using the PROSPECT leaf optical properties model. *Remote Sens. Environ.* 56(3): 194–202. doi:10.1016/0034-4257(95)00238-3.

Jiang, Y., & Carrow, R. (2007). Broadband spectral reflectance models of turfgrass species and cultivars to drought stress. *Crop Sci.* 47(4): 1611–1618.

Lee, H., Bremer, D. J., Su, K., & Keeley, S. J. (2011). Relationships between Normalized Difference Vegetation Index and visual quality in turfgrasses: effects of mowing height. *Crop Sci.* 51(1): 323–332. doi:10.2135/cropsci2010.05.0296.

Menges, R. M., Nixon, P. R., & Richardson, A. J. (1985). Light reflectance and remote sensing of weeds in agronomic and horticultural crops. *Weed Sci.* 33(4): 569–581. doi:10.1017/s0043174500082862.

Morris, K. (2000). 1995 National Kentucky bluegrass test. Progress report NTEP 00-12. National Turfgrass Evaluation Program, USDA-ARS, Beltsville, MD.

Morris, K. N., & Shearman, R. C. (2008). NTEP turfgrass evaluation guidelines. Natl. Turfgrass Eval. Program, Beltsville, MD. http//www.ntep.org/pdf/ratings.pdf (accessed 27 Jan. 2018).

Murphy, R. (1995). The effects of surficial vegetation cover on mineral absorption feature parameters. *Int. J. Remote Sens.* 16(12): 2153–2164.

Richardson, M.D., Karcher, D.E., & Purcell, L. C. (2001). Quantifying turfgrass cover using digital image analysis. *Crop Sci.* 41(6): 1884–1888. doi:10.2135/cropsci2001.1884.

Xiong, X., Bell, G. E., Solie, J. B., Smith, M. W., & Martin, B. (2007). Bermudagrass seasonal responses to nitrogen fertilization and irrigation detected using optical sensing. *Crop Sci.* 47(4): 1603–1610. doi:10.2135/cropsci2006.06.0400.

Collection and Submission of Turf Insect Samples

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ABSTRACT

Several insect pests attack turfgrass. Most often, the manager sees the damage on the turfgrass rather than the pest itself because most insects are highly mobile and active at certain times of the day. They either move away or remain hidden when we look for the cause of damage on turfgrass. Sometimes, insects leave behind evidence of their activity as frass (insect waste) or old cast skin, which helps us to determine the cause of damage. The injury caused by insects can be found on various plant parts such as roots, stem, or foliage depending on its feeding habit or where the life stages develop. Insect-related damage can be due to direct feeding, egg laying, or the transmission of plant pathogens such as bacteria or a virus. Thus, sampling is a critical component in determining the cause of the damage. When samples are collected from turfgrass, it is essential to include some roots and some soil regardless of where the damage was observed. Along with the sample, indicating the sampling location, any observed pattern of damage in the field, and any recent applications of pesticides or fertilizer will help to determine the cause of the damage. Collected samples can be shipped overnight or directly handed over to the entomology laboratory at the University of Georgia Griffin campus for identification.

INTRODUCTION

Turfgrass is susceptible to several types of insect pests. These insect pests can be broadly classified as surface foliar feeders, with either chewing or fluid extraction mouthparts, and subsurface feeders. The surface foliar feeders with chewing and biting mouthparts munch the foliage to produce direct-feeding damage. A few examples of insect pests in this category are caterpillars such as fall armyworms, sod webworms, and cutworms. The surface-feeding pests with piercing and sucking mouthparts remove the nutrients in the vascular bundles (phloem and xylem) of the turfgrass, which can cause yellowing leaf blades or stunting. Prolonged feeding on plant sap can kill the turfgrass. A few examples of pests that fit in this category are the southern chinch bug, Rhodesgrass mealybug, ground pearl, bermudagrass mite, or zoysiagrass mite. Subsurface feeders typically feed on the root system of the grass. When they feed on the roots, the damage can appear as yellowing of leaves or stunted grass. Most of the subsurface feeders are at the larval stages of beetle pests such as billbugs, June beetles, or Japanese beetles.

In addition to those insects that directly feed on a turfgrass host, several others cause damage to the turfgrass by their dwelling habits. Examples of pests falling in this category are mole crickets, earthworms, ants, mason bees, and tiger beetles. Mole crickets dig tunnels in the ground searching for prey (southern mole cricket) or to feed on roots (tawny mole cricket). Either way, this tunneling habit rips the turfgrass apart and often causes severe damage. Similarly, earthworm activity moves the soil up from the deeper zones of the soil profile, which is considered beneficial for plant development as nutrients are cycled up. However, pelleted soil on the turfgrass surface is definitely considered undesirable in golf courses, sod farms, and residential turfgrass. Ants are mostly considered a nuisance in turfgrass and can make ant mounds, which are certainly not appreciated by turf managers. Other insects, such as mason bees or tiger beetles, can become pests when they dig holes to colonize, no matter how beneficial they are. On some occasions, insect damage is caused by egg laying on the plant tissue. For example, insects like billbugs lay eggs within the plant tissue, and the egg-laying process can cause plant injury.

While considering taking samples for an insect pest problem, it is critical to understand the daily activity, life stages causing feeding damage, mobility, and the feeding location (roots, stem, or foliage) of the potential pests in the area. Some pests, such as fall armyworms, actively feed in the night, whereas moths of sod webworms are active during dusk hours. Some pests such as moths and mole crickets are mobile, whereas scales and mealybugs are not mobile. Some insects specifically feed on roots, and others feed on stems (stolon) or foliage.

Proper sampling is a critical step in identifying the pest and its associated damage. Sometimes the insect damage is clearly apparent along with the insect pest causing it. However, there are occasions where the suspect is either too small to be seen by the naked eye or hidden in the plant material, for instance, under the leaf sheath or roots. In addition to insect samples, information associated with sampling can be critical in determining the problem. Helpful information includes any observed pattern in the damage; adjacent plant hosts; timing; and recent inputs such as fertilizer, insecticides, or herbicides; as well as turfgrass type and affected cultivars. Any specific observations related to activity may be critical in determining the issue.

MATERIALS AND METHODS

To determine the insect-related damage, it is critical to have the insect specimen in the sample. Without an insect specimen, the exact cause of the problem cannot be determined. If only the turfgrass sample is available for evaluation, the exact cause cannot be determined, but the best diagnosis will be made based on the injury symptoms, circumstances, turfgrass host, and potential pest candidates active at the given time of the year or location where the samples were collected. If feeding injury is observed on foliage, attempts should be made to sample the foliage with insect samples. In instances where the insect specimen or insect activity is not observed after several searches, an entire plant sample, along with the root system, will be required. Plant or insect samples can be placed in plastic bags and transported to the UGA turfgrass and ornamental entomology laboratory at UGA-Griffin. If possible, submit the sample within 24 hours to ensure the quality of the sample.

RESULTS

The principal investigator will process the submitted samples. If the submitted insect sample is common in the area, it will be identified at the laboratory at UGA-Griffin and the contact on file will be notified within 24 hours. If the insect species is not common and requires a taxonomist's expertise, it will be sent to an appropriate laboratory in the country for identification.

If the samples do not have any insect specimens, the turfgrass sample will be thoroughly evaluated for insect-related injury and the presence of insect parts or eggs. The investigator will contact the submitter for further details to understand the circumstances related to the problem. If evidence of insect activity is observed in the sample, the problem will be diagnosed appropriately. If insect activity is not clear after examination, other potential causes such as plant pathogens, abiotic factors such as unusual temperature response, and agricultural inputs such as pesticides and fertilizer phytotoxicity will be considered. The samples will be passed on to the appropriate discipline laboratory within the UGA Turfgrass Team for determination of the damage.

Mechanisms of Drought Tolerance in Bermudagrasses

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ABSTRACT

Bermudagrasses (*Cynadon* spp.) are widely grown in the Southeastern United States as valuable turfgrasses. During drought conditions, bermudagrasses, like other turfgrasses, experience severe declines in performance and quality. One of the major goals of turfgrass-breeding programs is the development of new cultivars with improved drought tolerance. Understanding the mechanisms responsible for drought tolerance in bermudagrasses will help future turfgrass varieties use these pathways to improve abiotic stress tolerance, ultimately improving the sustainability and resilience of turf area during water-limited conditions.

INTRODUCTION

Drought causes major stress that leads to damage and poor performance of turfgrass areas. A lack of available soil moisture results in reduced growth and density, wilting, leaf firing and loss of color, as well as eventual plant death (Fry and Huang, 2004). Multiple factors have been identified in other plant species as playing important roles in tolerating and surviving drought. These factors include extensive root systems, the ability to regulate leaf surfaces to reduce water loss and maintain active metabolism, the activation of antioxidant metabolism, and the accumulation of solutes and protective proteins (Huang *et al*., 2014). Newer bermudagrass cultivars have been developed with improved drought tolerance, and being able to withstand water-limited conditions is a trait of great interest. While differences in drought tolerance have been documented among bermudagrasses, the underlying differences responsible for increased levels of drought tolerance are not well understood (Zhou *et al.*, 2013). The goal of this project is to compare the drought performance between six bermudagrasses and better understand the mechanisms responsible for differences in drought tolerance between these turfgrasses. Understanding which of these pathways is responsible for enhanced drought tolerance in bermudagrasses will not only help us better understand how plants tolerate drought, it will also aid in the development of future cultivars.

MATERIALS AND METHODS

Plant materials were planted in field plots containing an automatic rainout shelter, which, when activated, prevents rainfall from reaching the plots and influencing soil moisture. A total of six lines were tested in this study, including three cultivars, ‘Celebration’, ‘Tifway’ and ‘TifTuf’, along with three experimental lines, ‘UGB-42’, ‘UGB-70’, ‘UGB-208’. Plugs were planted in the summer of 2017 and allowed to establish, being watered, mowed, and fertilized regularly (Figure 1). Plant responses to drought were assessed in the fall of 2017 and the summer of 2018. To assess drought performance, all irrigation was withheld and the rainout shelter was activated. Measurements included a visual turf quality rating on a 1-9 scale to assess overall performance. Additionally, normalized difference vegetative index (NDVI) and digital image analysis via light box were performed to assess plot color and density. To better understand drought performance and mechanisms responsible for differences in drought tolerance between cultivars, additional measurements were also taken during the drought period. These included relative water content to assess leaf hydration, osmotic adjustments to determine the accumulation of protective solutes, and membrane stability to estimate cell damage during drought. Additionally, photosynthesis was measured to determine how drought affected metabolic processes within the plant.

RESULTS

A number of significant differences were found between lines throughout the 35-day drought period. While all lines had declines in performance as measured by turf quality, the extent of damage was not the same among tested materials (Table 1). Significant differences were also found for NDVI, which estimates green coverage, and membrane stability, which estimates cellular damage. NDVI values ranged from 56.3 in ‘TifTuf’ to 45.5 in ‘Tifway’ (Figure 2). Membrane stability values ranged from 32.7% relative damage in ‘Celebration’ to 22.1% in ‘UGB-42’, with higher values representing greater damage to plant tissues (Figure 3). The cultivar ‘TifTuf’ and experimental line UGB-42 were in the top statistical group for both NDVI and membrane stability, while ‘Celebration’, ‘Tifway’, and ‘UGB-208’ were in the bottom grouping. During the more-than-monthlong drought period, ‘TifTuf’ was able to maintain greater moisture in leaf tissues compared to most other lines tested. At 35 days of drought, tissue hydration as estimated by relative water content had dropped to 78% in ‘TifTuf’, 71% in ‘UGB-42’, 67% in ‘UGB-70’, 65% in ‘Tifway’, 64% in ‘UGB-208’, and 63% in ‘Celebration’.

Figure 1. Field map with plot.

