RUTGERS UNIVERSITY
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Proceedings of the Thirty-Fourth Annual Rutgers Turfgrass Symposium

March 20, 2025

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Stacy A. Bonos, Associate Director

Center for Turfgrass Science

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Ming Yi Chou
Barbara Fitzgerald
Bingru Huang
James A. Murphy
Bradley S. Park

Proceedings of the Thirty-Fourth Annual Rutgers Turfgrass Symposium

Bingru Huang and Barbara Fitzgerald, Editors

Director's Remarks

Welcome to the 34th Annual Rutgers Turfgrass Symposium. Established in 1991, the Symposium provides Rutgers faculty, students, staff, and guests the opportunity to exchange ideas and encourage collaboration on research topics in turfgrass science. One of the foci of this year's symposium is the use of remote sensing for data collection in our field research of turfgrasses. In addition, I thank our invited speakers, Leah Brilman (Director of Product Management, DLF USA Inc.) who will present a keynote on "40 Years of Cool-Season Turfgrass Improvement and Goals for the Future – The Importance of Rutgers – Industry Cooperation," as well as Dr. James Baird (Botany and Plant Science Department, University of California, Riverside), Dr. Doug Richmond (Department of Entomology, Purdue University), Dr. Dominic Petrella (Department of Horticulture and Crop Science, Ohio State ATI) and Mr. Chris Kahn (Geospatial Professional, AlphaRTK), and all the Center faculty and students who have agreed to share their expertise at this year's symposium.

I also thank Drs. Ming Yi Chou, Stacy Bonos, and Stephanie Rossi, for serving as session moderators, and the Planning Committee, comprised of Drs. Stacy Bonos, Ming Yi Chou, Bingru Huang, Ning Zhang (Symposium Chair), Mr. Bradley Park and Ms. Barbara Fitzgerald for their contributions to the Symposium. Co-editors of the Symposium Proceedings were Dr. Bingru Huang and Ms. Barbara Fitzgerald. We appreciate the technical support of Mr. Bernard Ward, who made it possible to livestream this year's Symposium.

Our faculty, staff, and graduate students continue to be recognized for their excellence this past year. Dr. Ming Yi Chou received the Merle V. Adams Award presented to junior extension specialist faculty for their outstanding achievements within Rutgers Cooperative Extension. Mr. Brad Park received the Dr. William H. Daniel Founders Award from the Sports Field Management Association, recognizing an individual who has made significant contributions to the industry through research, teaching, or extension. Three graduate students were recognized during the annual meeting of the Crop Science Society of America in San Antonio, TX. Graduate student Mark Labarge won second place in the graduate student oral presentation competition for Turfgrass Breeding, Genomics, Physiology, and Molecular Biology for "Evaluation of Improved Cold Hardy Bermudagrass and Zoysiagrass for Use in New Jersey." Graduate student Ryan Earp won second place in the graduate student poster presentation under the Turfgrass Breeding, Genomics, Physiology, and Molecular Biology category for "Comparison of Genotype Calling Methods for Kentucky Bluegrass." William Errickson, agricultural agent, Rutgers Cooperative Extension of Monmouth County, won the Outstanding Paper in Turfgrass Science Award as the principal author of the article: Promotive Effects of Endophytic Rhizobacteria on Tiller and Root Growth in Creeping Bentgrass During Drought Stress and Post-stress Recovery Involving Regulation of Hormone and Sugar Metabolism. Crop Science, 63(4), 2583-2593. Mr. William Errickson was also awarded a Watson Fellowship from the Golf Course Superintendents Association of America, which recognizes graduate students identified as scientists who will be leaders in turfgrass management. I am also pleased to announce that, due to the generosity of Mr. Sean Pattwell, Eric MacPherson was the recipient of the Sean S. Pattwell Graduate Student Internship, which provided him with an educational experience at Bandon Dunes Golf Resort in Bandon, Oregon.

Finally, we are indebted to the outstanding industry partnerships throughout the state and nation, providing invaluable intellectual, material, and financial support. Rutgers Center for Turfgrass Science is better for it.

We are glad you chose to spend time with us and hope you enjoy the many opportunities the Rutgers Turfgrass Symposium offers.

