Symposium Organizing Committee

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Stacy A. Bonos
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Ning Zhang

Proceedings of the Thirty-Third Annual Rutgers Turfgrass Symposium

Ning Zhang and Barbara Fitzgerald, Editors

Associate Director's Remarks:

Welcome to the Thirty-Third Annual Rutgers Turfgrass Symposium. The Symposium was established in 1991 to provide an opportunity for Rutgers faculty, staff and students to discuss current research and share ideas on a broad range of topics in turfgrass science. This year, I would like to extend a special welcome to our keynote speaker, John Sorochan (*Department of Plant Sciences, University of Tennessee Knoxville*) who will present a seminar on "Research and Testing Focusing on Soccer Field Consistency and Uniformity for World Cup 2026*."* This is exciting since the final World Cup 2026 game will be played at MetLife Stadium in New Jersey. I would also like to extend a warm welcome and thank you to our invited speakers this year, Glen Groban (*USDA-ARS Beltsville*), David McCall (*School of Plant and Environmental Sciences, Virgina Tech)*, and Cole Thompson (*United States Golf Association*), and all of the turf center faculty and students who have agreed to present their research at this year's symposium.

I would also like to thank our session moderators Dr. Ning Zhang, Dr. James Murphy, and Dr. Albrecht Koppenhöfer and the Symposium Planning Committee, Mr. Brad Park (Symposium Committee Chair), Drs. Rong Di, Jim Murphy, Stacy Bonos, and Dr. Ning Zhang and Ms. Barbara Fitzgerald (Co-Editors of the Symposium Proceedings) for their hard work in planning this year's symposium. We also appreciate the technical support of Mr. Bernard Ward and Phil Wisneski for their help with live streaming and website postings. Without their efforts, the symposium would not be possible.

Faculty, staff and students in the turfgrass science program have been recognized nationally for their excellent research. This year, one graduate student was recognized at the National Crop Science Society Annual Meeting in St. Louis, MO. William Errickson won second place in the Water Conservation Poster presentation category in the Division of Turfgrass Science. As was announced last year, due to the generosity of Mr. Sean Pattwell, an internship for graduate students studying turfgrass science was initiated in 2022. Mr. Pattwell graciously continued the support for 2023. Mr. Mark LaBarge, the second recipient of the Sean S. Pattwell Graduate Student Internship, completed a three-week internship at Bandon Dunes Golf Resort in Bandon, Oregon. He will give a presentation about his experience at the symposium this year.

This year we celebrated Dr. Matthew Elmore's promotion to Associate Professor with tenure and welcomed a new member to our Turfgrass Center faculty. Dr. Ming-Yi Chou joined the Department of Plant Biology and the Center for Turfgrass Science faculty as an Assistant Extension Specialist in Turfgrass Pathology in April of 2023. Welcome Dr. Chou!

Finally, I would like to acknowledge the unique partnership we have with the turfgrass industry in New Jersey and beyond and are grateful for the support they provide to the turfgrass program at Rutgers University. We are glad that you have decided to spend the day with us to discuss the exciting topics in turfgrass science presented at today's Symposium!

Sincerely,

Stacy A. Bonos, Associate Director

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THIRTY-SECOND ANNUAL RUTGERS TURFGRASS SYMPOSIUM

School of Environmental and Biological Sciences, Rutgers University

March 14, 2024

Institute for Food, Nutrition, and Health Building, Room 101

8:30 – 9:00 AM	**Registration**
9:00 – 9:10 AM	**Welcome** – **Wendie Cohick** (*Dean of Research and Graduate Education)*
9:10 - 10:30 AM	**SESSION I: *Turfgrass Pathology*** (Moderator: Ning Zhang)
9:10 - 9:30	**Ming Yi Chou** (*Department of Plant Biology, Rutgers Unive*rsity) -- Improving the Detection and Quantification of Current Diseases and Discovering Emerging Diseases in Turfgrass in New Jersey
9:30 - 9:50	**Pingyuan Zhang** (*Department of Plant Biology, Rutgers University*) – Impact of Host Susceptibility and Autumn Fungicide Applications on the Suppression of Dollar Spot the Following Spring
9:50 - 10:10	**Glen Groben** (*USDA-ARS, Beltsville, MD*) – Fungicide Effects on *Clarireedia jacksonii* Load in Creeping Bentgrass Fairway Turf
10:10 - 10:30 AM	**Discussion and Break**
10:30 - 11:50 AM	**SESSION II: *Technological Advances*** (Moderator: Stacy Bonos)
10:30 – 10:50	**David McCall** (*School of Plant and Environmental Sciences, Virginia Tech)* Reducing Pesticide Use Through Targeted Applications: An Overview of Precision Turfgrass Management
10:50 – 11:10	**Juan Gonzalez** (*Department of Plant Biology, Rutgers University*) – Computer Vision for High Throughput Quantitative Genetics in Sweet Corn
11:10 – 11:50	**KEYNOTE: John Sorochan** (*Department of Plant Sciences*, *University of Tennessee Knoxville*) – Research and Testing focusing on Soccer Field Consistency and Uniformity for World Cup 2026
11:50 – 1:00 PM	**Lunch Break and Poster Session**

1:00 – 1:40 PM	**SESSION III: *Golf and Fine Turf*** (Moderator: James Murphy)
1:00 – 1:20	**Mark LaBarge** (*Department of Plant Biology, Rutgers University*) – Bandon Dunes Golf and Agronomy (2023 Sean M. Pattwell Scholarship)
1:20 – 1:40	**Cole Thompson** (*United States Golf Association – Greens Section*) A Long-Term View of USGA Turfgrass and Environmental Research Priorities
1:40 – 2:00 PM	**Discussion and Break**
2:00 – 3:20 PM	**SESSION IV: *Abiotic and Biotic Stress*** (Moderator: Albrecht Koppenhöfer)
2:00 – 2:20	**William Errickson** (*Agriculture and Natural Resources, Rutgers University*) Novel Rhizobacteria for Promoting Drought Stress Tolerance and Post-Drought Recovery of Creeping Bentgrass
2:20 – 2:40	**Tarikul Islam** (*Department of Entomology, Rutgers University*) – Silicon Fertilization to Induce Resistance to Annual Bluegrass Weevil
2:40 – 3:00	**Christopher Tkach** (*Department of Plant Biology, Rutgers University)* – QTL Map for Anthracnose Disease Severity in an Octoploid Switchgrass Mapping Population
3:00 – 3:20	**Matthew Elmore** (*Department of Plant Biology, Rutgers University*) – Understanding False-Green Kyllinga and Strategies for Integrated Management
3:20 – 3:45 PM	**Discussion Session and Closing Remarks**
3:45 PM	**Social Hour and Poster Session**

PLENARY PRESENTATIONS

Improving the Detection and Quantification of Current Diseases and Discovering Emerging Diseases in Turfgrass in New Jersey

Ming-Yi Chou, Chase Bauberger, Patrick Fardella, Kyle Genova, and Salma Mukhtar

Department of Plant Biology, Rutgers University

Both anecdotal observations and empirical evidence have indicated the continuous shift in turfgrass disease landscapes. Climate change is likely to disrupt the dynamics of current plant-pathogen relationships, challenging existing assumptions regarding climate zones, host species specificity, and disease patterns. It is crucial to rigorously re-examine known diseases and look out for new ones to avoid false assumptions that could lead to mismanagement and pandemics.
In 2023, fungal pathogen *Phialocephala bamuru*, previously found causing fairway patch disease on bermudagrass (*Cynodon dactylon*) and kikuyugrass (*Pennisetum clandestinum*) in Australia, was discovered in Noth Brunswick, New Jersey causing root rot disease on hard fescue (*Festuca brevipila*). In the same year, 18 turfgrass samples showed root disease symptoms underwent comprehensive fungal isolation using non-selective media to verify the causal agent. The isolation results revealed that the roots in 6 out of 18 samples were dominated by fungus *Slopeiomyces cylindrosporus* and its pathogenicity was validated with Koch's postulate. In order to efficiently survey the distribution and gauge the importance of these pathogens, PCR primer sets were developed to specifically detect *Phialocephala bamuru* and *Slopeiomyces cylindrosporus*, respectively.

In addition to detecting emerging pathogens, decision support tool for turfgrass disease management programming based on common cool-season foliar pathogens quantification using digital PCR (dPCR) is currently under development. This multiplexed dPCR assay will also quantify plant genetic marker so that samples collected across time and space can be effectively compared using plant genetic marker quantity as a baseline. This assay is expected to be optimized in the 2024 growing season and potentially provided as a pilot service for the turfgrass managers in New Jersey and the Northeast in year 2025.