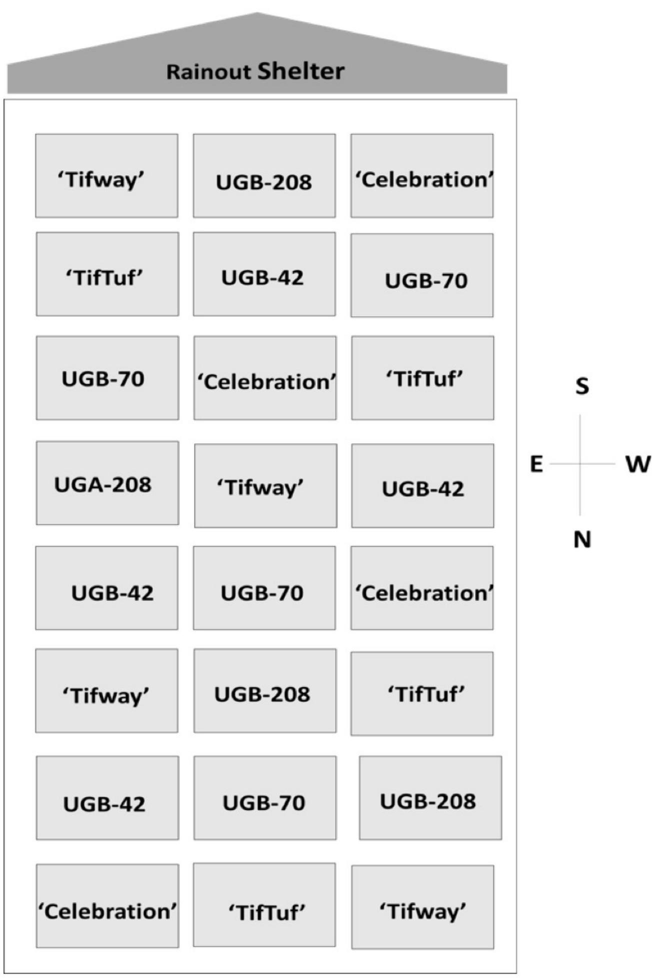


Table 1. Visual turf quality in response to drought.

Genotype	Visual Turf Quality					
	0 days	7 days	14 days	21 days	28 days	35 days
‘Celebration’	7.9	6.4	6.3	6.1	5.6	4.8
‘TifTuf’	8.0	7.6	7.5	6.9	6.8	6.6
‘Tifway’	7.0	6.6	6.4	5.3	5.3	5.0
UGB-42	7.6	7.3	7.0	6.4	6.5	5.9
UGB-70	7.6	7.4	7.4	6.9	6.5	5.8
UGB-208	7.9	8.0	7.6	7.0	6.8	6.3
LSD (0.05)	0.48	0.52	0.54	0.63	0.8	0.86

Figure 2. Differences in NDVI in response to drought.
Cultivar differences in NDVI based off of canopy reflectance at 35 days of drought stress. Bars represent standard error and capital letters correspond to LSD groupings. Cultivars sharing the same letter are not statistically different ($p < 0.05$).

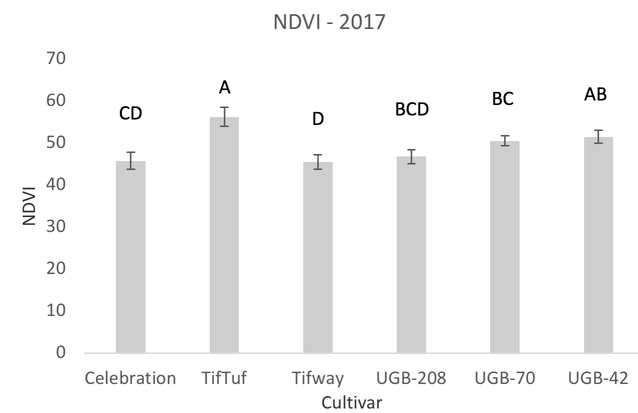
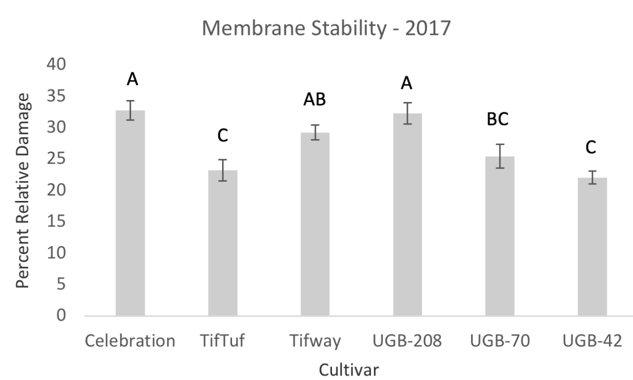


Figure 3. Differences in membrane stability in response to drought. Cultivar differences in membrane stability as estimated by electrolyte leakage at 35 days of drought stress. Bars represent standard error and capital letters correspond to LSD groupings. Cultivars sharing the same letter are not statistically different ($p < 0.05$).



Mechanisms of Drought Tolerance in Bermudagrasses, *continued*

CONCLUSIONS

A range of drought tolerance was found among the tested bermudagrasses. Top-performing lines demonstrated higher levels of several mechanisms associated with drought tolerance. It is likely that enhanced levels of drought tolerance seen in certain plants is due to the combination of multiple pathways or mechanisms and not a single factor. Further evaluations will be performed on the materials, including both controlled-environment growth chambers as well as additional drought periods, under field conditions to better quantify differences in stress tolerance and explore additional defense mechanisms related to drought.

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REFERENCES

Fry, J., & Huang, B. (2004). Applied Turfgrass Science and Physiology. John Wileys & Son Inc.

Huang, B., DaCosta, M., & Jiang, Y. (2014). Research Advances in Mechanisms of Turfgrass Tolerance to Abiotic Stresses: From Physiology to Molecular Biology. *Crit. Rev. Plant Sci.* 33(2–3): 141–189. doi:10.1080/07352689.2014.870411.

Zhou, Y., C.J. Lambrides, and S. Fukai. 2013. Drought resistance of bermudagrass (*Cynodon* spp.) ecotypes collected from different climatic zones. *Environ. Exp. Bot.* 85: 22–29. doi:10.1016/j.envexpbot.2012.07.008

Wetting Agents: An Added Bonus

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Wetting agents have traditionally been used to manage soil moisture in turfgrass environments. Applications are often made to rehydrate localized dry spots, reduce overall water consumption, or increase moisture uniformity in the soil profile. Several research projects conducted at the University of Georgia have identified alternative uses and benefits of wetting agents. Greenhouse and field trials revealed increases in rooting depth/mass; increases in surface firmness of putting greens due to enhanced water infiltration; reductions in total nitrogen leaching and increases in fertilizer use efficiency; and increases in pesticide efficacy, including pre-emergence herbicides and soil-applied fungicides and insecticides.

Warm-season Turf Disease Management

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A. Management of Rhizoctonia Large Patch of Zoysiagrass: Latest Research

ABSTRACT

Zoysiagrass (*Zoysia* spp.) tolerates a broad range of environmental conditions and it is used throughout Georgia in residential lawns, commercial landscapes, golf tees, and fairways. Rhizoctonia large patch (LP) caused by the soilborne fungus *Rhizoctonia solani* Kuhn AG 2-2 LP is the most common and severe disease of zoysiagrass across the state of Georgia. Large patch spring infections and reinfections are common. The objectives of these investigations were to determine the efficacy of fungicides and the application rates, as well as to evaluate pre-epidemic and postepidemic control of large patch. Fungicide trials were conducted on an area of zoysiagrass cv. 'El Toro' at the University of Georgia Griffin campus. The evaluated fungicides tebuconazole (Mirage) at 1.0 fl oz/1000 sq ft; penthiopyrad (Velista) 0.5 or 0.7 oz/1000 sq ft; trifloxastrobin + triadimefon (Armada) 1.5 fl oz/1000 sq ft; azoxystrobin + propiconazole (Headway) at 1.5 fl oz/1000 sq ft provided significant (α<0.05) disease suppression. Combination of fall and spring applications provided the highest disease suppression while spring applications applied postepidemically curtailed further advance of the disease while accelerating turfgrass recovery. Results obtained in these investigations provide turfgrass managers with new disease management tools, improved disease control, and better turf quality.

INTRODUCTION

Zoysiagrass (*Zoysia* spp.) tolerates a broad range of environmental conditions and it is used throughout Georgia as residential lawn, commercial landscape, golf tee and fairways. Rhizoctonia large patch (LP) caused by the soilborne fungus *Rhizoctonia solani* Kuhn AG 2-2 LP is the most common and severe disease of zoysiagrass across the state of Georgia. Symptoms of the disease appear in fall and spring when the grass is entering or coming out of dormancy. (For complete information on Rhizoctonia large patch, visit http://extension.uga.edu/publications/detail.html?number=C1088.) There are several fungicides labelled for large patch control. Preventive fungicide applications applied in early to mid-fall, before disease development, have shown to be efficacious in controlling the disease. Large patch spring infections and reinfections are common. This becomes particularly important in warm winters, such as those experienced in 2015-2016 and 2016-2017, where large patch infections extended for over 6 months. The objectives of these investigations were to determine the efficacy of fungicides and the application rates, as well as to evaluate pre-epidemic and postepidemic control of large patch.

MATERIALS AND METHODS

The efficacy of several new fungicide chemistries and application timings against *R. solani* on *Zoysia* spp. was evaluated. Fungicide trials were conducted on an area of zoysiagrass cv. 'El Toro' at UGA-Griffin. The site was selected due to a history of fall and spring large patch epidemics that had resulted in >90% incidence and severity. Treatments were arranged as plots (5 ft x 5 ft) in a randomized complete block design with four replications. The evaluated fungicides include tebuconazole (Mirage) at 1.0 fl oz/1000 sq ft; penthiopyrad (Velista) 0.5 or 0.7 oz/1000 sq ft; trifloxastrobin + triadimefon (Armada) 1.5 fl oz/1000 sq ft; azoxystrobin + propiconazole (Headway) at 1.5 fl oz/1000 sq ft. Timings of application included two applications in the fall (AB); two applications in the fall and one in spring (ABC); one application in the fall and one application in the spring (AC); and one application in spring (C). Fungicide products were mixed with water and sprayed in 2.0 gal water per 1000 sq ft with a hand-held, CO_2-pressured boom sprayer at 30 psi using XR TeeJet 800 2vs nozzles. To accentuate disease incidence, experimental plots were inoculated with a zoysiagrass isolate of *R. solani* grown on a tall fescue/barley/wheat seed mixture previously soaked in water overnight and then double sterilized in Erlenmeyer flasks. The infected seed was manually placed into center of the plot and into crowns of plants by pulling the stolons apart with a soil probe. Visual ratings were performed from 7- to 14-day intervals from the initial application date and depending on disease activity. Visual estimates of large patch disease severity were made using a modified Horsfall-Barratt rating scale (0 to 11), and then transformed to percent disease severity (0 = 1.17%, 5 = 37.5%, 11 = 98.82%). Turf quality was also rated using 1-9 (1 = bad, unsightly, dead grass; 9 = excellent color, uniformity, texture and density). Percent of disease severity and turf quality data were subjected to analysis of variance and means were separated using Fisher's Protected LSD $\alpha = 0.05$.

RESULTS

During the fall, winter and spring of 2015-2016, Rhizoctonia large patch epidemics were particularly heavy and unusually persistent. Environmental conditions for disease development were in place from the beginning of October 2015 to April 2016. Disease severity in the nontreated control progressed quickly, reaching greater than 47% on October 21, and the infection continued through the winter to reach greater than 90% on April 7. Throughout the study, all treatments provided significant ($P<0.05$) disease suppression compared to the non-treated check. The evaluated fungicides, tebuconazole (Mirage) at 1.0 fl oz/1000 sq ft, penthiopyrad (Velista) 0.5 or 0.7 oz/1000 sq ft, trifloxastrobin + triadimefon (Armada) 1.5 fl oz/1000 sq ft, azoxystrobin + propiconazole (Headway) at 1.5 fl oz/1000 sq ft, provided significant ($\alpha<0.05$) disease suppression compared to the nontreated check. Preventive applications of these active ingredients in the fall were shown to be efficacious in controlling the disease. A combination of fall and spring applications provided the highest disease suppression, while spring applications applied postepidemically curtailed further advance of the disease while accelerating turfgrass recovery. No phytotoxicity was observed in any of the treatments. An added benefit of spring fungicide applications was the control and/or prevention of other diseases, especially dollar spot and Drechslera/Bipolaris leaf spot. Results obtained in these investigations provide turfgrass managers with new disease management tools, improved disease control, and better turf quality.

B. Warm-season Turf Disease Management: Latest Research

Spring dead spot of bermudagrass

Bermudagrass (*Cynodon* spp.) is the single most popular, widely used warm-season grass in Georgia. It is found in most sport fields, lawns, greens, tees, and fairways. It is also extensively produced in sod farms and found in pastures. Spring dead spot (SDS) (caused by *Ophiosphaerella korrae*, *O. narman*, *and O. herpotricha*) is a persistent and destructive disease of bermudagrass in Georgia. The disease is particularly prevalent and damaging in the northern part of Georgia, especially in the Piedmont physiographic area. However, SDS can be observed throughout the state after harsh winters and in areas where bermudagrass has been exposed to freezing temperatures for extended periods of time. To date, there is no consistent and efficacious control of the disease. Cultural practices as well as fungicide availability have proven erratic and ineffective at reducing disease. Additionally, inability to identify Ophiophaerella infection timing has led to inconsistent control, varying from area to area and from year to year. Furthermore, environmental stewardship, overreliance on chemical control, and increasing concerns about pesticide resistance has led turfgrass managers to examine alternative practices to reduce plant disease. We have implemented comprehensive, multipronged, integrated research to develop new and efficacious control of SDS in Georgia. The objectives of this research were to evaluate the combination of temporal (spring and fall), cultural (aerification), and chemical practices, as well as to re-evaluate SDS-labeled fungicides and to examine several new fungicides and biofungicides/ organic products.