Sincerely,

James A. Murphy, Director

Table of Contents

THIRTY-FOURTH ANNUAL RUTGERS TURFGRASS SYMPOSIUM

School of Environmental and Biological Sciences, Rutgers University

March 20, 2025

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

8:30 – 9:00 AM	**Registration**
9:00 – 9:10 AM	**Welcome – Laura Lawson** (*Executive Dean of Agriculture and Natural Resources)*
9:10 - 10:30 AM	**SESSION I: Turf Biotic Pests** (Moderator: Ming Yi Chou)
9:10 - 9:30	**Doug Richmond** (*Department of Entomology, Purdue University*) Billbugs: The Cryptic Culprits That Kill Your Turf
9:30 - 9:50	**Dominic Petrella** (*Food, Agricultural, and Environmental Sciences – Plant Science Engineering Technologies, Ohio State University*) The Influence of Light Quality on Turfgrass Biology and Stress Responses
9:50 - 10:10	**Salma Mukhtar** (*Department of Plant Biology, Rutgers University*) Exploring the Antifungal Metabolites and Biocontrol Potential of Bacteria Associated with Dollar Spot Disease Suppressive Soil
10:10 – 10:30	**Ning Zhang** (*Department of Plant Biology, Rutgers University*) New Fungal Species Discovery and Culture Preservation
10:30 - 10:50 AM	**Discussion and Break**
10:50 - 11:50 AM	**SESSION II: History and Future of Turfgrass Breeding and Management** (Moderator: Stacy Bonos)
10:50 – 11:10	**Eric MacPherson** (*Department of Plant Biology, Rutgers University*) Bandon Dunes: 25 Years Later (2024 Sean M. Pattwell Scholarship)
11:10 – 11:50	**KEYNOTE: Leah Brilman** (*Director of Product Management and Technical Services, DLF-Pickseed*) 40 Years of Cool-Season Turfgrass Improvement and Goals for the Future: The Importance of Rutgers – Industry Cooperation
11:50 – 1:10 PM	**Lunch Break and Poster Session**

1:10 – 2:10 PM **SESSION III: Turf Evaluation/Improvement** (Moderator: James Murphy)

1:10 – 1:30 **James Baird** (*Botany and Plant Sciences Department, University of California – Riverside*) Breeding Bermudagrass for California and the Southwest

1:30 – 1:50 **Rong Di** (*Department of Plant Biology, Rutgers University*) CRISPR-Gene Editing to Improve Turfgrass Disease Resistance and Stress Tolerance

1:50 – 2:10 **Bradley Park** (*Department of Plant Biology, Rutgers University*) Assessing Establishment of Kentucky Bluegrass with Remote Sensing

2:10 – 2:30 PM **Discussion and Break**

- **2:30 – 3:30 PM** **SESSION IV: Remote Sensing** (Moderator: Stephanie Rossi)

2:30 – 2:50 **Chris Kahn** (*Alpha RTK*) Leveraging GIS for Extraction and Visualization of Multispectral Statistics from Drone Data

2:50 – 3:10 **Juan Gonzalez** (*Department of Plant Biology, Rutgers University*) Using Computer Vision to Phenotype Turfgrass at Scale

3:10 – 3:30 **Haoguang Yang** (*Department of Plant Biology, Rutgers University*) Remote-Sensing Evaluation of Creeping Bentgrass Responses to Variable Drought Stress Levels in a Linear Gradient Irrigation System

3:30 – 4:00 PM **Discussion Session and Closing Remarks**

4:00 PM **Poster Session**

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PLENARY PRESENTATIONS

Billbugs: The Cryptic Culprits That Kill Your Turf

Douglas Richmond

Department of Entomology, Purdue University

Billbugs are among the most significant insect pests affecting turfgrass in managed landscapes, including golf courses, sports fields, and residential lawns. This presentation provides a comprehensive overview of billbug biology, damage symptoms, monitoring techniques, and management strategies to aid turfgrass professionals in mitigating infestations effectively.

Billbugs primarily damage turfgrass during their larval stage, as larvae feed internally within the stems, crowns, roots, stolons, and rhizomes. Damage symptoms often include irregular patches of dead or thinning grass, which can be mistaken for drought stress or fungal infections. There are at least 4 species of billbugs associated with turfgrass in the Eastern U.S. These include the bluegrass billbug, the hunting billbug, the lesser billbug, and the unequal billbug. The distribution of these four species overlaps significantly and it is not uncommon to find mixed populations of two or more species at a single location.

Effective management of billbugs relies on an integrated pest management (IPM) approach. Proper identification is crucial, as different billbug species require tailored control methods based on their seasonal biology. Monitoring efforts, such as visual inspections and pitfall traps can be helpful for assess adult activity, but these methods do not necessarily predict larval outbreaks. Additionally, degree-day models provide useful insights into the seasonal activity of billbug species, facilitating timely intervention.