Impact of Host Susceptibility and Autumn Fungicide Applications on the Suppression of Dollar Spot the Following Spring

Pingyuan Zhang[1], Glen Groben [2,3], Patrick Fardella[1], Bruce Clarke[1], James Murphy[1]

[1] *Department of Plant Biology, Rutgers Universtiy*

[2] *United States Department of Agriculture, Agricultural Research Service, Foreign Disease/Weed Science Research Unit, Frederick, MD*

[3] *Oak Ridge Institute for Science and Education, Agricultural Research Service Research Participation Program, Oak Ridge, TN*

Anecdotal observations suggest that autumn-applied fungicide can reduce dollar spot the subsequent growing season. However, the optimal timing of autumn-applied fungicides and possible interactions with cultivars varying in resistance to dollar spot are unclear. Two trials were seeded in 2021 and 2022 and managed as a fairway turf at a mowing height of 9.5-mm. Twelve autumn fungicide levels and three creeping bentgrass (*Agrostis stolonifera* L.) cultivars ('Coho', '007', and 'Independence', in order of decreasing resistance to dollar spot) were evaluated for the suppression of dollar spot the subsequent season in a factorially arranged randomized complete block design with four replications. Seven calendar-based fungicide timing levels were applied using a tank mix of fluazinam and propiconazole (0.7 kg a.i. and 1.5 kg a.i. per ha, respectively) either once (three timings), twice (three timings), or thrice (one timing) in September, October and/or November. The eighth fungicide level was a calendar-based timing of chlorothalonil (15.3 kg a.i. per ha) applied thrice. The ninth and tenth fungicide levels were two weather dependent (Smith-Kerns model) timings of the fungicide tank mix applied when the risk index reached 20 or 40%. The eleventh fungicide level was a damage threshold-based application of the fungicide tank mix when dollar spot damage reached 105 mm^2 m^{-2} and the twelfth level was a non-treated control. Disease onset was recorded for each plot and the number of days between the first observance of disease in the entire trial and the appearance of disease onset in each plot was calculated. Dollar spot severity during the onset period was measured as the area under disease progress curve (AUDPC) from the first date of disease onset on any plot through the date when disease was evident on all plots. Disease onset and AUPDC during the onset period were strongly influenced by the cultivar factor, which interacted with the fungicide and year factors. The latest disease onset occurred on Coho creeping bentgrass regardless of the autumn fungicide level or year. There was a limited delay in disease onset among autumn fungicide levels during 2022; however, some fungicide levels significantly delayed onset on 007 and Independence creeping bentgrass compared to the non-treated control during 2023. The lowest disease severity (AUDPC) during the onset period was observed on Coho and, therefore, there was little effect among autumn fungicide levels on this cultivar. Conversely, several autumn fungicide levels suppressed AUDPC on 007 and Independence creeping bentgrass; the sequential application of the tank mix in September and October was always among the autumn fungicide levels with the best suppression of disease in both years. Sequential applications of chlorothalonil in September, October and November had no or limited effect on AUDPC in both years indicating that fungicide chemistry is a factor needing further evaluation. These results indicate that the adoption of disease resistant cultivars is a management option with great potential for reducing fungicide inputs.

Fungicide Effects on *Clarireedia jacksonii* Load in Creeping Bentgrass Fairway Turf

Glen Groben[1,2], Pingyuan Zhang[3], Patrick Fardella[3], Bruce Clarke[3], James Murphy[3], Ning Zhang[3,4]

[1] United States Department of Agriculture, Agricultural Research Service, Foreign Disease/Weed Science Research Unit, Frederick, MD
[2] Oak Ridge Institute for Science and Education, Agricultural Research Service Research Participation Program, Oak Ridge, TN
[3] Department of Plant Biology, Rutgers University
[4] Department of Biochemistry and Microbiology, Rutgers University

Clarireedia jacksonii causes dollar spot disease of turfgrasses. Dollar spot is one of the most economically important turfgrass diseases requiring numerous fungicide applications to obtain control during the growing season. Previous research has shown that fungicide applications in autumn delayed disease onset and reduced disease severity the following spring.
Previously, we developed a qPCR assay that can quantify the concentration of *Clarireedia* in asymptomatic and symptomatic turfgrass tissue. A series of epidemiological studies utilizing the qPCR assay were conducted proving that *Clarireedia* is randomly distributed in the field, foliar tissue has the highest *Clarireedia* concentration, *Clarireedia* development is inhibited more by tolerant than susceptible cultivars, and *Clarireedia* is an endophyte that causes latent infections that are not visually expressed until environmental conditions are conducive for symptom development.

A two-year study was designed to investigate the effects of cultivar and late-season fungicide treatment on dollar spot development on creeping bentgrass (*Agrostis stolonifera* L.) the following spring. Two trials were seeded in 2021 and 2022 and managed as a fairway turf at a mowing height of 9.5-mm. Twelve autumn fungicide levels and three creeping bentgrass cultivars (‘Coho’, ‘007’, and ‘Independence’, in order of decreasing tolerance to dollar spot) were evaluated for the suppression of dollar spot the subsequent season in a factorially arranged randomized complete block design with four replications. Seven calendar-based timing levels were applied as a tank mix of fluazinam (0.7 kg a.i. per ha) and propiconazole (1.5 kg a.i. per ha) either once (three timings), twice (three timings), or thrice (one timing) in September, October and/or November. The eighth fungicide level was a calendar-based timing of chlorothalonil (15.3 kg a.i. per ha) applied thrice. The ninth and tenth fungicide levels were two weather dependent (Smith-Kerns model) timings of the fungicide tank mix applied when the risk index reached 20 or 40%. The eleventh fungicide level was a damage threshold-based application of the fungicide tank mix when dollar spot damage reached 105 mm^2 m^{-2} and the twelfth level was a non-treated control.

This was a joint study with Pingyuan Zhang who’s research focused on the visual disease onset and severity, while this study used the qPCR dollar spot assay to quantify the *Clarireedia* load (population) two weeks after the last fungicide application in late-November and the following spring in mid-May before dollar spot symptoms appeared.

The results consistently showed that cultivar and fungicide treatment significantly altered the pathogen load. In each sampling, the most susceptible cultivar ‘Independence’ had the highest pathogen load. Moreover, the sequential fungicide application timed in September and October was always among the treatments with the lowest pathogen load. Pearson correlation of qPCR cycle threshold (Ct) values and disease onset for all plots indicated a weak correlation the first year of the study, while the second year showed a moderate to strong correlation. Correlations were moderate to strong for autumn 2021, autumn 2022, and spring 2023 Ct values with disease severity reported as area under the disease progress curve (AUDPC) during the onset period. Spring 2022 Ct values and AUDPC were not significantly correlated. One possible explanation why spring 2022 Ct values did not correlate with AUDPC is that we collected a reduced amount of clippings in spring 2022 compared to the other sampling dates, which may have resulted in a non-representative sampling for the pathogen in spring 2022. Overall, the qPCR assay was able to quantify pathogen load and detect significant differences in load among cultivars and late-season fungicide treatments before symptoms appeared in the field the following spring. The results indicate that autumn applied fungicides reduce the pathogen load in disease susceptible cultivars resulting in delayed disease onset and reduced disease severity.

Reducing Pesticide Use Through Targeted Applications: An Overview of Precision Turfgrass Management

David McCall, Ph.D.

School of Plant and Environmental Sciences, Virginia Tech

Professional turfgrass management has an estimated $60 billion-dollar annual economic impact in the United States across industry segments. My role as an Extension Turfgrass Pathologist is to provide practical and responsible disease management solutions to these industry stakeholders, including golf course superintendents, sports field managers, lawn care operators, and sod producers. One pillar of responsible disease management is through the judicious use of pesticides. While the distribution of pests across turfgrass systems is non-uniform, management of these pests are typically treated as if they are by applying broadcast chemical applications. Shifting philosophies of turfgrass professionals from broadcast pesticide applications towards only targeting a particular pest is a complex process. Members of my lab have spent the last decade developing adoptable strategies for targeted pesticide applications on golf courses and recreational fields. The implementation of agricultural technologies has increased over time from manual pest mapping and treatment as a proof-of-concept to automated pest detection using aerial image analysis with machine learning and GPS-guided pesticide applications with individual nozzle control. Our lab has developed strategies to reduce fungicide inputs by as much as 80% for spring dead spot of bermudagrass, a common disease on golf courses and athletic fields, without compromising efficacy. This success has inspired our lab to map other pests and abiotic stresses for targeted applications. Despite these successes, adoption by industry professionals is still low. To address this low adoption rate, we have engaged industry stakeholders through surveys, hands-on demonstrations, and focus groups with both users and non-users to improve the human-technology interface. Our engagement has led to a better understanding of the barriers to adoption, including high perceived implementation costs without a clearly defined return on investment, a lack of knowledge and/or understanding of the technologies, and concerns over application accuracy. To address these concerns, our lab is currently quantifying the accuracy and precision of targeted applications, as well as expanding the opportunities of precision turfgrass management with mapping and suppressing other key turfgrass pests or abiotic stressors. Increasing stakeholder implementation through continued involvement is currently a high priority for members of my lab to ensure widespread adoption of targeted applications across turfgrass systems.