Field experiments were conducted on a 'TifSport' bermudagrass sward with SDS history located at UGA-Griffin and at one golf course in Georgia. Fungicide application timing (spring or fall) was used as the main factor, and cultural treatment (core aeration or no core aeration) and fungicide chemistry were sub-factors. Fungicide treatments consisted of tebuconazole at 0.6 fl oz/1000 sq ft, metconazole at 0.37 oz/1000 sq ft, azoxystrobin + propiconazole at 3 fl oz/1000 sq ft, azoxystrobin + difenconazole at 0.75 fl oz/1000 sq ft, pyraclostrobin + triticonazole at 3 lb/1000 sq ft, fluoxapyroxad at 0.26 fl oz/1000 sq ft, tebuconazole + wetting agent at 6 fl oz/1000 sq ft, and fenarimol at 6 fl oz/1000 sq ft. The fungicide penthiopyrad at 0.7 fl oz/1000 sq ft was added later in the trial. Ammonium nitrate, calcium nitrate, ammonium sulfate, and 10-10-10 fertilizers at a rate of 1 lb/1000 sq ft and the

Warm-season Turf Disease Management, *continued*

biofungicides/organic products Companion® at 6 fl oz/1000 sq ft, Essential plus® at 3 oz/1000 sq ft, Rhapsody® at 10 fl oz /1000 sq ft, and Holganix at 7 fl oz/1000 sq. ft were also evaluated.

RESULTS

1. Core aeration (solid tine) cultural practice before fungicide application was statistically similar to non-core aeration in both fall and spring. Thus, core aeration did not increase fungicide efficacy in spring or fall applications in any of the sites. Solid tine did not negatively impact fungicide efficacy, nor did it promote disease severity.
2. All fungicide treatments provided statistically significant spring dead spot suppression when compared to the untreated control at both locations.
3. Fungicide treatments applied either in the fall and/or in the spring were beneficial as they reduced disease incidence.
4. Fungicide application in the fall was still the most efficacious timing for SDS management (preventive, pre-epidemic).
5. In the fall, the use of a DMI-containing fungicide (Torque, Tourney, Rubigan); a DMI-strobilurin combination fungicide (Briskway, Headway, Pillar); or a succinate dehydrogenase inhibitor (SDHI) (Velista, Xzemplar, Kabuto) provided the most significant SDS suppression.
6. In the spring, a DMI-strobilurin combination fungicide (Briskway, Headway, Pillar) provided the most significant SDS suppression. Use of these fungicides shortens the time up to four weeks to achieve acceptable turf quality.
7. An unforeseen benefit of spring fungicide applications was the control and/or prevention of other diseases, especially dollar spot and large patch.
8. The use of a wetting agent did not significantly enhance fungicide efficacy.
9. For a complete report, visit http://cdn.cybergolf.com/images/994/Final-Report-Martinez.pdf.

Improved control against turfgrass-parasitic nematodes

Plant-parasitic nematodes (PPNs) adversely affect the health, quality, production, and maintenance of warm- and cool-season turfgrass on golf courses. In Georgia turfgrass parasitic nematodes account for a 0.5% to 3.0% reduction in turfgrass value, resulting in a loss of the crop and a cost of control of an average of $44 million annually. We have evaluated several chemistries as potential nematicides. Abamectin, fluopyram, and fluensulfone were tested on an ultradwarf bermudagrass putting green using different rates, timings of application, product combination, and cultural practices to enhance efficacy. Abamectin in combination with the Heritage fungicide provided better disease control and improved turf quality when compared to abamenctin by itself and the nontreated control. Abamectin was most effective when applied on moist turf and then watered in by irrigating the treated area shortly after application. On separate trials, fluopyram provided statistically significant, better nematode control than the nontreated control. Fluopyram was especially efficacious in our root-knot-nematode-infested putting green and delivered outstanding turf quality. It was noted that fluopyram provided up to six months of nematode suppression and maintained or improved turf quality for this amount of time. Fluensulfone provided up to 62% reduction in root-knot nematode numbers while enhancing turf quality. Turfgrass quality and root vigor greatly improved as well. Results from our research facilitated the registration and labeling of two new nematicides, called “Divanem” and “Indemnify.” Fluensulfone has been previously registered as “Nimitz Pro G.” Results from this research provide Georgia turfgrass managers with PPN control strategies that are consistent, promote long-term control, reduce applications, and improve turfgrass health and quality.

Impact of Biologicals on Turf Quality and Soil Health

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ABSTRACT

This project evaluates the impact of biologicals (i.e., biostimulants) on turf quality and soil biological health. Biologicals include a collection of products that contain “effective” microorganisms and/or plant- or animal-derived ingredients that are alleged to stimulate turf growth and quality while improving soil biological health. They are marketed as being more sustainable alternatives and/or supplements to some conventional agrochemicals. However, there have been limited studies evaluating their effectiveness in turf. To address this, we established field plots on greens at the University of Georgia Griffin campus and Rivermont Golf Club in Johns Creek, Georgia. The field plots include seven treatments with two biological products (KaPre RemeD8-NSP and KaPre RemeD8-NSL). We don’t yet have results to report as the project was recently started. We anticipate monitoring key parameters that are indicators of turf quality and soil biological health. We are also testing a novel method of product delivery (Air_2G_2) for biologicals.

INTRODUCTION

In this project, we are evaluating the impact of biologicals (also known as biostimulants) on turf quality and soil biological health. Biologicals include a collection of products that contain “effective” microorganisms (informally called “bugs in a jug”) and/or plant- or animal- derived constituents that are alleged to stimulate plant growth and improve soil health (Jardin, 2015; Wang *et al.*, 2017). The commonly stated benefits of biologicals include the stimulation of root growth and formation, promotion of nutrient acquisition, prevention and control of diseases, and release of plant-usable nutrients from organic sources. They are marketed as being more sustainable alternatives and/or supplements to conventional agrochemicals. The biostimulant market in the U.S. is projected to grow significantly (Yakhin *et al.*, 2017). Biologicals are commonly used by superintendents. However, research is needed to evaluate how effective they are in improving turf quality and soil health.

One important consideration when evaluating biological products is the method of application. Products are commonly surface-applied, leading to the exposure of microorganisms contained in biological products to extreme climatic fluctuations (e.g., heat and UV exposure from sun). This exposure can reduce the survival and establishment of microbial inoculants in the soil. This can be minimized through the subsurface application of the product. One way of achieving this is by using the novel Air_2G_2 delivery system that applies the product directly to the root zone. This system was originally designed to aerate the soil by blasting air below the surface but has been modified to inject products. As part of this project, we will examine whether applying the products at the surface vs. below the surface with Air_2G_2 will make any difference in the performance of the biological products.

The objectives of this project are to: 1) determine the impact of biological products on turf quality and biological soil health, 2) determine how the performance of the biological products is affected by method of application (surface vs. subsurface), and 3) determine the relationship between turf quality and biological soil health.

MATERIALS AND METHODS

Field plots were recently established on greens at two separate locations: UGA-Griffin (A1-A4 bentgrass) and Rivermont Golf Club (‘Tifgreen’ bermudagrass) in Johns Creek. Each plot will be 8 ft x 8 ft. The field study included seven treatments with two biological products (KaPre RemeD8-NSP and KaPre RemeD8-NSL). The biological products were surface- or subsurface-applied with or without aerification. The subsurface application was made with the Air_2G_2 injection system. The biological products were applied based on the recommended rate on the label. Each treatment was replicated four times in a completely randomized

Impact of Biologicals on Turf Quality and Soil Health, *continued*

design. Samples will be collected from the top 4 inches periodically (early, middle, and end of treatments) to capture short- and long-term trends in turf quality and soil health as stated below. Samples will also be characterized for basic soil properties (e.g., pH, organic matter, nutrient contents). Soil temperature and moisture are monitored with automatic sensors. Location-specific weather data are collected from the UGA Weather Network (http://www.georgiaweather.net/).

Turfgrass quality will be assessed visually for color, uniformity, texture, and density. The scale ranges between 1 (poorest quality) to 9 (best quality). This method is subjective and could vary from one person to another, but we include it because this method is commonly used by superintendents. However, we will also measure turf quality by using an optical sensor that measures reflectance from the turf canopy to calculate the Normalized Difference Vegetation Index (NDVI). The use of NDVI will provide the objective assessment of the overall turf quality by estimating color and ground cover. It generates quantitative data for robust statistical analysis. We will use the GreenSeeker Hand Held Optical Sensor (NTech, Ukiah, California) for this purpose according to the manufacturer's instructions.

We will monitor biological soil health indicators that are reflective of the activity and abundance of soil microorganisms. The activity indicators will include soil respiration (a generic indicator of microbial activity) and enzymes that mediate nitrogen and phosphorous transformations (e.g., urease, phosphatase). The abundance of key groups of organisms that carry out beneficial functions (e.g., ammonia oxidizers, arbuscular mycorrhizal fungi) will be quantified. Soil respiration and enzyme assays will be determined based on standard protocols (Wallestein and Weintraub, 2008; Tabatabai, 1994). Microbial abundance will be determined by a combination of traditional, culture-based and quantitative polymerase chain-reaction techniques (e.g., Habteselassie *et al.*, 2013; Coelho *et al.*, 2009).

The data will be summarized into descriptive statistics (e.g., mean, range and standard errors). An analysis of variance will be carried out to test the statistical significance of the effects of the biological products on turf quality and soil health. To determine the relationship between turf quality and soil biological health, we will carry out multivariate statistical analyses to identify soil biological health indicators that can best predict turf quality. The data on soil biological health and turf quality will be interpreted in relation to other soil and weather data.

RESULTS

The study was started recently, and we do not yet have any results to report.

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REFERENCES

Coelho, M.R., *et al.* (2009). Molecular detection and quantification of nifH gene sequences in the rhizosphere of sorghum (Sorghum bicolor) sown with two levels of nitrogen fertilizer. *Appled Soil Ecology,* 42:48-53.

Habteselassie, M.Y., Xu, Li, & Norton, J.M. (2013). Ammonia-oxidizer communities in an agricultural soil treated with contrasting nitrogen sources. *Frontiers in Microbiology,* 4:326-335.

Jardin, P. (2015). Plant biostimulants: definition, concept, main categories and regulation. *Scientia Horticulturae,* 196:3-14.

Tabatabai, M.A. (1994). Soil enzymes. In Methods of Soil Analysis, Part 2 – Microbiological and Biochemical Properties. R.W. Weaver, J.S. Angle and P.S. Bottomley (eds.) Soil Science Society of America, Inc. Madison, WI. pp. 775–834.

Wallenstein, M.D., & Weintraub, M.N. (2008). Emerging tools for measuring and modeling the in situ activity of soil extracellular enzymes. *Soil Biology and Biochemistry,* 40, 2098-2106.

Wang, *et al.* (2007). Microbial biostimulants in grower toolboxes. *Tilth Producers Quarterly,* 27:9-11.

Yakhin *et al.* 2017. Biostimulants in plant science: a global perspective. *Frontiers in Plant Science,* 7:1-23.

Overseeding: Site Prep and Grasses

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ABSTRACT

Overseeding is the practice of planting a cool-season turfgrass species into a permanent warm-season species for aesthetic purposes and to abate wear. Overseeding is primarily used on fields that receive use during dormancy of warm-season grass. The optimal germination temperature range for ryegrass is generally considered between 60-70 °F. The objective of this research was to evaluate ryegrass species and cultivars for establishment throughout the fall and early winter for acceptable turfgrass quality. Seeding at the early October (EO), October (O), and November (N) timings, all cultivars had 80% or greater ryegrass cover at 30 days after seeding. The turfgrass quality by the first of February was acceptable (i.e., >6.0) for all species and cultivars seeded during these timings. If turfgrass managers are considering overseeding bermudagrass sports fields, commercial properties, or home lawns, seeding when environmental conditions are most favorable and using a perennial ryegrass is suggested.