Cultural management practices play a fundamental role in reducing billbug damage. Maintaining proper turfgrass species selection, irrigation, mowing height, and soil fertility can enhance turfgrass resilience against infestations. Endophyte-enhanced turfgrass varieties have shown increased resistance to billbugs, providing a viable preventive measure. Biological control methods, including the use of entomopathogenic nematodes offer environmentally sustainable alternatives for billbug suppression, but chemical control with systemic and contact insecticides targeting both adult and larval stages remains the most widely used approach. Timing is critical to maximizing efficacy while minimizing non-target effects.

The Influence of Light Quality on Turfgrass Biology and Stress Responses

Dominic Petrella

Agricultural Technical Institute, The Ohio State University

Shade is consistently one of the most problematic issues across all sectors of the turfgrass industry. Moreover, we currently have few sound solutions that increase turfgrass health and performance under shade. This is primarily due to the complex environmental interactions produced by different shade sources, either foliage, structures, or a combination of both. The source of shade can both decrease the quantity of light, alter the quality of light, and lead to fluctuations in the light environment that are difficult to measure. While we have a good grasp on how turfgrasses respond to reductions in the quantity of light, we still do not know enough about the physiological and genetic responses to altered light quality in different turfgrass species. To combat this, we have been collecting real-world light data under common shade scenarios and have been able to better define common changes in light quantity/quality experienced by turfgrasses under foliar-shade. This data has been used to simulate shade environments for field and controlled environment research, and to select improved germplasm for breeding efforts. Current results show that turfgrass response to reductions in light intensity are interconnected with the degree to which light quality is altered, however, management practices can also influence this. Interestingly, we have observed the ability of a low ratio of red to far-red (R:FR) light (a common change to light quality under foliar shade) to dwarfen multiple different turfgrass species, especially when light intensity was high. These same treatments showed the ability to induce flowering when vernalization dependent plants were not vernalized. We continue to learn more about turfgrass responses to light quality and shade every year due to new environmental data, examining unique interactions, and continually to use new technology to aid our efforts. However, there are still unique approaches to this problem to be explored to help us tackle this complex problem.

Exploring the Antifungal Metabolites and Biocontrol Potential of Bacteria Associated with Dollar Spot Disease Suppressive Soil

Salma Mukhtar[1], Pual Koch[2], Qing-li Wu[1], Shashikant Kotwal[1],
James E Simon[1] and Ming Yi Chou[1]*

[1]Department of Plant Biology, Rutgers University
[2]Department of Plant Pathology, University of Wisconsin, Madison

Dollar spot caused by *Clarireedia* spp. is the most economically important disease in cool-season turfgrass. The control of dollar spot relies largely on the repeatedly application of synthetic fungicides. Biological control agents, such as antifungal metabolites could offer environmentally sound alternatives to control dollar spot, while more research is needed. Dollar spot suppressive soil and the bacteria associated with dollar spot suppression were previously identified. This study investigates seven bacterial isolates derived from the dollar spot suppressive soil with antifungal activity. These bacterial isolates include three *Bacillus* strains, two *Stenotrophomonas* strains, one *Pedobacter* and one *Streptomyces* strain. These bacteria showed antifungal activities against *C. jacksonii*, *C. bennettii*, *C. homoeocarpa* and *C. monteithiana* in dual culture assays. To further identify the antifungal compounds involved in pathogen suppression, crude metabolites from *Stenotrophomonas* sp. and *Pedobacter* sp. were fractionated using four solvents with different polarity and the extracts were then tested against *Clarireedia* spp. with a disc diffusion method. Secondary metabolites from ethyl acetate and butanol fractions of *Stenotrophomonas* sp. and *Pedobacter* sp. showed the strongest overall growth inhibition of *Clarireedia* spp. UHPLC-QTOF/MS analysis through an untargeted approach showed that the studied *Stenotrophomonas* isolate produced 64 secondary metabolites that may have fungicidal or fungistatic effects. This study revealed that bacterial strains from the disease suppressive soils produce *Clarireedia* inhibiting metabolites and have the potential to be further developed into biological agents against dollar spot and other diseases in turf.

New Fungal Species Discovery and Culture Preservation

Ning Zhang*, Jing Luo, Emily Walsh

Department of Plant Biology, Rutgers University

Fungi have significant impact on plant health. In the past 16 years, Zhang lab has been collecting fungi associated with plants in the barren ecosystem as well as turfgrasses. A new order, two new families, and many new genera and species have been uncovered and published, some of which are plant pathogens or plant growth promotors. These novel fungal species may be used in improving turfgrass health.

Successful inoculation is essential in turfgrass breeding and management research on improving germplasm disease resistance or disease control. A challenge in inoculation experiment is contamination of cultures. Another challenge is that the fungal strains may decrease or lose virulence during preservation. In this project, we conducted experiments to optimize the fungal culture preservation methods, to support future research on germplasm improvement and management.