Computer Vision for High Throughput Quantitative Genetics in Sweet Corn

Juan Manuel Gonzalez

Department of Plant Biology, Rutgers University

Fresh market sweet corn is a crop that depends on the size, color, and shape of its ears for its value. However, other agronomic traits, such as fungal disease resistance, are also important for its production. In the context of fresh market sweet corn, the ear's architecture is crucial for marketability, impacting producers, distributors, and consumers. Particularly in subtropical regions, resistance to Southern Corn Leaf Blight is vital due to high disease pressure and the unsustainability of conventional chemical controls.

To address these challenges, we have developed computer vision-based tools for quantitative phenotyping of ear architecture and disease resistance. These tools, built using open-source Python and OpenCV, enable the measurement of fungal diseases and quality traits in sweet corn using photographs. EarCV, functions effectively under various conditions, measuring ear dimensions and characteristics like tip fill and color. It can adapt to different backgrounds and lighting situations and categorizes ears according to USDA quality grades. It is versatile, handling any number of ears and tolerating some level of debris. Another tool, LeafCV, quantifies diseased leaf area, specifically identifying leaf blight lesions from healthy leaf sections. These innovations improve the accuracy and efficiency of phenotyping, providing a high-throughput, quantitative approach to traits traditionally measured qualitatively.

We have applied these computer vision tools to phenotypically characterize a diverse population of sweet corn. By combining this phenomic data with corresponding genomic data, we conducted a comprehensive quantitative genetic analysis. This included genome-wide association analysis and genomic selection analysis based on traits identified using our computer vision tools, some of which had never before been directly measured such as tip fill. The results of these analyses are instrumental in enhancing breeding strategies for complex traits in sweet corn. They help in identifying superior inbred lines, understanding inheritance patterns and genetic correlations, dissecting the genetic architecture, and developing predictive models for key traits.

In light of our findings regarding high-throughput phenotyping and quantitative genetics in sweet corn, we examine how these methodologies could be adapted and applied in the context of turfgrass breeding. This consideration is pivotal for exploring how similar strategies might accelerate genetic gain in a turfgrass breeding program.

Research and Testing Focusing on Soccer Field Consistency and Uniformity for World Cup 2026

John Sorochan, Ph.D.

University of Tennessee

The upcoming 2026 FIFA Men's World Cup, set to be hosted across the United States, Canada, and Mexico, promises to be the grandest edition yet. With an expansion to 48 participating countries and a staggering 104 matches scheduled—marking a significant increase from previous tournaments—the scale of this event is unprecedented. Spanning 16 host cities, ranging from the heights of Mexico City's 9,500 ft elevation to the sea-level enclosure of Vancouver's indoor stadium, the logistical challenges are immense.

Among these challenges is the mandate from FIFA for natural grass playing surfaces, presenting a unique opportunity for the University of Tennessee (UT) and Michigan State University (MSU) to spearhead research ensuring consistent playing conditions across all venues. From exploring sod production techniques to pioneering hybrid reinforced playing systems, and even experimenting with LED grow lights for indoor grass management, the collaborative efforts between UT and MSU have been extensive, with 74 research trials conducted since 2021.

Moreover, the World Cup necessitates not only the 16 host stadiums but also an additional 49 base camps and 178 total fields for training and practice, underscoring the critical need for uniformity and consistency in playing surface quality. This encompasses various factors such as ball-to-surface interactions, athlete traction, and maintaining field conditions over the duration of multiple matches.

The primary research areas of emphasis encompass turfgrass establishment, stadium floor construction/renovation, pitch installation, and turfgrass management. Numerous stadiums are not primarily designed for soccer or having natural grass, necessitating the provision of temporary turf systems for half of these stadiums, including the five domed structures.

Beyond the technical advancements, one of the most significant outcomes of this research collaboration is the invaluable opportunity it provides for undergraduate and graduate students to engage in sports turf research at the highest level. From collecting baseline data at prominent stadiums across the host nations to conducting trials in challenging environments like Mexico City's high altitude, students are actively contributing to the advancement of sports turf science in preparation for the world's most prestigious football event.

Bandon Dunes Golf and Agronomy (2023 Sean M. Pattwell Scholarship)

Mark LaBarge

Department of Plant Biology, Rutgers University

The Sean M. Pattwell Turfgrass Award supports graduate students at Rutgers University in the turfgrass field by providing an opportunity to study and engage in turfgrass management during a summer internship at Bandon Dunes Golf Resort (Bandon, OR). Bandon Dunes was founded by Mr. Mike Keiser and opened in 1999 with the construction of the Bandon Dunes course. It is a public golf resort and features some of the only "true" links golf courses in the United States. The resort has expanded since 1999 to include 6 golf courses: Bandon Dunes, Pacific Dunes, Bandon Trails, Old MacDonald, Bandon Preserve, and Sheep Ranch, with the ongoing construction of a 7^{th} course (Shorty's).

The management style for these links courses differs from typical parkland golf course maintenance as would be seen in New Jersey. The preferred management style is low maintenance. Some basic management practices include mowing, topdressing, spraying, divot repair, hand-raking bunkers, and irrigation. The goal of links golf management is to achieve a playable course while still maintaining the natural aesthetic of the land. Bandon Dunes agronomy does an exceptional job in highlighting the course layout and natural beauty of the Oregon coast while also maintaining a superb links style playing surface that is hard and fast. Interning at Bandon Dunes provided insight into a completely different management style and course environment than golf courses in New Jersey. In addition, golfing at Bandon Dunes also provided insight into why golf course maintenance and management is so pivotal to the experience of a golfer. Playing the courses at Bandon Dunes allows a turfgrass manager to see the course from the perspective of a golfer. This is extremely useful when making decisions on maintenance practices as a turfgrass manager. This unique graduate student internship provided an unparalleled experience that will be carried throughout my career in turfgrass science.

A Long-Term View of USGA Turfgrass and Environmental Research Priorities

Cole Thompson

USGA – Turfgrass and Environmental Research

The USGA has invested more than $50 million in turfgrass research, which has advanced, among other things, putting green construction, turfgrass breeding, landscape naturalization, and water, fertilizer, and pesticide management. The grasses and management practices developed through this funding have been broadly adopted and provide an estimated $2 billion annual benefit to the golf industry. Golf course superintendents consider labor availability, weather-related challenges, budget limitations, and golfer expectations to be among their largest maintenance challenges. As such, the USGA intends to continue to invest in research that will optimize sustainable golf course management and playing conditions, conserve and protect water resources, identify and develop novel and resource-efficient plant materials, and develop metrics to better quantify how golf course management considerations affect golfer experience. Additionally, there is a broad opportunity to better demonstrate the ways that turfgrass research investment benefits end-users and communities, which will require engaging new audiences, technologies, and partners for maximum benefit.

Novel Rhizobacteria for Promoting Drought Stress Tolerance and Post-Drought Recovery of Creeping Bentgrass

William Errickson[1], Bingru Huang[2], Ning Zhang[2]

[1]*Agriculture and Natural Resources, Rutgers University*
[2]*Department of Plant Biology, Rutgers University*

Sustainable approaches to improving plant and soil health while reducing inputs of water and nutrients are of great value for turfgrass management. Summer decline and abiotic stress are major problems that result in premature leaf senescence and overall reductions in turf quality. Unpredictable growing seasons exacerbated by climate change further compound the challenges of sustainable turfgrass management. Plant growth promoting rhizobacteria (PGPR) may offer a potential solution to improving the performance of turf under abiotic stress conditions, while reducing inputs of water and fertilizer. PGPR are microorganisms that form beneficial symbiotic relationships with the roots of plants. Some PGPR contain deaminase enzymes (ACC-deaminase) that breakdown the precursor of ethylene, 1-aminocyclopropane-1-carboxylic acid (ACC). The bacteria use the ACC produced from plants as the nitrogen source, resulting in the reduction or removal of stress-induced ethylene from the host plant. Because ethylene is produced in response to stress and can lead to premature leaf senescence and reductions in root growth, incorporating ACC-deaminase PGPR in turfgrass management may be a sustainable approach to improve plant health by improving plant tolerance to abiotic stress. However, the effectiveness of those rhizobacteria for promoting turfgrass tolerance to abiotic stress and water conservation and the underlying physiological mechanisms are not well documented.

The objective of this study was to investigate the effects of endophytic bacteria (*Paraburkholderia aspalathi*) with ACC-deaminase enzymes in suppressing ethylene production on plant tolerance to drought stress and post-stress recovery and the underlying physiological mechanisms of *P. aspalathi*-regulation in creeping bentgrass (*Agrostis stolonifera* L.). A novel strain of *P. aspalathi,* 'WSF23', with ACC deaminase activity was used to inoculate the roots of creeping bentgrass plants (cv. 'Penncross') subjected to drought stress for 35 days and re-watered for 15 days (post-stress recovery) in controlled-environment growth chambers. Inoculation with 'WSF23' bacteria resulted in an increased number of tillers, tillering production rate, root viability, and root growth (quantified in length, surface area, volume, and dry weight) during drought stress or re-watering. Inoculation of plants with 'WSF23' bacteria increased cytokinin (CK) (c-Zeatin and tZ-riboside) and jasmonate (JA-Ile) content and reduced ACC and abscisic acid (ABA) content in roots during drought or re-watering. Sugar accumulation in crowns was promoted by inoculation during drought stress. The differential changes in ACC, CK, ABA, and JA-Ile and sugar accumulation due to the bacterial inoculation could contribute to ACC deamination bacteria-improved drought tolerance and post-stress recovery in terms of tiller production and root proliferation and elongation in creeping bentgrass.