INTRODUCTION

Overseeding is the practice of planting a cool-season turfgrass species (e.g., annual and perennial ryegrass) into a permanent warm-season species (e.g., bermudagrass) for aesthetic purposes and to abate wear. In the Southeastern U.S., the practice of overseeding has declined overall, but recently it has been observed that the practice is increasing, particularly in sports field use associated with park and recreation departments and school systems. Overseeding is primarily used on fields that receive use during dormancy of warm-season species but are multiuse fields (e.g., football, soccer, and lacrosse) and baseball fields where the season begins (i.e., February) before the warm-season grass transitions to active growth. Often these fields are not seeded at optimal times and site preparation is not conducive for desired stand densities.

The objective of this research trial was to evaluate ryegrass species and cultivars for rate of germination and establishment throughout the fall and early winter for acceptable turfgrass quality in spring and impact on bermudagrass recovery.

MATERIALS AND METHODS

Overseeding plots were in a mature stand of 'TifSport' bermudagrass. Site preparation prior to seeding consisted of applying a sulfonylurea herbicide (e.g., Revolver) 14 days prior to seeding to minimize annual bluegrass (*Poa annua*) weed pressure. One to two days prior to seeding, individual plots were mowed to just below ½ inch to lightly open the turfgrass canopy and blow it free of debris. The mowing preparation was a commonly observed site preparation method that maintained a green bermudagrass canopy with minimal scalping discoloration.

There were five seeding timings (Table 1). Ideally the early-October (EO) timing would have been mid-September, but Hurricane Irma delayed site preparation and seeding. One annual ryegrass and three perennial ryegrass cultivars were used (Table 2). All grasses were seeded at 10 lbs/1000 ft^2 using a shaker jar technique. Plots were regularly irrigated the first 10 days following seeding to ensure adequate soil moisture for germination.

Table 1. Seeding dates.

Timing	Seeding Date
Early October (EO)	October 3, 2017
October (O)	October 16, 2017
November (N)	November 14, 2017
December (D)	December 15, 2017
January (J)	January 17, 2018

Table 2. Ryegrass species and cultivars.

Perennial Ryegrass	Annual Ryegrass
Carly	Gulf
Silver Sun	
New Sealand	

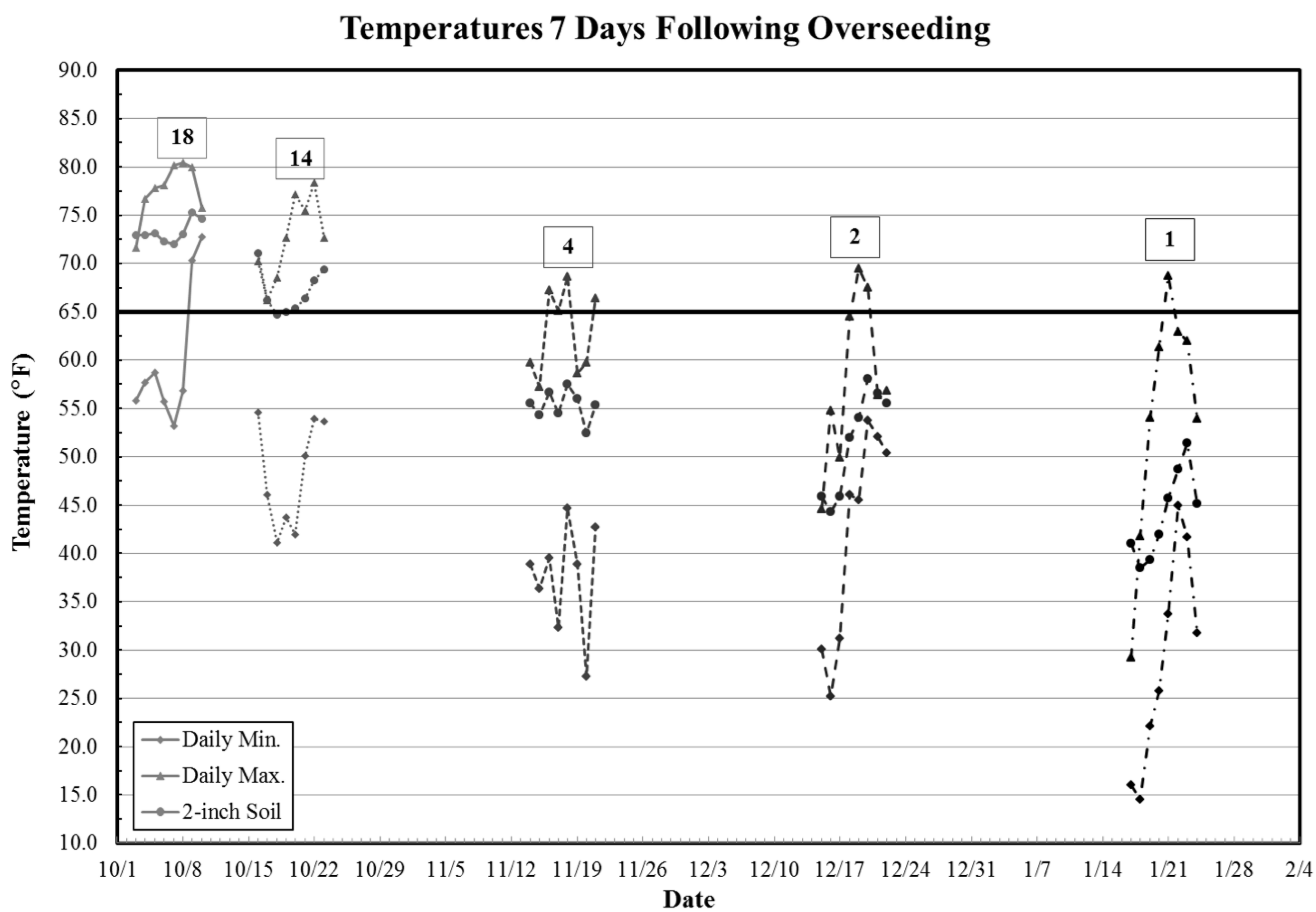
Overseeding: Site Prep and Grasses, *continued*

Postgermination maintenance consisted of maintaining plots at a ¾-inch mowing height and an 18-1-18 (≈70% slow release N) fertilizer was applied 2, 6, and 12 weeks after seeding at a rate of 1.25 lbs N/1000 ft^2. Fertilizer was applied to individual plots using a shaker jar technique. Due to irrigation needed for multiple seeding timings, the plan was to apply fungicides on a curative basis. Fortunately, disease was not a problem and fungicides were not applied during the study.

Visual evaluations for ryegrass density, turfgrass color (data not presented), and quality were evaluated monthly. Turfgrass color and quality were rated on a NTEP consistent scale of 1 to 9 with 6 being a commercially minimally acceptable level. For 7 days following seeding, daily minimum and maximum air temperatures and the 2-inch soil temperatures were recorded (Figure 1). Data were collected from a University of Georgia Weather Network station (www.GeorgiaWeather.net) located within 200 yards of the plot area.

The statistical design was a randomized complete block with seeding timing as the main plot (10 ft x 12 ft) and grass cultivar as the strip plot (10 ft x 3 ft). There were four replications. Data were subjected to the analysis of variance and means separated by least significant difference (LSD) at $\alpha = 0.05$.

Figure 1. Daily air minimum, maximum, and 2-inch soil temperatures for the day of seeding and seven days following.



RESULTS

The optimal germination temperature range for ryegrass is generally considered between 60-70 °F. Figure 1 includes the daily minimum and maximum air temperature and the 2-inch soil temperature for day of seeding and seven days following. Noted on Figure 1 are the number of occurrences within this period that a temperature was 65 °F or greater. Within a seeding timing there were a total of 24 possible incidences (i.e., eight for each daily air minimum, maximum, and 2-inch soil). For the EO timing, either the air or soil temperature was at least 65 °F 18 times. As expected, the number of times optimal conditions were recorded declined as the season progressed: 14, 4, 2, and 1 for O, N, D, and J, respectively.

At 30 days after seeding, within seeding timings there were no statistical differences (NS) among species or cultivars (Figure 2). Seeding at the EO, O, and N timings, all cultivars had 80% or greater ryegrass cover. Thirty days following the D timing cover was not greater than 65%. For the J seeding timing, all cultivars had greater than 75% cover despite only one occasion when a temperature was greater than 65 °F within the first 7 days following seeding.

Parks and recreation departments and school systems may choose to overseed athletic fields to establish winter color for spring baseball season. The turfgrass quality by the first of February was acceptable (i.e., >6.0) for all species and cultivars seeded during the EO, O, and N timings (Figure 4). For the D and J timings, no grass achieved an acceptable turfgrass quality by February. For the D seeding, all three perennial ryegrass cultivars had better turfgrass quality than the annual ryegrass.

A high school field may be overseeded to have a consistent color and quality appearance for outdoor graduation on the "stadium" field. By the first of May, most ryegrass cultivars had acceptable turfgrass quality regardless of seeding timing (Figure 5). However, 'Gulf' annual ryegrass greatly declined in quality and did not have an acceptable appearance.

While ryegrass can be seeded with a reasonable expectation of germination any time from early October to mid-January, seeding earlier provides the best turfgrass quality by start of spring baseball season (e.g., February). Also, although annual ryegrass rapidly germinates and can have an acceptable turfgrass quality early in the season, its late-season performance is not acceptable and is significantly lower than perennial ryegrass. If turfgrass managers are considering overseeding bermudagrass sports fields, commercial properties, or home lawns, seeding when environmental conditions are most favorable and using a perennial ryegrass is suggested.

ACKNOWLEDGEMENTS

We gratefully acknowledge the support of Pure Seed.

Figure 2. Percent ryegrass cover for 30 days following seeding.

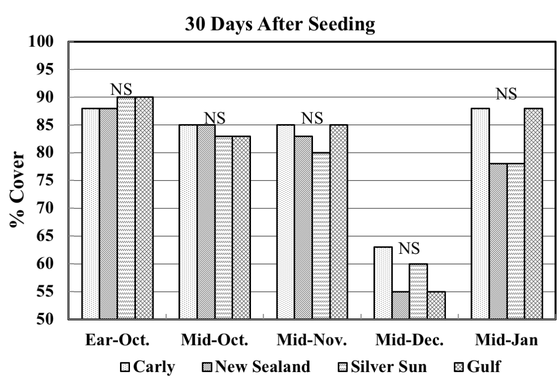


Figure 3. Percent ryegrass cover for 60 days following seeding.

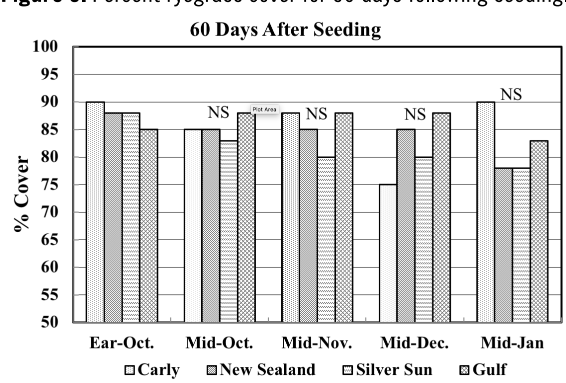


Figure 4. Turfgrass quality for the first of February.

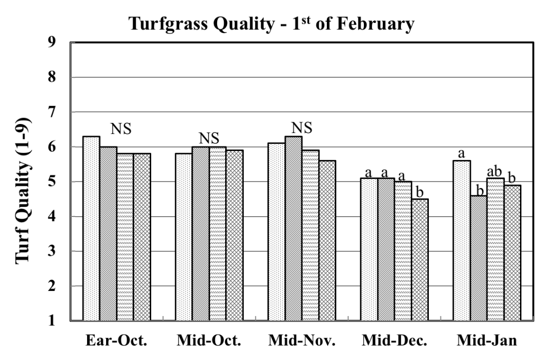
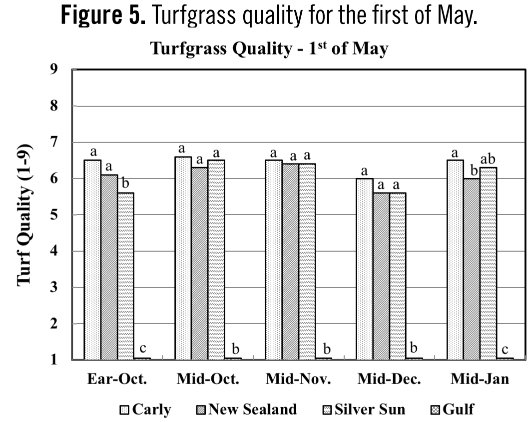


Figure 5. Turfgrass quality for the first of May.