Based on turfgrass fungal cultures stored in our lab, we compared four fungal culture preservation methods—Agar slant (PDA), Filter paper, Barley seed, and Glycerol (20%)—by evaluating contamination rate, viability, strain correctness, and maximum storage duration. The Agar slant (PDA) method, stored at 4°C, had the lowest contamination rate (0.1) but showed moderate viability (0.85) and strain correctness (0.75), with a maximum storage duration of 12 months. Both the Filter paper and Barley seed methods, stored at -20°C, had higher contamination rates (0.2) and lower viability (0.80 and 0.85, respectively), with strain correctness values of 0.60 and 0.65, allowing preservation for up to 24 months. The Glycerol (20%) method, stored at -80°C, demonstrated the highest viability (0.90) and strain correctness (0.80), along with a low contamination rate (0.1), and provided the longest storage duration of up to 36 months. Our findings suggest that while Agar slant is suitable for short-term storage, Glycerol (20%) is the most effective method for long-term fungal culture maintenance.

To further optimize fungal culture preservation, we will incorporate cryogenic vials (Mr. Frosty freezing container and CoolCell alcohol-free freezing container) into the Glycerol method to enhance long-term viability. We will also revive, examine, and re-preserve cultures using five replicates with three different preservation methods to ensure high survival rates and to maintain virulence, sporulation, and other biological characteristics. Additionally, we will initiate a comprehensive turfgrass fungal culture database to systematically document and manage preserved fungal strains, ensuring their long-term accessibility and utility for future research.

Bandon Dunes: 25 years later (2024 Sean M. Pattwell Scholarship)

Eric MacPherson

Department of Plant Biology, Rutgers University

The Sean M. Pattwell Scholarship, established in 2022, provides a Rutgers University turfgrass graduate student the opportunity to spend a summer interning and studying at Bandon Dunes Golf Resort (Bandon, OR). Opening in 1999, Bandon Dunes, became an immediate sensation among golfers, owing to its unique design, breathtaking views, and "links" style golfing conditions. Since opening, Bandon Dunes Golf Resort has expanded to include five top 100, championship 18-hole golf courses (Bandon Dunes, Pacific Dunes, Bandon Trails, Old MacDonald, and Sheep Ranch) and three short courses. Bandon Dunes has also hosted numerous USGA, PGA of America, and collegiate events.

As a "links" style golf course, Bandon Dunes practices a low maintenance management style, preferring to highlight the design and natural beauty of the landscape. Utilizing reduced fertilizer and water, curative fungicide applications, and selective species, Bandon Dunes can maintain exceptional turf quality and aesthetics even with the demands of non-stop golf.

25 years after opening, the management style, expectations, and play have increased. In this time, Bandon Dunes greens have transitioned from a fine fescue mix to a predominate annual bluegrass putting surface. The fairways have also transitioned over those 25 years. Originally seeded as a blend of fine fescues (80%) and colonial bentgrass (20%), Bandon Dunes fairways have slowly begun to favor a fine fescue mix, leaving out the bentgrass entirely. This talk will highlight the agronomic practices that make Bandon Dunes a golfer's destination and map the current species composition of its playing surfaces in relation to its opening 25 years ago.

40 Years of Cool-Season Turfgrass Improvement and Goals for the Future: The Importance of Rutgers – Industry Cooperation

Leah A. Brilman

DLF NA/ Seed Research by DLF

Rutgers University in 1961 started the first program in the US dedicated to breeding cool season turfgrasses with Dr. C. Reed Funk. Dr. Funk realized the importance of working with the grass seed production industry for his cultivars to make it to market. In addition, he recognized the importance of protecting those cultivars through Plant Patent (Kentucky Bluegrass), contracts and later by Plant Variety Protection, so a royalty stream would continue to finance improvements. I first came to Rutgers in 1981 as an employee of Jacklin Seed. Kentucky bluegrass was important to them but walking and talking to Dr. Funk I quickly realized tall fescues and perennial ryegrasses were going to be important in the future. Turfgrass breeders select cultivars that require reduced total inputs of water, fertilizer and pesticides while maintaining their functional goals. Breeding turfgrass species presents many challenges since most breeders deal with multiple species and most turfgrasses have high ploidy levels. Often not recognized is turf breeders must also be breeding for seed yield at the same time as they improve turf qualities. Cooperation between Rutgers and Private Breeders allows for selection for seed yield as turf quality is improved. Due to differences in species requirements for increased seed yield and the many areas of seed production, priorities must be established for seed yield screenings. Climate change increases the difficulty of breeding more sustainable turfgrass cultivars that also are more sustainable for the seed grower. As an example, much of the production of turf-type perennial ryegrass has shifted to Minnesota, Canada and the Columbia Basin. Cultivars screened for seed yield in Oregon may be less suitable for these locations.