Silicon Fertilization to Induce Resistance to Annual Bluegrass Weevil

Tarikul Islam [1], Ana Luiza Sousa [2], Matthew S. Brown [1], Joseph R. Heckman [3], Albrecht M. Koppenhöfer [1]

[1] *Dept. of Entomology, Rutgers University*
[2] *Syngenta Seeds Development – R&D Innovation Center, Malta, IL*
[3] *Dept. of Plant Biology, Rutgers University*

The annual bluegrass weevil (ABW), *Listronotus maculicollis*, is a major pest of short-mown turf on golf courses across the eastern United States and southeastern Canada. ABW poses significant management challenges, particularly due to its resistance to many conventional insecticides. Silicon (Si) fertilization has been consistently shown to enhance plant resistance to insect herbivores, specifically in grasses, as they can accumulate high levels of Si in tissues. Si is taken up by plants as monosilisic acid and is deposited in tissues as amorphous silica gel or phytoliths ($SiO_2.H_2O$). Si deposition confers physical resistance to insect herbivores, as siliceous tissues are tougher and abrasive, and thus harder for insects to consume and digest. Insect herbivores can experience mandibular wear, stunted growth and weakened immunity when feeding on Si-supplemented plants. Although the negative effects of Si against lepidopteran larvae are well-documented, how Si impacts coleopteran feeders such as ABW remains uncertain. Furthermore, we have limited understanding of how feeding on Si-supplemented plants affects insect susceptibility to biocontrol agents including entomopathogenic nematodes. We conducted glasshouse and field experiments to examine how Si supply to annual bluegrass and creeping bentgrass impacts ABW survival and development and its susceptibility to the entomopathogenic nematode *Steinernema carpocapsae*. Greenhouse experiments revealed that Si fertilization suppressed ABW performance more strongly on creeping bentgrass compared to annual bluegrass. Si reduced ABW egg-laying by 12-37% and larval density by 0-35% in annual bluegrass with no effect on the development speed of larvae. Conversely, in creeping bentgrass, Si fertilization reduced egg-laying by 22-37% and larval density by 68-85% with a retardation in larval development. In field trials, Si supplementation increased Si concentrations in leaf tissues of both grass species, with mean concentrations rising from 0.37-0.47% in control plots to 1.54–2.48% in Si-treated plots. While ABW population density in the field was higher in annual bluegrass relative to creeping bentgrass, the effect of Si on ABW performance was inconclusive. Our data so far suggest that Si fertilization has a strong negative effect on ABW when feeding on creeping bentgrass compared to annual bluegrass. Thus, Si fertilization could provide a competitive advantage to creeping bentgrass over annual bluegrass in mixed annual bluegrass-creeping bentgrass fairways when challenged by ABW.

QTL Mapping of Anthracnose Disease Severity in an Octoploid Switchgrass Mapping Population

Christopher Tkach[1], Christine Kubik[1], Jennifer Vaiciunas[1], Joshua Honig[1], John E. Carlson[2], Stacy Bonos[1]

[1]Department of Plant Biology, Rutgers University
[2]Penn State University

Switchgrass (*Panicum virgatum*) has been identified as a model bioenergy crop by the US Department of Energy due to its potential for high biomass yields and its wide range of adaptability throughout the United States. A major roadblock to the widespread use of switchgrass in the Northeastern US is the prevalence of anthracnose disease caused by the fungal pathogen, *Colletotrichum navitas*. To overcome this challenge quantitative trait loci (QTL) map-based approach was carried out using a switchgrass mapping population consisting of 202 full-sib progeny that segregate for anthracnose infection severity. This population was developed previously as part of the Northeast Woody/Warm-season Biomass (NEWBio) Consortium project. This population has been screened for severity of anthracnose disease ratings and growth parameters during six separate growing seasons (2014, 2015, 2019, 2020, 2021 and 2022). Preliminary data collected during these years indicate that the mapping population approaches a normal frequency distribution in disease response, as would be expected. Best linear unbiased predictions were calculated using the lme4 package in R and anthracnose disease severity was found to have an estimated broad sense heritability of ~71%. Using a genotyping by sequencing approach, small nucleotide polymorphisms (SNPs) were identified using Stacks and allele dosage for each SNP was then subsequently estimated using polyRAD to obtain polyploid genotype calls. A total of 4,129 SNP markers were mapped to 19 linkage groups using the MAPpoly R package, resulting in a cumulative length of 1907.6 cM and an average of 2.08 SNP markers per cM. The R package, QTLpoly was used to build multiple QTL model. QTL mapping identified two significant QTL for anthracnose disease severity. A significant QTL was identified on chromosome 8K which accounts for ~20% of the phenotypic variation and a second QTL was identified on chromosome 1K that accounts for ~ 16% of the variation observed. The identification of these QTLs serves to improve our understanding of anthracnose disease resistance and can be used as an aid in the generation of improved, anthracnose disease-resistant cultivars that will be well suited for biomass production in the northeastern United States.

Understanding False-Green Kyllinga and Strategies for Integrated Management

Matthew T. Elmore, Trevor S. Watson, Daniel P. Tuck

Department of Plant Biology, Rutgers University

False-green kyllinga (*Kyllinga gracillima*) is a problematic warm-season weed in the Cyperaceae family. Previous research provided guidance on postemergence herbicide use for practitioners but has not addressed other factors important for integrated management. Experiments were conducted to 1) investigate the potential for false-green kyllinga to establish from seed in turfgrass and 2) investigate the efficacy of various preemergence herbicides for false-green kyllinga control.

The first experiment was field experiment replicated in time at Hort Farm No. 2 in North Brunswick, NJ. False-green kyllinga was seeded at 5 and 500 kg ha^{-1} into kyllinga-free Kentucky bluegrass managed under high and low intensity. Smooth crabgrass was also seeded at 500 kg ha^{-1} for comparison. False-green kyllinga establishment from seed was influenced more by turfgrass management intensity than smooth crabgrass. Smooth crabgrass cover in August 2021 was 91 and 75% under low and high management intensity, respectively, whereas FGK seeded at 500 kg ha^{-1} resulted in 73 and 8% cover. False-green kyllinga established less successfully at the 5 kg ha^{-1} rate, resulting in 1 and 11% cover under low and high management intensity, respectively. When this experiment was repeated in 2022, results were similar, although the effect of turfgrass management regimen was less intense. These experiments indicate false-green kyllinga can establish in turfgrass from seed and that establishment from seed is reduced by a dense sward of turfgrass more than smooth crabgrass. It also suggests seed are the primary mechanism by which false-green kyllinga spreads across large distances.

Since false-green kyllinga can establish from seed, greenhouse experiments were conducted to evaluate preemergence herbicides to control establishment from seed. Twelve herbicides were evaluated in a preliminary efficacy screen at 10 and 100% of typical use rates to control smooth crabgrass and false-green kyllinga from seed. Corn gluten meal, dithiopyr, pendimethalin, methiozolin, and siduron were less effective against false-green kyllinga than smooth crabgrass. Oxadiazon, dimethenamid, and bensulide were equally effective against false-green kyllinga and smooth crabgrass. This preliminary screen indicated a more detailed dose-response experiment was warranted to better understand the efficacy of pendimethalin, dithiopyr, prodiamine, oxadiazon, bensulide, and dimethenamid. These herbicides were evaluated at 100, 50, 25, 12.5, 6.3 and 3.1% of typical use rates. Non-linear regression was used to evaluate efficacy. Oxadiazon, bensulide, and dimethenamid were more effective against false-green kyllinga than pendimethalin, dithiopyr, prodiamine. Practitioners typically rely exclusively on pendimethalin, dithiopyr, or prodiamine for preemergence weed control in turfgrass and this research found limited efficacy of these preemergence herbicides against false-green kyllinga. This suggests preemergence herbicide selection is another reason false-green kyllinga is a prolific weed of cool-season turfgrass.

POSTER PRESENTATIONS

Regulation of Carbon Balance Using Biochemicals to Improve Heat Tolerance in Creeping Bentgrass

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Heat stress, especially high night temperature (HNT) is a primary factor limiting cool-season turfgrass growth, which is associated with the interruption of carbon balance in photosynthesis and respiration. The objective of this study was to determine whether foliar application of respiration inhibitors may mitigate the effect of high-temperature stress by regulating carbon balance due to changes in photosynthesis and respiration rate for creeping bentgrass. Plants were maintained in an environmentally controlled growth chamber under non-stress (22/17 ºC day/night) conditions for 7 days and then (35/35 ºC day/night) temperature conditions for 35 days. Plants were foliar sprayed with 10 organic chemicals of different concentrations during heat stress at 7-day intervals and 6 out of these have shown promising results in improving heat tolerance. Respiration inhibitors were effective in improving turf quality and suppressing the ratio of leaf respiration rate to photosynthetic rate. The results suggested that plant heat tolerance could be improved by reducing carbohydrate consumption in the process of respiration relative to carbohydrate production from photosynthesis.