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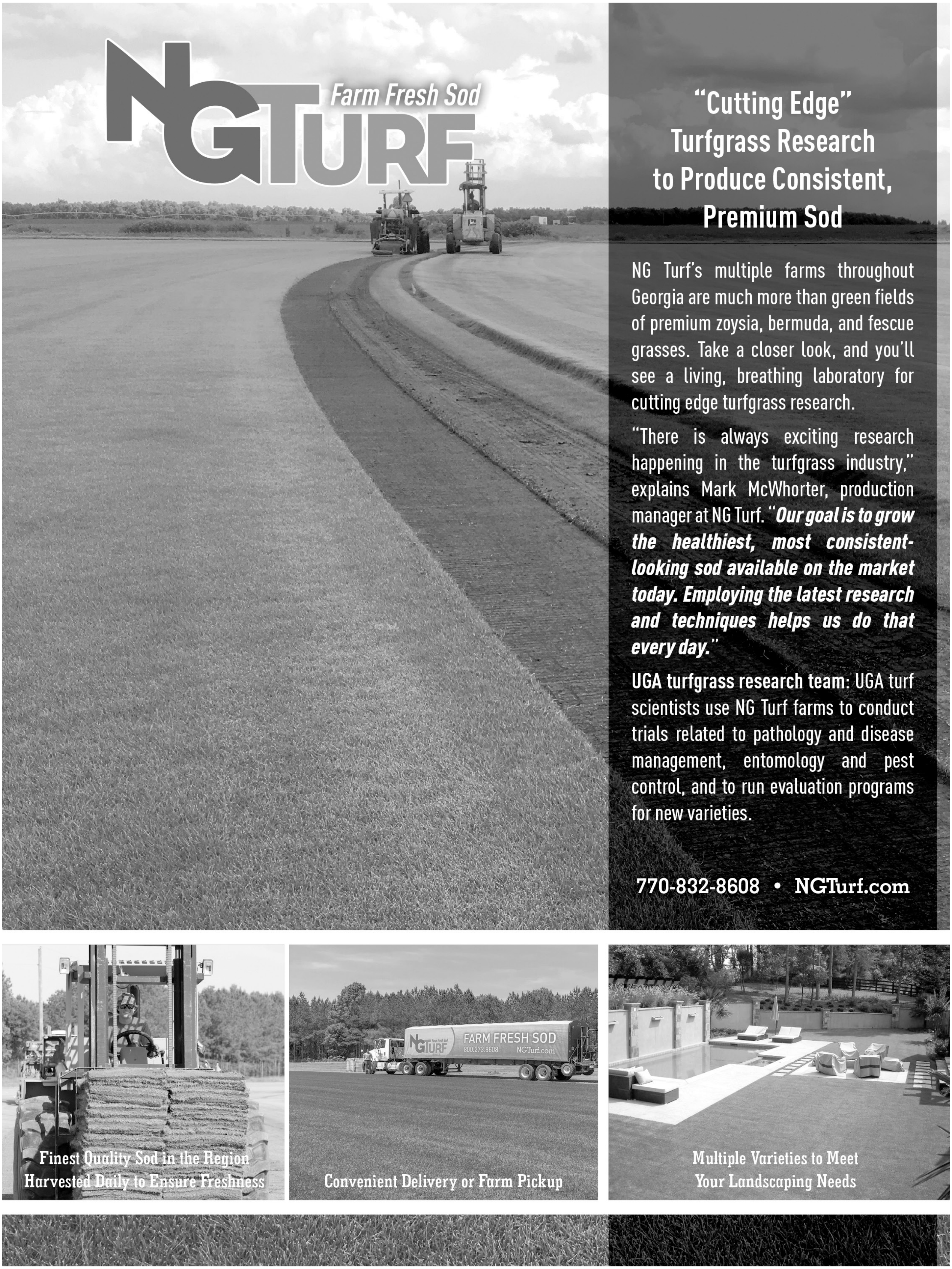
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New Herbicides for Turfgrass

Patrick McCullough, Associate Professor and Extension Weed Scientist, Crop and Soil Sciences
UGA-Griffin

Several new herbicides will be available for weed control in turfgrass over the next year. **Relzar** is a postemergence herbicide from Corteva (formerly Dow AgroSciences) that contains two active ingredients, halauxifen and florasulam. Relzar will be used for controlling broadleaf weeds in all warm- and cool-season turfgrasses. **GameOn** is another new product from Corteva that will be released this year. It contains halauxifen, 2,4-D, and fluroxypyr. It will be labeled for cool-season turfgrasses, bermudagrass, and zoysiagrass for controlling a wide spectrum of broadleaf weeds.

Vexis is being developed by PBI Gordon for turfgrass. The active ingredient, pyrimisulfan, inhibits acetolactate synthase in susceptible plants and controls many broadleaf weeds, including dollarweed and various sedges. It will be introduced as a combination product with penoxsulam on a fertilizer carrier before being launched as a stand-alone liquid formulation.

Coastal is a three-way combination product from Sipcam that will be released within the next year. It contains simazine, imazaquin, and prodiamine. Coastal will be used in warm-season grasses only for pre- and postemergence weed control. This product contains three different modes of action that will be a tool for controlling herbicide-resistant annual bluegrass and other problem weeds in turf.

Manuscript is a new postemergence herbicide from Syngenta for controlling grassy weeds in bermudagrass. The active ingredient is pinoxaden, which is a Group 1, ACCase inhibitor. Manuscript has shown to control crabgrass, dallisgrass, and tropical signalgrass in previous research. The efficacy of these products will be presented at field day.

Agronomic Applications of UAS

Clint Waltz, Professor and Turfgrass Specialist, Crop and Soil Sciences
UGA-Griffin

Clay Bennett, Technician, Crop and Soil Sciences
UGA-Griffin

This stop will introduce multiple applications of unmanned aerial systems (UAS) for turfgrass management and application. Because of the low (and declining) price point and ease of operation, the use of UAS for turfgrass management is increasing. Through social media, UAS are predominately being used to take high-definition images and movies to market golf courses and sports fields and to communicate current conditions to users. Other applications include photo-documentation of renovations and projects that can serve as an as-built. There have been instances where turfgrass managers have used images from a UAS to educate municipal officials and end users; examples include aerification and the impact of traffic. UAS make these applications easier than in the past, but they only scratch the surface of the potential of their use.

UAS can be fitted with other sensors or cameras, like a near-infrared (NIR) camera to measure a turf canopy's normalized difference vegetation index (NDVI) of stressed and non-stressed grass. The objective is that stress is simply and cost effectively, detectable with a UAS-mounted NIR camera, such that a turfgrass manager can use images to improve fertility, pest management, and irrigation practices (i.e., reduce fertilizer and pesticide applications and conserve water). Potential applications of integrating UAS will be demonstrated and discussed, as will the legal and logistical operation of UAS by turfgrass management personnel.

Carbon Dynamics of Warm-season Turfgrass Measured Using the Eddy-Covariance Technique*

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Paul Raymer, Professor, Crop and Soil Sciences
UGA-Griffin

Despite their ubiquitous presence in the urban landscape throughout the United States, scant attention has been given to the positive aspects of the net carbon dioxide balance from turfgrasses. It is particularly true for warm-season turfgrasses. With questions frequently raised on the environmental friendliness of warm-season turfgrasses, detailed and robust studies focusing on the carbon behavior of such systems are useful as they may dispel common misconceptions.

This recent study delves into the carbon balance of 'Tifway' bermudagrass, the extensively used warm-season turfgrass in Georgia and other subtropical and warm, temperate areas. Using a powerful technique called "the eddy-covariance method," the amount of CO_2 captured by a highly managed turfgrass system was measured by deploying two eddy-covariance systems over a period of 31 months.

The results of seasonal and monthly fluxes clearly show that turf is a carbon sink during its active growth period of summer and fall months. The yearly net carbon sequestration results show that 'Tifway' bermudagrass removes carbon dioxide from the atmosphere at the rate of 4.51 – 5.15 Mg C ha^{-1} yr^{-1}, corresponding to 16.5 – 18.9 tons CO_2 ha^{-1} yr^{-1}. These figures in turf are considerably higher than those found in many agricultural crops. Results from the present study suggest that the turf canopy as well as management activities carried out on the sod production farm exert a substantial influence on turf's atmospheric "scrubbing" of carbon dioxide.

(Left) Setup of a fast-response sonic anemometer, a CO_2 analyzer, and other supporting instrumentation at the sod production farm in Fort Valley, Georgia; (right) Roshani Pahari, master's student working on this project, checks readings from the instruments.

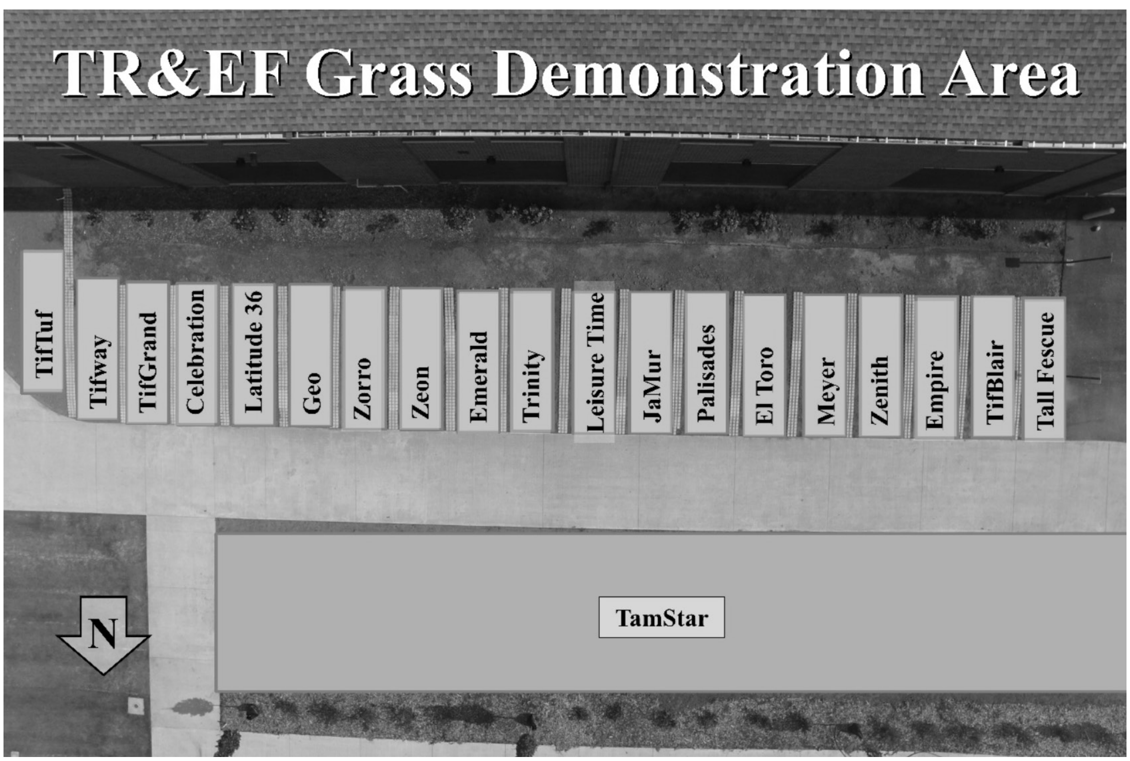
*Pahari, R., Leclerc, M. Y., Zhang, G., Nahrawi, H., Raymer, P. (2018). Agriculture, Ecosystems and Environment, 251, 11-25.

Research Facility Tour

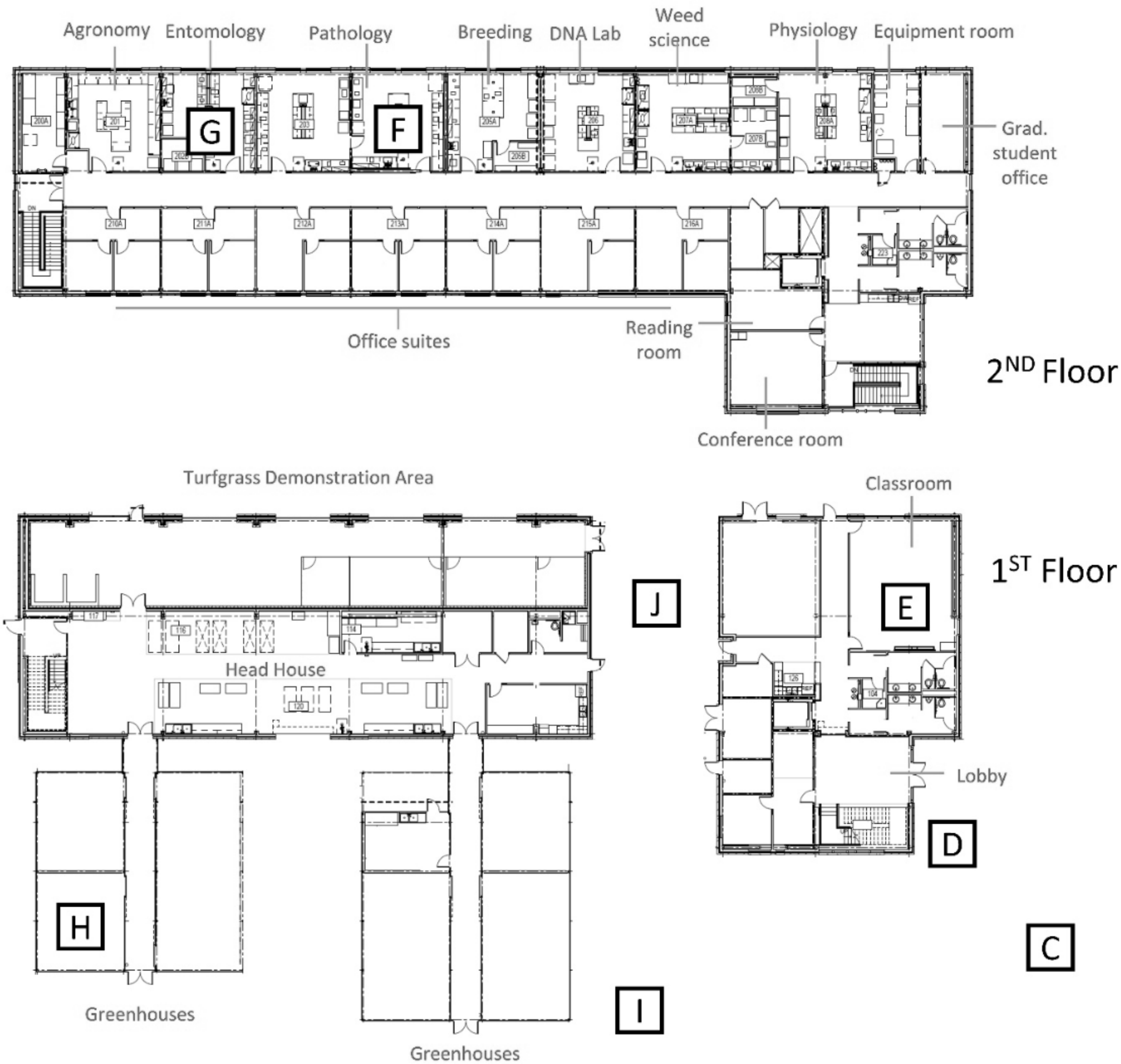
The Turfgrass Research and Education Center on the University of Georgia Griffin campus will be open to field day participants for self-guided tours of the facility. In 2014, the state legislature approved $11.5 million for the renovation and construction of new turf facilities at UGA's Athens, Griffin, and Tifton campuses. These funds supported the construction of greenhouse facilities in Tifton to support the turfgrass breeding program, greenhouse and teaching laboratory facilities in Athens to support research and undergraduate education, and greenhouse and research facilities in Griffin. The Griffin turfgrass facility is a state-of-the-art building that was dedicated in September 2017. The building houses research programs with faculty specializing in agronomy, breeding, entomology, pathology, physiology, and weed science. The new facility contains faculty and staff offices, research laboratories, greenhouses, a conference room, and a classroom. The building replaced outdated, aging facilities with cutting-edge facilities that improve efficiency and research capabilities, making Griffin's Turfgrass Research and Education Center one of the most advanced turfgrass facilities in the world. These facilities build on UGA's legacy of excellence in turfgrass science and help support the improvement of turfgrasses in Georgia for years to come. Signs throughout the building lead field day participants through the building to highlight design features and future use. Additional self-guided afternoon tour stops are located in and around the building.

ACKNOWLEDGEMENTS

We gratefully thank those who supported and made this project possible, including state legislators, members of industry, and university administration.



Research Facility Tour, *continued*



☐ Self-guided afternoon tour stops

Athlete Injuries in Response to Sports Field Conditions

Gerald Henry, Professor, Crop and Soil Sciences
UGA-Athens

Natural turfgrass sports fields exhibit within-field variations due to climatic conditions, field construction, field management, and foot traffic patterns from field usage. Variations within a field could influence the playing surface predictability and require athletes to make abrupt or frequent adjustments that may lead to increased occurrences of ground-derived injuries. Our research introduces a new methodology aimed at evaluating the potential relationship between within-field variations of turfgrass sports field properties and ground-derived athletic injuries. Collegiate club-sport athletes self-reported ground-derived injuries over two years. Soil moisture, turfgrass quality, surface hardness, and turfgrass shear strength were quantified from their two home fields. Hot spot statistical analysis identified significantly high (hot spots) and low (cold spots) values within the fields. Injury locations were compared to hot spot maps each month. Binomial proportion tests determined if there were differences between observed injury proportions and expected proportions. Twenty-three ground-derived injuries were reported overall. The observed injury proportions occurring in turfgrass quality cold spots [0.52 (95% CI 0.29-0.76)] and soil moisture hot spots [0.43 (95% CI 0.22-0.66)] were significantly higher than expected [0.20 ($p < 0.001$) and 0.21 ($p < 0.05$), respectively]. Most injuries in significant areas of turfgrass quality, soil moisture, and surface hardness were along edges of hot and cold spots. These results suggest a potential relationship between within-field variations and ground-derived injuries, particularly in transition areas between nonsignificant and significant high and low values. Future larger-scale studies can incorporate the reported methodology to validate this relationship and implement strategies that reduce ground-derived injuries.

This research is published in the European Journal of Sports Science: Straw, C. M., Samson, C. O., Henry, G. M., & Brown, C. N. (2018). Does variability within natural turfgrass sports fields influence ground-derived injuries? European J. of Sports Sci. *doi:10.1080/17461391.2018.1457083*

Macroscopic and Microscopic Turf Disease Identification

Alfredo Martinez-Espinoza, Professor and Extension Plant Pathologist, Plant Pathology
UGA-Griffin

Effective and efficient disease control always begins with an accurate diagnosis of the problem. Turfgrass disease diagnosis should incorporate the possibility of biotic (living) as well as abiotic (nonliving) factors. At this stop, we will review practical and critical steps for an accurate turf disease diagnosis. Microscopy and visual observation will be part of the session. Main foliar and root turfgrass diseases will be discussed. Environmental and cultural factors that promote each disease will be reviewed. Turfgrass pathogen biology as well as the different methods of disease control will be emphasized.

Systematic approach to diagnosis of turfgrass diseases

Define the symptoms of the problem

- Patches, yellowing, chlorosis, leaf spots, etc.

Ask questions to narrow down the cause of the symptoms

- Could it be environmental?
- Was anything sprayed?
- When did you first notice the problem?
- Where did it start?
- Has it spread since then?
- What is your watering and fertilization schedule?

Examine the specimen

- Collect a representative sample, including leaf blades and roots, with a range of symptoms.
- Use half of the sample to perform a diagnosis. Store the rest of the sample inside a plastic bag containing a moist paper towel.
- Using a hand lens or compound microscope, observe any fungal signs that may be present (mycelia, sclerotia, pycnidia, etc.).
- Prepare a microscope slide mount based on signs and view with compound microscope.
- Place a small drop of water or stain on the slide.
- Pull sections from the roots, blade sheath, and/or crown and any leaf spots.
- Place the cover slip over the mount, view beginning with the smallest magnification, and change magnification as the desired signs in question are found.
- Consult resources. Use literature and resources to reach a diagnosis.

Example of turf disease identification

Rhizoctonia

Diseases: brown patch, large patch, yellow patch, leaf and sheath

Common species: *Rhizoctonia solani, Rhizoctonia cerealis, Rhizoctonia zeae, Binucleate Rhizoctonia*

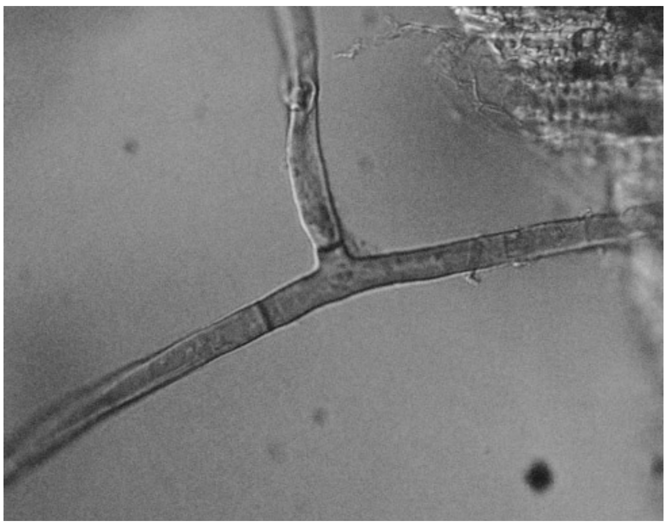
Diagnostic tips

Field:

Brown patch: The symptoms of brown patch can vary depending on the grass cultivar, climatic and atmospheric conditions, and soil management of the turfgrass. This disease typically causes rings and/or patches of blighted turfgrass that measure 5 inches to more than 10 feet in diameter. It also causes leaf spots and “smoke rings,” which are thin, brown borders around the diseased patches that appear most frequently in the early morning. After the leaves die in the blighted area, new leaves can emerge from the surviving crowns. On wide-bladed species, leaf lesions develop with tan centers and dark brown to black margins.

Large patch: This disease occurs during the spring and fall, when warm-season turfgrasses are entering or exiting their period of winter dormancy. Circular patches of diseased turf are observed, ranging in diameter from less than 3 ft up to 25 ft. Leaves of recently infected turf, located at the periphery of the patch, may appear orange in color. Some patches may be perennial, recurring in the same location and expanding in diameter year after year. In contrast to brown patch, *R. solani* infection of warm-season grasses occurs on the leaf sheaths, where water-soaked, reddish-brown or black lesions are observed. Foliar dieback from the leaf tip toward the base occurs as a direct result of these leaf sheath infections.

Microscope:



- Septated hyphae, uniform diameter
- Right-angle branching of hyphae
- Constrictions at the base of branching
- Color of hyphae is tan to light brown
- Mycelium formation, no spore production
- Start with dissecting scope and scan crowns of turf
- Using scalpel and tweezers, remove infected tissue containing mycelium
- Place on glass slide containing a drop of stain
- Examine at low magnification on compound microscope (4X, 10X objective)

Billbug Identification and Control in Zoysiagrass

Shimat V. Joseph, Assistant Professor and Extension Entomologist, Entomology
UGA-Griffin

How to identify billbugs

Billbugs are weevils in genus *Sphenophorus* spp. that feed on turfgrass. Weevils have a characteristic snout on the head and their chewing and biting mouthpart is located at the tip of the snout. Other beetles do not have this characteristic feature.

Common billbug species that attack turfgrass in the Southeastern U.S.:

1. Hunting billbug (*Sphenophorus venatus vestitus Chittenden*)
2. Uneven billbug (*S. inaequalis*)
3. Lesser billbug (*S. minimus*)
4. *S. apicalis*
5. *S. coesifrons*
6. *S. cariosus*

Host plants: Billbugs primarily infest warm-season grasses, especially zoysiagrass (*Zoysia* spp.) and bermudagrass (*Cynadon* spp.). They also prefer yellow nutsedge (*Cyperus esculentus* L.).

Life history: Billbug adults primarily move around by crawling. They overwinter as adults and in late-larval stages in protected areas such as thatch and crevices between turfgrass and a sidewalk. Adult billbugs are active at night. Legless larvae initially feed within the stem or roots, and larval feeding causes economic damage. The larvae pupate in soil.

Damage: The young larvae of billbugs feed within the stem, whereas later larval stages feed on the roots and crown of turfgrass. Feeding initially causes discolored brown patches and, eventually, several patches coalesce to form a large, dead area. Affected zoysiagrass struggles to grow, especially after winter dormancy. Bermudagrass can tolerate certain levels of billbug infestation.

Monitoring: Adult activity can be nondestructively monitored using linear pitfall traps. Larval stages are monitored using destructive sampling of roots.

Management: For adult control, bifenthrin (Talstar, Menace), deltamethrin (Deltagard), lambda-cyhalothrin (Scimitar or Battle), and imidacloprid (Merit) can be used. For larval control, clothianidin (Arena) and thiamethoxam (Meridian) provide effective control. For both adult and larval control, chlorantraniliprole (Acelepryn), clothianidin + bifenthrin (Aloft), and imidacloprid + bifenthrin (Allectus, Atera) are advised.