The Golf Course Pest, Annual Bluegrass weevil, Operates as a Beneficial Control Agent of *Poa annua* at Reduced Weed Cover

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The annual bluegrass weevil (ABW) is a destructive golf course pest. Creeping bentgrass is a common turfgrass grown on golf courses, though *Poa annua*, a persistent weed, often makes up 50% or more of the turf. ABW prefers to oviposit on *P. annua,* whereas creeping bentgrass can tolerate 3–4 times higher larval densities. Reducing insecticide applications targeted at ABW can allow ABW to preferentially damage *P. annua*, leading to the replacement of *P. annua* by creeping bentgrass in mixed stands. However, encouraging extensive ABW damage to *P. annua* can reduce turfgrass quality to unacceptable levels. The level of *P. annua* cover in the turfgrass is a primary factor influencing the decline in turfgrass quality and, therefore, the viability of using ABW to control *P. annua*. Therefore, we conducted field experiments to study the impact of *P. annua* coverage on the viability of using ABW to control *P. annua* without unacceptable declines in turfgrass quality. We evaluated the effect of three insecticide programs (no-insecticide, threshold, and preventive) at four percentages of initial *P. annua* cover (0%, 10%, 25%, and 50%) on *P. annua* cover and turfgrass quality over two years in 2021–2022 and 2022–2023. *Poa annua* coverage declined in spring when ABW damage was most severe, especially at higher *P. annua* cover. ABW damage led to a brief decline (< four weeks) in turfgrass quality when turfgrass consisted of more *P. annua*. The no-insecticide and threshold programs reduced *P. annua* cover in 2022 and 2023 but not 2021, indicating that ABW can provide control of *P. annua*. Due to increased ABW damage, the no-insecticide and threshold programs caused a limited and temporary decline in turfgrass quality. When turfgrass has higher levels of *P. annua* cover, ABW damage may reach unacceptable levels. Therefore, combining a threshold-based program with a plant growth regulator to control *P. annua* may be necessary to limit unacceptable declines in turfgrass quality when turfgrass consists of > 30% *P. annua*.

Optimization of Hazelnut Harvesting for Farms in New Jersey

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In 2020, four eastern filbert blight-resistant hazelnut cultivars were released from Rutgers University (Raritan, Monmouth, Hunterdon, and Somerset) and one from our Hybrid Hazelnut Consortium partners (OSU 541.147 "The Beast"), which are now available from nurseries. Sales data shared from licensed nurseries indicate ~150 acres have been planted between 2021-2023 with an additional 50 acres expected in 2024 based on pre-order sales. As New Jersey farmers are now planting hazelnut trees in commercial orchards with significant nut production expected in 2-3 years, options for harvesting the nuts must be considered. In support of our local hazelnut industry, we have been investigating mechanical harvesting machines to help inform our growers of available options. Currently in the U.S., commercial production is done in the Willamette Valley of Oregon at very large scale (100 to 500+ acre scale per farm), which is in stark contrast to the small, diversified farms now planting hazelnuts in New Jersey. Here, 1–5-acre orchards are currently the norm. Thus, the size and scale of the machines used to harvest nuts in Oregon are too large for small orchards and crops in New Jersey. Fortunately, small-scale equipment exists in Italy and Turkey, and two machines were acquired for testing. Furthermore, a small-scale pecan harvester was identified from a manufacturer in Georgia (U.S.) that looked promising for use with hazelnuts and warranted testing. Here we describe preliminary observations from field trials in 2021-2023, which we are using to optimize operating protocols for these three harvesting machines to share with New Jersey growers.

The mechanical harvesters under test include the Chianchia K530 vacuum harvester (Italian), Hasatsan 2200 vacuum harvester (Turkish), and the Savage 8042 pull-behind sweeper-style harvester (U.S.). These three machines represent two different harvesting approaches. Vacuum-style harvesters require hand movement of a vacuum tube to suck nuts directly from the orchard floor. This is a strenuous activity, and its effectiveness depends heavily on orchard floor preparation and the consolidation of the hazelnuts through blowers into rows or piles. A sweeper-style machine is driven across the orchard where rubber "fingers" move nuts from the orchard floor up into the harvesting mechanism. As such, this machine requires less physical effort for harvest and nuts do not need to be consolidated into piles; however, they do need to be blown out from under the trees into the orchard roadway areas to be placed into the path of the machine's harvesting mechanism. All three machines were found to present a very significant labor savings over harvesting by hand, which requires picking nuts from the trees or from the orchard floor after they have fallen. However, there were significant differences between the machines that may present options to fit different production situations and budgets. Descriptions of the models are presented.

The Chianchia K530, the least expensive model and one able to be powered by a relatively small tractor (Kubota B2320 ~25 HP), has a single vacuum hose capacity with a maximum reach of ~10 m. In our tests, while it was effective at harvesting the nuts from the orchard floor much faster than by hand, it was found to be under-powered in many situations. We found the vacuum hose frequently became clogged when too many nuts were sucked in at once or when orchard floor debris was present (sticks, leaves, etc.). This slowed harvest rates and required time taken away from harvest to clear the jammed vacuum hose. The machine also lacked a cleaning stage, which requires a later debris separation step. Despite the power issues, operation could be done by one person safely; however, its short vacuum tube it requires moving the tractor frequently.

In contrast to the Chianchia K530, the Hasatsan 2200 is much larger and more powerful and could handle movement of large piles of nuts with little propensity for clogging, even in the presence of orchard floor debris. It has a cleaning stage that removes nut husks and various debris, leaving behind very clean nuts. It can also run two vacuum hoses at once up to 20 m each, more than doubling its capacity over the Chianchia K530 machine and allowing the machine to stay stationary for longer. However, it is a more expensive machine than the K530 and requires a large tractor (minimum 55 PTO HP) to power it, with additional maintenance due to its size and increased complexity. Its use was most effective with two harvesters and one tractor operator who also helped rotate storage bags. Operation requires at least two people.

The final machine was the Savage 8042 pull-behind, sweeper-style harvester. This machine was the most expensive of the three, but is self-powered and can be towed behind a variety of vehicles including a golf cart or 4-wheeler, potentially reducing overall equipment expenses/needs. We found that grass covered areas were required for harvest as it struggled to pick up nuts from bare orchard floor areas; nuts need to be blown into the turf areas of the orchard. Also, it lacks a cleaning mechanism, necessitating a separate cleaning stage to remove orchard debris. It requires relatively little physical labor when compared with either of the vacuum style devices, supporting its use by a wider range of people.

In summary, we have found that the three harvesters provide a significant advantage over harvesting by hand. The lower power of the Chianchia K530 and its related lower rate of harvest compared to the Hasatsan 2200 reduced its utility under our production setting where we harvest ~10 acres of trees. But for growers who have a smaller orchard or do not have access to a 50 hp tractor, a significant expense on its own, the Chianchia K530 might provide a useful option. The Savage 8042 stood out for its ease of use and provides an advantage where the physical labor required for harvest is reduced. However, it needs a well-prepared orchard floor and an extra cleaning stage after harvest that is not needed by the Hasatsan 2200. If fact, we ran the nuts collected by the Savage 8042 through the Hasatsan machine for cleaning prior to processing. Ultimately, we found having access to the two machines is very helpful and allows flexibility for harvesting approaches.

Goosegrass (*Eleusine indica*) Competition in Turfgrass Affected by Ecotype and Cultural Management Practices

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Goosegrass (*Eleusine indica*) is a diverse species, many ecotypes have evolved herbicide resistance and can be difficult to control, especially on golf courses reliant on chemical control. Competitiveness of goosegrass ecotypes has not been investigated under turfgrass management regimens.

The objective of this research was to determine effects of mowing height, nitrogen fertilizer, and a plant growth regulator (PGR) on the competitiveness of two different goosegrass ecotypes in a field experiment. Research was conducted on Kentucky bluegrass (*Poa pratensis*), annual bluegrass (*Poa annua*) turf at Rutgers Hort Farm No. 2 (North Brunswick, NJ). The site was mowed weekly to 4.0 cm starting 3 May 2023 and fertilized twice with slow-release fertilizer (25 kg N ha^{-1}) before the start of the experiment. Treatment factors consisted of; 1) PGR and Nitrogen (N) fertilizer program (hereafter referred to as cultural management) 2) goosegrass ecotype and 3) mowing height. Treatments were arranged in 1 by 2 m plots as a strip-plot RCBD, with a whole-plot factors of cultural management (non-treated, N only, PGR only, and N+PGR) and morphologically distinct goosegrass ecotypes (turf-type and ag-type). These treatments were replicated four times and strips of mowing height (2.0 cm and 4.0 cm) were imposed in each block. Mowing height treatments were initiated 16 May 2023 and applied twice weekly until mid-October. Nitrogen treatments (urea 46-0-0; 25 kg N ha^{-1}) and PGR treatments (trinexapac-ethyl; 190 g ai ha^{-1}) were applied every 21 days (19 May, 8 June, 29 June, 20 July, 14 August and 4 September) using standard small plot spray equipment. N was applied first and irrigated in immediately after application; PGR treatments were not irrigated. Goosegrass ecotype treatments were innitiated on 10 July 2023, when 20 leaf-stage seedlings from each ecotype were transplanted into field plots in two rows on 13 cm inter-row spacing.