Improving Salt Tolerance in Warm-season Grasses

Paul L. Raymer, Professor, Crop and Soil Sciences
UGA-Griffin

ABSTRACT

A greenhouse salt screening protocol developed at the University of Georgia was used to evaluate 50 bermudagrass experimental germplasm lines from Southern breeding programs. All genotypes were simultaneously evaluated using subirrigation on ebb and flow benches to test lines at four salt concentrations. Plants were visually rated for turf quality, photographed to obtain digital RBG images for digital image analysis, and clipped to determine top-growth dry weight. Using this technique, we were able to identify several experimental germplasm lines with salt tolerance superior to commercially available cultivars. This research demonstrates that salt tolerance of bermudagrass cultivars can be significantly improved.

INTRODUCTION

As potable water supplies available for irrigation of turfgrass continue to decline throughout the world, one alternative is to use nonpotable water, such as brackish or reclaimed water, for turfgrass irrigation (Loch *et al*., 2003). Using such water sources requires the selection of salt-tolerant grasses. Previous research has demonstrated that turfgrass species and cultivars vary greatly in their level of tolerance to salt (Uddin *et al*., 2011; Lee *et al*., 2004). Therefore, it is necessary to screen potential cultivars prior to their release to ensure that they have high levels of salt tolerance. Furthermore, genetically controlled variability for salt tolerance among breeding lines implies that it may be possible to further improve salt-tolerance through breeding and selection. To accomplish these breeding objectives, an effective greenhouse salinity screening protocol was developed at UGA and is being used to identify the most salt tolerant genotypes of bermudagrass, St. Augustinegrass, seashore paspalum, and zoysiagrass.

MATERIALS AND METHODS

The materials and suppliers being used are shown in Table 1. Ebb and flow benches constructed in-house were used to provide daily subirrigation with a solution containing Excel soluble fertilizer at 2 g per gallon of irrigation solution. A synthetic sea salt mix was gradually added to individual benches to achieve final salt concentrations of 0, 15, 30 and 45 dS m^{-1}. Electrical conductivity of the irrigation solution was monitored using a portable pH/conductivity meter equipped with a conductivity electrode.

Four replications of 54 bermudagrass genotypes, including four released cultivars, and 50 experimental germplasm lines from Southern breeding programs were simultaneously evaluated at each of the four salt concentrations. Plants for evaluation were grown in washed play sand in 10 cm pots. To minimize chlorosis associated with sulfur deficiency, the equivalent of 1 ton per acre of gypsum was added to the sand and 0.6 grams of $MgSO_4$ were added per gallon of irrigation solution. All plants were maintained by daily subirrigation with fertilizer solution for 30 days prior to initiating salt treatments. After the grow-in period, all plants were clipped to a standard height of 3.8 cm and salt concentration was increased by 5 dS m^{-1} at three- to four-day intervals until target concentrations were reached. All tables were subirrigated simultaneously once per day using an electronic timer to turn on pumps submersed in the irrigation solutions. Timers were set to a duration that allowed irrigation solutions to completely cover the pots to minimize surface accumulation of salts.

Improving Salt Tolerance in Warm-season Grasses, *continued*

Table 1. Materials used in greenhouse salt screening.

Salt Mix - Instant Ocean Synthetic Sea Salt, Aquarium Systems, Mentor, Ohio 44060
EC Meter – Horiba pH/Conductivity Meter, Model D-24 equipped with Horiba DO Electrode, Model 9382-10D and distributed by Spectrum Technologies, Inc., Plainfield, Illinois
Fertilizer – Miracle-Gro Professional Excel water soluble fertilizer, 13-2-13 + 6 Ca + 3 Mg plug special distributed by Scotts-Sierra Horticultural Products Company, Marysville, Ohio 43041
Turf Analyzer software - https://www.turfanalyzer.com

Each week all plants were visually rated for turf quality, photographed to obtain digital RBG images for digital image analysis (DIA), and clipped to determine top growth dry weight. Digital image analysis for dark green color (DGC) was performed using Turf Analyzer software. This analysis provided a consistent and repeatable inverse measurement for leaf firing, which has been traditionally used as a measure of salt tolerance.

RESULTS

As salt levels increased, reductions in plant growth were observed in response to salt concentrations, with severe reductions in plant growth occurring at the 30 and 40 dS m^{-1} treatment levels (Figure 1). A similar pattern was observed for both visual quality (data not shown) and leaf firing measured as changes in color (Figure 2). Leaf firing began to increase rapidly at week 3 as salt levels in the 30 and 45 dS m^{-1} treatments went above 20 dS m^{-1}. Table 2 summarizes the response of to salt-level treatments of a small subset of the 54 entries tested. Of the released cultivars (checks) tested, ‘TifTuf’ and ‘Latitude 36’ were more salt tolerant than ‘Tifway’ and ‘Celebration’. Several of the tested experimental lines demonstrated much better salt tolerance than any of the released cultivars used for comparison. The seven top-performing experimental lines are shown in Table 2. These data indicate significant variability within advanced bermudagrass germplasm and clearly demonstrate that substantial improvements in the salt tolerance of bermudagrass cultivars are possible.

Table 2. Average reduction in color expressed as a percentage of freshwater control of selected bermudagrass lines.

	Dark Green Color as a Percentage of the Freshwater Control			
Line	**0 dS**	**15 dS**	**30 dS**	**45 dS**
TifB16109	100	85.56135	46.97797	0.654122
TifB16116	100	118.6234	39.3893	1.331856
TifB16111	100	97.28105	39.35357	4.296751
TifB16104	100	102.2244	27.40023	9.003951
TifB16101	100	73.36551	21.66763	0.930978
OSU1337	100	50.03914	20.77606	5.307338
TifB16108	100	47.88261	20.41738	3.829785
TifTuf	100	64.72827	12.45529	1.288485
Tifway	100	42.35736	4.610139	0.439832
Latitude36	100	82.7499	2.290597	0.293941
Celebration	100	43.13958	0.875483	0.041139

CONCLUSION

A greenhouse screening protocol can be used to effectively screen large numbers of germplasm lines to identify lines with superior salt tolerance. The variability among advanced breeding lines demonstrated in this experiment and the identification of breeding lines with superior salt tolerance to currently available cultivars offers great promise for improvement of the level of salt tolerance of bermudagrass. This research also implies that similar progress may be possible in other warm-season turfgrass species using this approach.

Figure 1. Impact of salinity on average growth of bermudagrass lines.

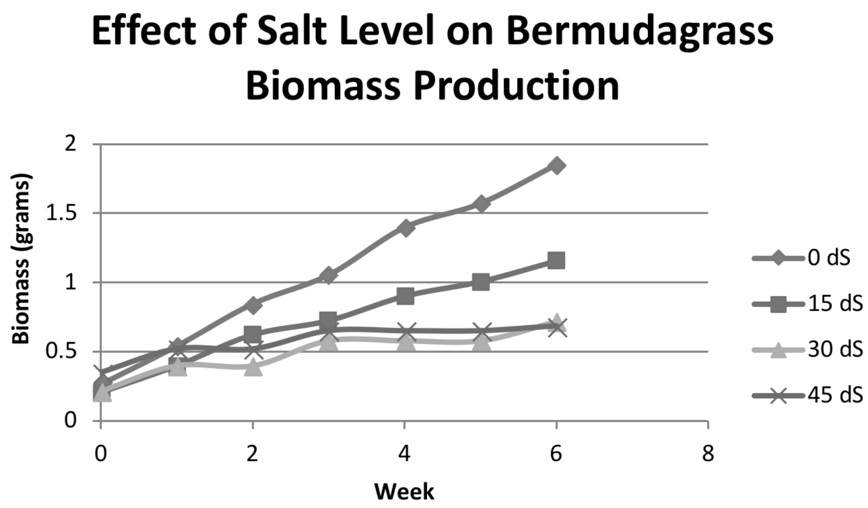
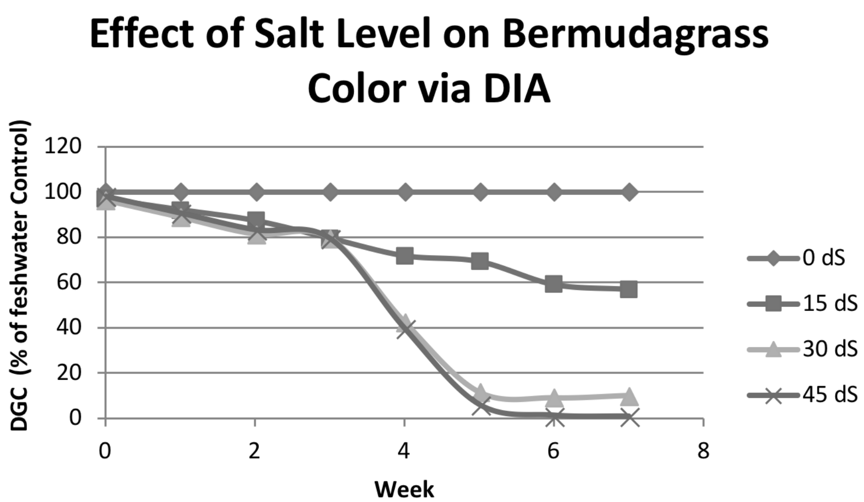


Figure 2. Impact of salinity on average color (DGC) of bermudagrass lines tested.



REFERENCES

Loch, D.S., Barrett-Lennard, E., & Truong, P. (2003). Role of salt tolerant plants for production, prevention of salinity and amenity values. Proc. of 9th National Conf. of Productive Use of Saline Lands (PUR$L). 29 Sept.-Oct. 1, Rockhampton, QLD, Australia.

Lee, G., Carrow, r. n., & Duncan, R R. (2004). Salinity tolerance of selected seashore paspalums and bermudagrasses: root and verdure responses and criteria. *HortSci.*, 39(5):1143-1147.

Uddin, M. K., Juraimi, A. S., Ismail, M. R., Othman, R., & Rahim, A. A. (2011). Relative salinity tolerance of warm season turfgrass species. *Journal of Environmental Biology,* 32(3), 309-12. Retrieved from http://proxy-remote.galib.uga.edu:80/login?url=https://search.proquest.com/docview/876868461?accountid=14537

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Tools for Understanding Turfgrass Plant Health

David Jespersen, Assistant Professor, Crop and Soil Sciences
UGA-Griffin

ABSTRACT

Understanding the plant health and environmental factors that influence plant performance is essential to managing high-value turf areas. Various tools and technologies are available to assist turf managers by helping them assess plants and their environments. These tools can be used for the measurement of leaf chlorophyll, canopy temperature, overall canopy quality and greenness, and important environmental factors such as light and soil moisture, all of which influence plant performance. Effectively using these tools may help turf managers better understand the grasses they're growing and how to adjust inputs for optimal performance.

SUMMARY

Turfgrasses are sessile organisms, unable to move. This means that their growth and performance depends on their environmental conditions, and how well they are able to withstand stresses within their environment. Factors that influence plant performance include temperature, the amount of light they receive for photosynthesis, soil moisture, and availability of nutrients, to name a few. Optimal plant performance requires a specific range of environmental conditions, and too much or too little of any aspect can potentially have drastic consequences. Understanding the environment and plant conditions is essential to making management decisions that efficiently use resources and improve plant performance. Advances in technology have made measurement tools more affordable than ever. Various tools and technologies are available to help turfgrass managers assess both plant performance as well as the environmental conditions that influence plant growth and health. Measurement tools for assessing environmental conditions include light meters, soil moisture meters, and soil compaction meters. Additional available tools can be used to estimate plant nutrient status and overall plant health. While these tools cannot replace experience and other sound management techniques such as regular soil sampling and record keeping, they may help provide additional insight to turfgrass managers. A variety of instruments related to turfgrass science will be demonstrated and discussed.

Graduate Student Research at UGA

Graduate students studying turfgrass science
UGA

Graduate students pursuing their master's or doctoral degrees are an integral part of the University of Georgia's turfgrass programs. In addition to taking classes, these students perform independent scientific research while earning their degrees. These students represent the next generation of turfgrass managers and scientists. Graduate student research will be presented through a poster session to highlight graduate work and the research they are performing at UGA.

KEY POINTS: Georgia's Turfgrass Industry and UGA's Turfgrass Program

INDUSTRY

- Estimates suggest that, at 1.8 million acres, turfgrass is one of the largest agricultural commodities in the state.
- This includes home lawns, sports fields, golf courses, sod farms, and other managed landscape areas.
- Georgia turfgrass and related industries contribute a total of $7.8 billion annually to the economy.
- In terms of earnings and value added, turfgrass and related industries contribute $4.6 billion each year.
- The federal, state, and local tax impact is more than $1 billion annually.
- This industry accounts for 87,000 full- and part-time jobs.
- The majority of these jobs are related to landscape maintenance of buildings and households.
- The landscape industry has a history of professional development and use of research-based information.
- Through drought periods, the golf and landscape segments have demonstrated exceptional environmental stewardship with their best management practices (BMP) approach to water use efficiency and conservation.
- This industry has strived to be a part of the solution to Georgia's environmental issues.