Goosegrass tillers on each plant were counted one and three wks after transplanting (WAT). The number of surviving goosegrass plants in each plot was counted 2, 4, 6, 8 and 10 WAT. Goosegrass cover was evaluated visually and determined by grid intersect at 6 and 8 WAT. On 28 September, at 10 WAT, total aboveground goosegrass biomass was harvested. Data were analyzed in SAS (v 9.4) as a strip-plot RCBD and Fisher's protected LSD test (α=0.05) to separate means.

Interactions between cultural management program (N and PGR treatments) and ecotype were detected in goosegrass cover and biomass data on each date. Mowing height had no effect on goosegrass biomass or cover. In plots not treated with N or PGR, the turf ecotype had more biomass than the ag ecotype (47 g and 6 g, respectively). N alone reduced goosegrass cover and biomass of the turf ecotype by >50% compared to the non-treated, but N treatment did not affect the ag ecotype. PGR treatment increased biomass of both the ag and turf ecotypes by 31% and 549%, respectively, compared to the non-treated, and the turf ecotype treated with PGR alone had the greatest biomass of all treatments (63 g). N+PGR treatment reduced goosegrass biomass by 23% compared to the nontreated for the turf ecotype, but increased biomass of the ag ecotype to 234% of the nontreated. This research shows the PGR trinexapac-ethyl can increase the competitiveness goosegrass in turf, despite having a positive effect on turfgrass density. Trinexapac-ethyl increased the competitiveness of ag ecotypes more than turf ecotypes. Nitrogen treatment reduced goosegrass competitiveness overall, but the magnitude of the effect varied by ecotype. A second run of this experiment will be conducted in summer 2024.

Needs Assessment for Remote Sensing- and Machine Learning-guided Precision Turfgrass Irrigation Programs: Findings from a Socioeconomic Survey

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New technologies including mobile remote sensing and artificial intelligence-guided precision irrigation management (PIM) programs may offer turfgrass managers additional tools to reduce water use and improve turf quality. However, adoption of these new practices may be limited by factors such as startup costs, perceived importance, and the learning curve associated with new technology. This project conducted an industry-wide survey of turfgrass professionals to investigate their current irrigation management strategies, and how likely they may be to adopt new PIM technologies. Survey participants included turfgrass researchers, superintendents, sod farmers, and landscape professionals. One hundred survey responses were received from 15 different states, with New Jersey (32%), Georgia (27%), and New York (16%) having the highest representation.

Survey responses indicated current water use and cost for existing operations, importance ratings of various characteristics associated with PIM and water conservation, and likelihood of adoption based on cost-benefit scenarios. Respondents indicated that the most important factors for conserving water use in their organization were drought or infrequent rainfall, regulations, and water use restrictions. Early detection of biotic and abiotic stress emerged as a primary and practical application for PIM technology. Additionally, while only 18% of respondents were currently using PIM technology, 68% indicated they would be interested in purchasing either PIM devices or an annually renewable PIM service. These findings provide valuable insights that can steer future research, development, training, and education initiatives. This includes the advancement of Extension programs dedicated to turfgrass PIM and the associated decision support systems.

Silage Feed Quality from Organic Lawn Grass Clippings

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Although lawns are recognized as being an amenity for quality of life they are generally viewed as having no agricultural value to feeding humanity. However, with the ability of ruminants to digest grass clippings harvested from lawns there is potential to convert these otherwise nonproductive landscapes into highly desirable foods. Often the same plant species are used for turfgrass or pasture. Allowing livestock to graze home lawns is possible but generally not practical. Leaving clippings on the lawn is encouraged for the purpose of recycling of nutrients in place but it is not always possible. And there are sometimes advantages to occasional clipping removal. With a lawnmower, clippings can be harvested for livestock feed. Making the harvested clippings into a silage is an alternative to using them for composting or garden mulch. The purpose of this study of organic lawn care was to demonstrate feasibility of fermenting fresh lawn clippings into a grass silage that can be stored for long periods and to be used as winter livestock feed and to evaluate the palatability and silage quality by laboratory analysis. In this case study the silage fermentation was performed in plastic bags by air removal with a vacuum. After about 200 days after harvest on 27 May 2020 and 21 June 2021 and storage as fermented feed, silage samples were sent to Cumberland Valley Analytical Services. This study compared organic fertilizer amended plots to an unamended soil. Except for increasing yield with fertilizer, there were no silage quality differences between treatments. Thus, silage quality as presented are means across treatments and years. Silage average Dry Matter (DM) content was 41%, Protein Crude Soluble19%, Acid Detergent Fiber 66%, Ash 9.6%, Total Volatile Fatty Acid 7.7%, Lactic Acid 7.8, Acetic Acid 1%, Propionic and Butyric Acids <1%, pH 4.2, and Net Energy Lactation 1433 calories/kg. The silage analysis demonstrated that lawn clippings when fermented and stored can be an acceptable feed for ruminants. The lawn silage pH was sufficiently acidic, and the other measured indicators are like other more common types of silage. When this lawn clipping silage was offered to goats and cattle, both species readily consumed the feed that they were provide. As with any type of feed the animals should be provided with a balanced diet that may include supplementation and other complimentary feedstuffs. Occasional clipping harvest and removal may be beneficial in terms of nutrient management. Because organic lawns typically rely on natural organic fertilizer materials, they often supply more P than is needed for lawn maintenance. Many New Jersey turf soils already have soil test P levels above the optimum range. Thus, adding more P from organic fertilizers is sometimes not desirable unless a nutrient management plan can be designed to balance P fertilizer inputs with P harvest by clipping removal. This study found that a single harvest of clippings for silage may remove about 10 kg/ha of P from the lawn soil. This study demonstrates that sustainable lawn care can potentially contribute to feeding humanity by employing ruminates to transform clippings into meat and milk.

Turfgrass Performance Evaluation of Bermudagrass and Zoysiagrass in New Jersey

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Warm-season turfgrass, including bermudagrass (*Cynodon* spp.) and zoysiagrass (*Zoysia* spp.), have typically been utilized in the lower transition zone and southern portion of the United States. The plant hardiness zones provided by the USDA have undergone shifts as a result of climate change (USDA 2023). Future projections indicate that hardiness zones will continue to shift northward with annual average minimum temperatures increasing in New Jersey and the transition zone (Whitehead et al, 2023). In addition, heatwaves are projected to be longer and more severe which increases heat stress on turfgrass grown in New Jersey. This projected shift and increase in temperature will potentially further the application and use of cold adapted bermudagrass and zoysiagrass in New Jersey.

Bermudagrass and zoysiagrass selections with proven cold hardiness were vegetatively established (via sprigs) on June 30, 2022 in a randomized complete block design with three replications. The resulting turfgrass trial is being utilized to evaluate the performance of bermudagrass and zoysiagrass grown in New Jersey with regards to establishment rates, fall color retention, winter kill, spring green-up, and turf quality. Visual establishment ratings were evaluated using non-linear regression with a sigmoid variable slope model (Karcher et al, 2008) in GraphPad Prism version 10 (GraphPad Software Inc., La Jolla, CA). All bermudagrass selections established to 90% cover within 100 days after planting. Some zoysiagrass selections were able to establish to 90% cover within 125 days but many took over 125 days and some did not establish at all. Fall color retention, winter kill, spring green-up, and turf quality visual ratings were evaluated with an ANOVA test using SAS 9.4 software (SAS Institute Inc., Cary, NC). Fall color retention was generally higher among the zoysiagrass selections. However, the top 3 zoysiagrass entries for fall color retention also exhibited winter kill of greater than 50%. Four zoysiagrass and five bermudagrass selections showed less than 30% winter kill during the trials first green-up period. The top 4 performers for spring green-up included 2 zoysiagrass and 2 bermudagrass selections. DALZ 1701 zoysiagrass exhibited the best spring green-up being statistically significantly higher than all other entries except for one. Turf quality was generally higher in bermudagrass selections with the highest turf quality seen in Tiftuf (DT-1) over a 2-year period. Among the zoysiagrasses, DALZ 1808 and DALZ 1701 exhibited the highest turf quality. Turf quality decreased among bermudagrasses in the second year of the trial but increased among zoysiagrasses (likely due to lower maintenance practices). These results are being used to make selections of the best bermudagrass and zoysiagrass accessions for future research projects.