UGA TURFGRASS PROGRAM

- UGA is the research, development, and education arm of Georgia's turfgrass industry.
- UGA has a more-than-60-year history of providing scientifically based information to the turfgrass industry.
- UGA is known for its renowned scientists and specialists who develop practices, pest management strategies, and grasses that are best adapted to Georgia.
- Turfgrass breeding for warm-season species dates back to the 1950s and continues today with two productive programs focused on sustainable bermudagrass, centipedegrass, seashore paspalum, and zoysiagrass cultivars.
- These scientists continue to stretch the scientific boundaries with novel approaches and strategies to solve the most challenging management and environmental issues that face this industry.
- UGA scientists continue to be involved with water conservation and have demonstrated effective methods of achieving sustainability of natural resources (i.e., water) while maintaining industry viability.
- Extension and professional development for Georgia's turfgrass practitioners are also strong emphases at UGA. Without a well-educated workforce, the economic development of the turfgrass industry would not be where it is today.
- With the continued support of strong academic programs and industry partnerships to increase economic development, there are opportunities to further scientific exploration and enhance the environment.

2016 Georgia Agricultural Commodity Rankings

Rank	Commodity	Farm Gate	% of GA Total
1	Broilers	$4,370,498,425	31.79%
2	Cotton	$967,690,060	7.04%
3	Eggs	$772,609,464	5.62%
4	Timber	$681,114,224	4.95%
5	Peanuts	$624,380,318	4.54%
6	Beef	$592,854,362	4.31%
7	Greenhouse	$452,850,333	3.29%
8	Dairy	$397,501,015	2.89%
9	Pecans	$355,854,324	2.59%
10	Blueberries	$283,874,343	2.06%
11	Corn	$277,231,197	2.02%
12	Horses	$255,770,300	1.86%
13	Misc. Vegetables	$214,662,946	1.56%
14	Hay	$198,745,440	1.45%
15	Container Nursery	$164,052,969	1.19%
16	Breeder Pullet Unit	$160,179,699	1.17%
17	Onions	$156,881,260	1.14%
18	Sweet Corn	$156,210,920	1.14%
19	Watermelon	$124,491,830	0.91%
20	Pork	$118,443,229	0.86%
21	Ag-based Tourism	$115,032,225	0.84%
22	Bell Peppers	$112,983,837	0.82%
23	Soybeans	$112,201,927	0.82%
24	Turfgrass	$111,689,673	0.81%
25	Silage	$103,190,931	0.75%
26	Field Nursery	$102,648,114	0.75%
27	Hunting Lease - Deer	$82,582,497	0.60%
28	Cucumbers	$69,510,597	0.51%
29	Pine Straw	$66,796,065	0.49%
30	Tomato	$61,306,670	0.45%
31	Tobacco	$51,190,155	0.37%
32	Cabbage	$49,609,871	0.36%
33	Peaches	$48,030,446	0.35%
34	Greens (collards, Chard, kale, lettuce, mustard, spinach, turnip greens)	$44,944,340	0.33%
35	Honeybees	$37,413,405	0.27%
36	Quail	$32,761,690	0.24%
37	Squash (Yellow and Winter)	$32,144,356	0.23%
38	Catfish	$30,020,280	0.22%
39	Zucchini	$26,531,229	0.19%
40	Wheat	$26,013,694	0.19%
41	Eggplant	$25,912,664	0.19%
42	Snap Beans	$24,873,608	0.18%
43	Cantaloupe	$24,210,064	0.18%
44	Grapes	$20,414,060	0.15%
45	Goats	$19,472,309	0.14%
46	Apples	$14,329,175	0.10%
47	Straw	$11,939,323	0.09%
48	Hunting Leases - Turkey	$10,914,481	0.08%
49	Other Peppers (banana and hot)	$10,369,941	0.08%
50	Christmas Trees	$10,016,563	0.07%
51	Strawberries	$9,749,656	0.07%
52	Southern Peas	$7,616,104	0.06%
53	Sorghum	$7,039,659	0.05%
54	Blackberries	$6,846,790	0.05%
55	Oats	$6,594,259	0.05%
56	Rye	$4,535,082	0.03%
57	Sheep	$3,512,801	0.03%
58	Okra	$1,970,551	0.01%
59	Hunting Leases - Duck	$1,358,425	0.01%
60	Barley	$162,072	0.00%
	Crop Insurance	$138,924,940	1.01%
	Government Payments	$613,098,990	4.46%
	All Other Miscellaneous	$132,133,215	0.96%
	2016 Total Farm Gate Value	**$13,748,493,392**	

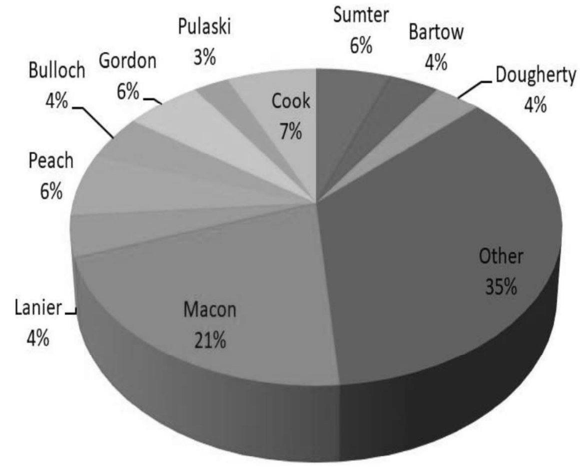
Turfgrass Farm Gate Value 2016

Rank	County	Acres	$/Acre	Farm gate Value
40	Appling	50	$6,050.00	$211,750
-	Atkinson			$0
-	Bacon			$0
-	Baker			$0
-	Baldwin			$0
39	Banks	45	$7,000.00	$220,500
-	Barrow			$0
8	Bartow	1,005	$6,050.00	$4,256,175
-	Ben Hill			$0
23	Berrien	250	$6,050.00	$1,058,750
-	Bibb			$0
-	Bleckley			$0
-	Brantley			$0
-	Brooks			$0
50	Bryan	1	$6,050.00	$4,235
6	Bulloch	1,200	$6,050.00	$5,082,000
40	Burke	50	$6,050.00	$211,750
-	Butts			$0
-	Calhoun			$0
-	Camden			$0
31	Candler	100	$6,050.00	$423,500
14	Carroll	500	$6,050.00	$2,117,500
21	Catoosa	280	$6,050.00	$1,185,800
-	Charlton			$0
-	Chatham			$0
-	Chattahoochee			$0
48	Chattooga	10	$6,050.00	$42,350
-	Cherokee			$0
-	Clarke			$0
-	Clay			$0
45	Clayton	20	$6,150.00	$86,100
-	Clinch			$0
49	Cobb	5	$6,050.00	$21,175
-	Coffee			$0
43	Colquitt	30	$6,050.00	$127,050
49	Columbia	5	$6,050.00	$21,175
2	Cook	1,800	$6,050.00	$7,623,000
-	Coweta			$0
-	Crawford			$0
-	Crisp			$0
-	Dade			$0
-	Dawson			$0
12	Decatur	672	$6,050.00	$2,845,920
-	Dekalb			$0
-	Dodge			$0
13	Dooly	550	$6,050.00	$2,329,250
9	Dougherty	950	$6,050.00	$4,023,250
-	Douglas			$0
18	Early	370	$6,050.00	$1,566,950
-	Echols			$0
19	Effingham	350	$6,050.00	$1,482,250
-	Elbert			$0
30	Emanuel	106	$6,050.00	$448,910
-	Evans			$0
-	Fannin			$0
-	Fayette			$0
46	Floyd	17	$6,050.00	$71,995
-	Forsyth			$0
42	Franklin	40	$6,050.00	$169,400
28	Fulton	150	$6,050.00	$635,250
-	Gilmer			$0
-	Glascock			$0
-	Glynn			$0
4	Gordon	1,520	$6,050.00	$6,437,200
38	Grady	55	$6,050.00	$232,925
-	Greene			$0
-	Gwinnett			$0
24	Habersham	200	$6,050.00	$847,000
-	Hall			$0
27	Hancock	165	$6,050.00	$698,775
-	Haralson			$0
42	Harris	40	$6,050.00	$169,400
35	Hart	74	$6,050.00	$313,390
25	Heard	175	$6,050.00	$741,125
-	Henry			$0
20	Houston	300	$6,050.00	$1,270,500
13	Irwin	550	$6,050.00	$2,329,250
20	Jackson	300	$6,050.00	$1,270,500
-	Jasper			$0
-	Jeff Davis			$0
29	Jefferson	120	$6,050.00	$508,200
-	Jenkins			$0
-	Johnson			$0
-	Jones			$0
-	Lamar			$0
7	Lanier	1,100	$6,050.00	$4,658,500
26	Laurens	169	$6,050.00	$715,715
24	Lee	200	$6,050.00	$847,000
-	Liberty			$0
-	Lincoln			$0
-	Long			$0
41	Lowndes	45	$6,505.00	$204,908
-	Lumpkin			$0
1	Macon	5,500	$6,050.00	$23,292,500
-	Madison			$0
-	Marion			$0
36	McDuffie	70	$6,050.00	$296,450
-	McIntosh			$0
37	Meriwether	60	$6,000.00	$252,000
15	Miller	380	$6,500.00	$1,729,000
16	Mitchell	400	$6,050.00	$1,694,000
-	Monroe			$0
-	Montgomery			$0
28	Morgan	150	$6,050.00	$635,250
-	Murray			$0
-	Muscogee			$0
-	Newton			$0
-	Oconee			$0
-	Oglethorpe			$0
-	Paulding			$0
3	Peach	1,700	$6,050.00	$7,199,500
-	Pickens			$0
-	Pierce			$0
-	Pike			$0
-	Polk			$0
10	Pulaski	540	$8,000.00	$3,024,000
-	Putnam			$0
-	Quitman			$0
-	Rabun			$0
-	Randolph			$0
31	Richmond	100	$6,050.00	$423,500
-	Rockdale			$0
-	Schley			$0
31	Screven	100	$6,050.00	$423,500

Rank	County	Acres	$/Acre	Farm gate Value
-	Seminole			$0
-	Spalding			$0
-	Stephens			$0
-	Stewart			$0
5	Sumter	1,500	$6,050.00	$6,352,500
-	Talbot			$0
-	Taliaferro			$0
-	Tattnall			$0
44	Taylor	25	$6,000.00	$105,000
-	Telfair			$0
-	Terrell			$0
33	Thomas	100	$5,500.00	$385,000
11	Tift	700	$6,050.00	$2,964,500
-	Toombs			$0
-	Towns			$0
-	Treutlen			$0
20	Troup	300	$6,050.00	$1,270,500
32	Turner	95	$6,050.00	$402,325
-	Twiggs			$0
-	Union			$0
-	Upson			$0
34	Walker	90	$6,050.00	$381,150
47	Walton	15	$6,050.00	$63,525
-	Ware			$0
29	Warren	120	$6,050.00	$508,200
17	Washington	380	$6,050.00	$1,609,300
-	Wayne			$0
-	Webster			$0
-	Wheeler			$0
-	White			$0
-	Whitfield			$0
22	Wilcox	278	$6,000.00	$1,167,600
-	Wilkes			$0
-	Wilkinson			$0
-	Worth			$0
	Totals & Avg.	**26,172**	**$6,096.46**	**$111,689,673**

Percent of Ornamental Horticulture 13.25%

Top Ten Counties for Turfgrass



Top Ten Counties by Value - Turfgrass

County	Acres	Price	Farm gate Value
Macon	5,500	$6,050.00	$23,292,500
Cook	1,800	$6,050.00	$7,623,000
Peach	1,700	$6,050.00	$7,199,500
Gordon	1,520	$6,050.00	$6,437,200
Sumter	1,500	$6,050.00	$6,352,500
Bulloch	1,200	$6,050.00	$5,082,000
Lanier	1,100	$6,050.00	$4,658,500
Bartow	1,005	$6,050.00	$4,256,175
Dougherty	950	$6,050.00	$4,023,250
Pulaski	540	$8,000.00	$3,024,000

NOTES

NEW Turfgrass Research and Education FACILITIES

The University of Georgia Turfgrass Team extends gratitude and thanks to Gov. Nathan Deal, the 2014 Georgia Legislature, the Georgia Urban Ag Council, and leaders of the Georgia turfgrass industry for their support in securing funds to improve our research and education facilities.

2018 Turfgrass Research FIELD DAY

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