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Creeping Bentgrass Cultivar Responses to Simulated Foliar Shade

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Shade stress and the resulting physiological responses are problems for grasses growing underneath. Creeping bentgrass (*Agrostis stolonifera*) a popular turfgrass species, is routinely grown in areas of vegetative shade. The object of this study was to identify traits of interest that differ between bentgrass grown under simulated foliar shade versus full sun. Two greenhouse and two growth chamber studies were carried out using 41 commercial cultivars and experimental selections. Simulated shade was provided by a photoselective film to reduce the red to far-red ratio by ~33%, while decreasing light intensity by ~50%. Height, tiller amount, biomass, and chlorophyll were measured. Height and chlorophyll were significantly different between cultivar and lighting condition across the four studies. Cultivars with a small percent change height were L93XD, 007XL, Oakley, and Piranha. Cultivars with larger changes in chlorophyll were Matchplay and MacDonald. There is significant variation in cultivar response and cultivar choice should be considered when seeding in shaded environments.

Differential Physiological and Metabolic Responses to Heat Stress in Annual Bluegrass (*Poa annua*) and Creeping Bentgrass (*Agrostis stolonifera*)

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Heat stress is a major factor limiting growth of cool-season turfgrass species. Different species vary in their response to heat stress. Annual bluegrass (*Poa annua*) is a cool-season grass species that is characterized to have relatively poor tolerance to heat stress. *P. annua* is commonly found co-present on putting greens with creeping bentgrass (*Agrostis stolonifera*). On these mixed greens heat stress induced summer decline is more severe in *P. annua* and often precedes that of *A. stolonifera*. This results in an uneven putting green surface that is unattractive and affects ball roll. Little is known about the mechanisms governing *P. annua*'s low tolerance to heat stress. The goal of this study is to compare *P. annua* physiological and metabolic responses to the more tolerant *A. stolonifera* and identify significant pathways associated with *P. annua*'s heat susceptibility. *P. annua* and *A. stolonifera* were grown in controlled growth chambers under two temperature treatments: 22/17 °C (day/night) for 42 days (unstressed control) and 35/30 °C for 42 days (heat stressed). Visual turf quality (TQ), percent green canopy cover, and electrolyte leakage (EL) were measured weekly during the study. After 42 days of heat stress, leaf samples were collected and analyzed by LC-MS for metabolite content to compare concentration differences between heat stressed and unstressed control groups. Relative to the control levels, heat stressed *P. annua* exhibited more severe declines in TQ and percent green canopy cover and higher levels of cell membrane EL than *A. stolonifera*. Metabolites were regulated differentially between *P. annua* and *A. stolonifera* after 42 days heat stress relative to control levels, including organic acids, amino acids, and carbohydrates. KEGG analysis identified unique pathways effected in *P. annua* based on the differentially regulated metabolites. These pathways include the downregulation of metabolites within the citric acid cycle, carbon fixation, glycolysis, and pyruvate metabolism, and the upregulation of metabolites involved in branch chained amino acid biosynthesis. The results highlighted in this study indicate pathways that may be involved in *P. annua* low heat tolerance and give insight on strategies to promote *P. annua* summer performance.

Surface Hardness Differences Among Kentucky Bluegrasses Subjected to Traffic

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Surface hardness can increase on highly trafficked sports fields where turf cover is reduced. Traffic tolerant Kentucky bluegrass (*Poa pratensis* L.) cultivars can be established on recreational sites to provide more uniform surfaces. The objective of this abstract is to report on surface hardness responses of entries in the 2017 National Turfgrass Evaluation Program (NTEP) Kentucky Bluegrass Test subjected to traffic stress. Three replications of 89 entries were seeded in September 2017 on a loam in North Brunswick, NJ. Traffic was applied in a strip across half of each plot using a combination of the Rutgers Wear Simulator and Cady Traffic Simulator during 2018 to 2022; the other half of each plot did not receive traffic. A Clegg Impact Turf Tester equipped with a 2.25 kg hammer was used to assess the surface hardness (G_{max}) of no traffic and traffic plots on 9 June and 3 August 2022. Data were analyzed as a 2 (no traffic and traffic) x 89 (entries) factorial strip-plot design. Greater surface hardness (higher G_{max}) was measured on trafficked Kentucky bluegrass plots compared to no traffic plots on 9 June and 3 August 2022. A significant entry main effect on surface hardness occurred on 9 June 2022; 30 entries had the lowest G_{max}. A significant traffic × entry interaction on 3 August 2022 indicated that traffic did not affect the surface hardness of Paloma. Fifty-four entries had the lowest surface hardness under traffic stress on 3 August 2022 including the following commercially available cultivars: Prosperity, Blue Gem, Jersey, Barvette HGT, Finish Line, After Midnight, Bombay, Acoustic, Paloma, Yellowstone, New Moon, Barserati, Twilight, Syrah, Babe, United, Blue Devil, Super Moon, Electric, Aviator II, Blue Magic, Blue Knight, Midnight, and Skye. Correlations (Pearson product movement) of turf cover (visually rated) and surface hardness revealed an inverse relationship.

Tulipalins: A Natural Herbicide for Turfgrass from a Tulip Bulb Waste Stream

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There is interest amongst the public to reduce synthetic herbicide use, but few practical alternatives are available. The only currently recognized organic pre-emergent is corn gluten which has limited efficacy. Preliminary screening with tulip bulbs indicates that tulip bulb powder has herbicidal properties both as a pre-emergent and as a post-emergent. Tulip bulbs contain tulipalin lactones that are released from tuliposides in response to increased pH or hydrolyzing enzymes. These compounds have anti-fungal and nematicidal properties. While investigating tulipalin for cut flower preservation we found it was phytotoxic when sprayed onto roses, corn leaves, and mint leaves. Further investigation found that applying tulipalin to pots seeded with smooth crabgrass and white clover decreased germination at 1.0 mmol. This effect was greater in pots filled with sand as compared to local field soil. It was also found that tulipalin was effective as a post-emergent at 100 umol and 1.0 mmol, with white clover and false green kylilinga exhibiting the most decrease in vegetative growth after three weeks. Using a rating scale of 0=no effect and 100=no growth, perennial ryegrass sprayed at 100 umol had a rating of 15 compared to a rating of 74 for false green kyllinga and 78 for white clover. This indicates selectivity which should be further evaluated. These investigations are preliminary but show surprisingly good weed control in a greenhouse environment. More research is warranted to determine efficacy for weed control and whether selectivity for weeds in turfgrass can be achieved. Tulip bulbs are organic and should be recognized as an OMRI product. Tulip bulbs from cut flower production are considered a substantial waste-stream product. One firm in New Jersey generates 20 million "waste" bulbs annually and there are several firms of this size along the East Coast including one of the largest tulip producers in the world, Fresh TulipsUSA, King George, VA. Currently, the only usage for this "waste" is deer feed (personal communication, Casey Jansen, Holland Greenhouse, Monroe, NJ). We believe that tulipalin could be extracted from dried tulip bulb powder and economically produced and applied as a pre-emergent and post- emergent herbicide for turfgrass.

Our objectives for 2023 were two-fold:

1. Test tulipalin in a greenhouse for preemergence crabgrass and white clover control in sand and soil.
2. Test tulipalin in a greenhouse for postemergence crabgrass, white clover, perennial ryegrass, and false green kyllinga control.

Genetic Mapping of Summer Patch Resistance in Hard Fescue

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Hard fescue (*Festuca brevipila* Tracey) is a cool-season turfgrass celebrated for its outstanding performance under low-maintenance conditions. Despite its resilience, it is notably susceptible to summer patch, a root disease caused by *Magnaporthiopsis poae* and *Magnaporthiopsis meyeri-festucae*. The objectives of this study were to establish a mapping population, construct a genetic linkage map, and identify Quantitative Trait Loci (QTL) for summer patch resistance in hard fescue. Preliminary investigations led to the selection of parental clones T10 (tolerant) and S5 (susceptible) based on their extreme phenotypic performance toward summer patch resistance. Full-sib progeny populations were created through crosses of T10 (♀) X S5 (♂) and S5 (♀) X T10 (♂). A total of 178 progeny, with 91 from the T10 (♀) X S5 (♂) population and 87 from the S5 (♀) X T10 (♂) population, were established in three identical mowed spaced-plant trials. The populations were organized in a randomized complete block design with four replications. Inoculation with a combination of *M. meyeri-festucae* isolate (SCR9) and *M. poae* isolate (C11) was used as the disease inoculum for the trials. Disease severity of hard fescue clones was evaluated by visually rating percent green on a scale of 1 to 10 during the summers of 2018 through 2021. Genomic DNA (gDNA) was extracted from plant leaf tissue and subjected to Next Generation Sequencing. The sequence data were demultiplexed using Stacks with a reference genome to call Single Nucleotide Polymorphisms (SNPs). We obtained 3876 SNPs for the T10 background dataset and 4432 SNPs for the S5 background dataset, shared by 80% of the progeny in each case. Two linkage maps with 21 linkage groups, one for T10 and another for S5, were independently constructed. The T10 linkage map comprised 1020 SNPs, spanning a total of 1981.1 cM, while the S5 linkage map contained 897 SNPs, covering a total of 1644.8 cM. Nine QTLs were identified with significant LOD scores exceeding the genome-wide LOD thresholds, distributed across three regions on three linkage groups. These QTLs explained phenotypic variations ranging from 4.1% to 5.3% for summer patch stress. This study represents the first QTL mapping of summer patch resistance in hard fescue, providing valuable insights that will contribute to the development of hard fescue cultivars with enhanced resistance to summer patch in a more efficient manner.

Exploring the Mechanism of Drought Tolerance in Perennial Ryegrass and Tall Fescue

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Knowledge of genetic variations in physiological traits of drought tolerance is important for developing drought-tolerant turfgrass cultivars. Genotypic variations in drought tolerance for perennial ryegrass (*Lolium perenne*) and tall fescue (*Festuca arundinacea*) were evaluated in this study. Three drought-tolerant and three susceptible cultivars of perennial ryegrass and tall fescue were selected from a two-year field trial based on the genetic variations in visual rating and remote-sensing data among over 40 cultivars for tall fescue and 20 cultivars for perennial ryegrass. Plants of six cultivars of each species were exposed to drought conditions in controlled-environment growth chamber. The parameters collected during the 22-day experimental period included visual rating, electrolyte leakage, relative water content and chlorophyll content measurement. Drought-tolerant cultivars of both tall fescue and perennial ryegrass had significantly higher turf quality than the susceptible cultivars. We also found significant difference in electrolyte leakage between the tolerant and susceptible cultivars under drought stress for both species. There was no significant difference of relative water content in perennial ryegrass cultivars, but susceptible tall fescue cultivars, TF099 and TF448 showed significantly lower leaf relative water content (RWC) from drought- tolerant cultivars, TF360 and TF291. Drought-tolerant cultivar, PR51, showed significantly lower chlorophyll content decline from other cultivars of perennial ryegrass. The results suggested that genetic variations in RWC in tall fescue and variations in chlorophyll content in perennial ryegrass, as well as membrane stability for both species could be useful traits for selecting cultivars of each species with top performance under drought stress.

Overexpression of Nonspecific Lipid Transfer Proteins in Creeping Bentgrass Enhances Resistance to Fungal Pathogens

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Breeding for improved resistance to fungal pathogens is one of the primary objectives in the Rutgers turfgrass breeding program to limit damage to the plant and reduce the need for fungicide applications. Turfgrasses are susceptible to numerous fungal pathogens and sources of broad-spectrum resistance are valuable to identify and utilize. Previous research in our laboratory has identified two non-specific lipid transfer proteins (nsLTPs) which are classified as pathogenesis-related (PR) proteins, i.e. proteins which are induced in response to pathogen infection and spread. PR proteins function at the innate immunity level in plant defense. nsLTPs from Arabidopsis (AtLTP4.4) and wheat (TaLTP3) have been shown to significantly limit *Fusarium graminearum* disease in wheat. In addition, AtLTP4.4 has been shown to limit ROS accumulation in response to mycotoxin exposure in both *Arabidopsis* and wheat. Plant nsLTPs are small cysteine-rich proteins which contain four conserved disulfide bridges, formed by a cysteine motif. This basic motif contains eight free cysteine thiols. When broken, those disulfide bridges generate free thiols, which may function to scavenge ROS molecules. Hence, a potential mechanism by which AtLTP4.4 may confer resistance, beyond functioning as an antifungal protein, is by scavenging ROS and reducing or suppressing oxidative stress that modulates disease progression.

To test the impact of these proteins on turfgrass fungal pathogens, we expressed AtLTP4.4-GFP in *Pichia pastoris* and isolated the protein for zone of inhibition assays. We found that AtLTP4.4-GFP was an effective antifungal protein against four major turf fungal pathogens, Summer Patch (*Magnaporthiopsis poae*), Snow Mold (*Monographella nivalis*), Brown Patch (*Rhizoctonia solani*), and Dollar Spot (*Clarireedia jacksonii*). To further test the impact of nsLTPs on turfgrass resistance, we generated individual overexpression vectors containing these genes and transformed creeping bentgrass (*Agrostis stolonifera*), Crenshaw variety with AtLTP4.4-GFP and TaLTP3-GFP along with the empty vector for comparison. Because these proteins are GFP-tagged, we were able to confirm expression via confocal microscopy. Western analysis will be used to confirm and quantify expression between the independently transformed lines. Detached leaf assays using Dollar Spot revealed significant inhibition of fungal growth in the high expressing AtLTP4.4 and TaLTP3 lines relative to the vector control.

A future goal will be to examine native *A.s*. nsLTPs that may function as effective resistance genes. Expression of turfgrass nsLTPs will be examined in response to fungal challenge. Select nsLTPs would then serve as targets for CRISPR editing/activation (CRISPRa) to generate potentially broad-spectrum disease resistance in bentgrass. The production of transgene-free turfgrasses with enhanced fungal disease resistance would be a boon for the industry.

Hollow Tine Cultivation Effect on Dollar Spot of Creeping Bentgrass

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Core cultivation is a common practice on golf course turf used to remove and dilute the accumulating organic matter in the thatch layer through soil incorporation. Our hypothesis was that modifying the thatch and lower canopy to be more soil-like may reduce the severity of dollar spot caused by *Clarireedia jacksonii*. Two cultivation treatments were evaluated for effects on the development of dollar spot on '007' and 'Putter' creeping bentgrass (*Agrostis stolonifera*) managed as fairway turf in North Brunswick, NJ and Storrs, CT, respectively during 2021, 2022, and 2023. Treatments included a non-treated control and hollow tine cultivation. Cultivation was performed with 16.7-mm o.d. hollow tines spaced in a 50- × 50-mm pattern to the 75-mm depth. Cultivation was applied during spring when the daily average soil temperature at the 5-cm depth reached 10°C for 3 consecutive days and a second time during early- to mid-October resulting in six cultivation events over 3 years. Soil brought to the surface with cultivation was immediately re-incorporated into the canopy and the residual thatch debris was removed. Disease severity was measured as the number of dollar spot infection foci per plot every 7 to 28 days from disease onset through August. Dollar spot inoculum was quantified as the concentration of *C. jacksonii* DNA in leaf tissue using a qPCR assay. Plots were sampled in 2023 when conditions first met the 20% risk threshold of the Smith-Kerns dollar spot model. At the same time, thatch-mat layer samples were taken to determine the organic matter concentration at the surface of plots. The suppression of dollar spot development in cultivated plots was greater in subsequent years at the CT site, suggesting a cumulative effect likely associated with an increasing modification of the thatch and lower turf canopy. A significant reduction in disease from cultivation treatment at the NJ site was only observed during 2022. The organic matter concentration in the thatch-mat layer was significantly reduced by core cultivation at both sites. The concentration of *C. jacksonii* inoculum in pre-symptomatic turf was lower in core cultivated plots compared to the non-cultivated plots at both sites after 5 cultivation events during the 3-year study. Data from these studies suggest that core cultivation can reduce dollar spot severity and primary inoculum. However, differences in degree and consistency of disease reductions exist between sites. Further research is needed to better understand soil characteristics among different locations to provide greater insight to improve the consistency of cultivation effects in dollar spot management.

Genetic Engineering of Switchgrass to Improve Biotic Resistance, Abiotic Tolerance and Biomass Production

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Switchgrass (*Panicum virgatum* L.) has been designated as a bioenergy feedstock species by the US Department of Energy (DOE). As a warm season, outcrossing polyploid and C_4 perennial grass native to most of North America, switchgrass is advantageous in high biomass productivity, suitability to thrive on marginal lands, low water and nutrient requirement and benefits to the environment. There have been tremendous research efforts in switchgrass, most of which has been focused on Alamo, one of the lowland ecotypes, to engineer for increased biomass and enhancement for the conversion of cellulosic biomass into fermentable sugar. Upland ecotypes are adapted to the colder and drier habitats in the northern region of the U.S. including New Jersey. To assist our breeding programs and to conduct forward and reverse genetics studies of upland switchgrass, we have developed an efficient tissue culture, transformation and regeneration protocol for Carthage and Kanlow cultivars. We have established our own CRISPR/Cas-gene editing toolbox for upland switchgrass genome editing. We have started using polyethylene glycol to screen drought tolerant calli induced from mature Carthage and Kanlow seeds. With the available genomic information, we have identified the potential genomic sequences for the *PvTB1* gene that are involved in tillering and biomass production, the *Flowering Locus T* gene that is putatively involved in delaying flowering and biomass increase, the *PvCOMT* gene that controls the plant lignin contents, the *dehydration responsive element binding* (*DREB*) transcription factor that negatively regulates drought tolerance, the *2OGO* gene encoding calcium-dependent protein kinase (CDPK) and *NPR3* (non-expressor of pathogenesis-related protein) as immunity negative regulators. We have cloned and sequenced the partial genomic DNA sequences of *PvCOMT* and *PvDREB*. We will use the CRISPR-gene editing approaches to study these genes linked to yield, environmental adaptability and disease resistance in Carthage and Kanlow, and to improve upland switchgrass biomass production, disease resistance and cellulosic biomass conversion.

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