Important areas of cooperation include increased endophyte research. Screening for endophytes that store better and transmit easier to seed is important. Endophytes that can influence more pest species including below ground larvae would improve the sustainability of turfgrasses. Rutgers has continued to be at the forefront in new germplasm collection and finding ways to integrate this into new cultivars.

Breeders are utilizing new technologies to improve selection. This includes genetic tools, digital tools and robotics. The aim is to increase the number of plants screened while decreasing the time spent on each analysis. Continued cooperation is important to enable turfgrasses to be grown with less inputs but with all the environmental benefits.

Breeding Bermudagrass for California and the Southwest

James H. Baird[1], Christian S. Bowman[1], Marta Pudzianowska[2], and Adam J. Lukaszewski[1]

[1]*Department of Botany and Plant Sciences, University of California, Riverside*
[2]*Department of Plant and Soil Sciences, Mississippi State University*

Bermudagrass [*Cynodon* (L.) Rich.] is all around the best turfgrass species for Mediterranean and desert climates like the Southwest due to its tolerance to low mowing, drought, heat, salinity, traffic, and pests. However, a longstanding challenge for widespread bermudagrass acceptance, especially in California, has been its winter dormancy period, which can vary according to temperature, altitude, and proximity to the Pacific Ocean. Thus, historically bermudagrass stands were overseeded during the winter months with cool-season turfgrass species like ryegrass (*Lolium spp.*), which requires additional water resources and invites annual bluegrass (*Poa annua* L.) invasion. Bermudagrass breeding at the University of California, Riverside (UCR) began in 1965 by Dr. Victor B. Youngner, who started his academic career in 1955 at UCLA. In 1966, Dr. Youngner released 'Santa Ana' hybrid bermudagrass (*C. dactylon* (L.) Pers. x *C. transvaalensis* Burtt Davy) with a deep blue-green color, medium-fine leaf texture, shorter winter dormancy period, and tolerance to smog and salinity. Today 'Santa Ana' remains a viable cultivar for golf courses and athletic fields in California and Australia. Unfortunately, the UCR turfgrass breeding program came to a standstill in 1984 when Dr. Youngner passed away at age 62. In 2012, Drs. Lukaszewski and Baird resurrected the breeding program at UCR by establishing in Riverside a collection of seven *Cynodon* species from the USDA and several other sources. Later, Drs. Pudzianowska and Bowman joined the program as turfgrass breeders. Using phenotypic recurrent selection, our primary selection criterion has been to shorten or potentially eliminate winter dormancy. We started intercrossing these species and generated many inter- and intra-specific hybrids. However, it soon became apparent that the assigned species of some accessions did not match with their traits, a finding echoed by a few other breeding programs. Efforts to characterize our germplasm were made through morphological, cytological, and genetic means, prompting the development of species-specific genetic markers. These markers may serve as a tool for screening both major and minor *Cynodon* taxa in germplasm collections. Work has also been done to identify genetic markers associated with winter dormancy. Although enhanced winter color retention is our primary breeding objective, we discovered along the way tremendous genetic variation in drought resistance among our hybrids as well as other commercial hybrids including 'TifTuf'. Two new hybrid bermudagrass cultivars from our program, 'Coachella' (licensed in 2024) and 'Presidio' (license pending), share a darker bluish-green genetic color compared to most other cultivars including 'Santa Ana' and improved winter color retention and drought resistance like only 'TifTuf'. Newer UCR hybrids under development possess even greater drought resistance unlike any commercial cultivars now available. Moving forward, our program aims to utilize breeding, genetics, and genomics to develop a better understanding of the mechanisms controlling winter dormancy and drought resistance in bermudagrass and to continue release of improved cultivars that maximize the potential of these traits.

CRISPR-Gene Editing to Improve Turfgrass Disease Resistance and Stress Tolerance

Rong Di

Department of Plant Biology, Rutgers University

Creeping bentgrass (*Agrostis stolonifera* L., *As*) is one of the most widely used cool-season grass species on golf courses. Many cultivars of creeping bentgrass are susceptible to dollar spot disease caused by *Clarireedia jacksonii*. CRISPR gene editing technologies allow us to knock-out (KO) plant immunity negative regulators in creeping bentgrass, resulting in plants that confer dollar spot disease resistance. We used our CRISPR- editing platform to KO *AsCPK12*, a calcium-dependent protein kinase (CDPK) that has been identified as a negative regulator for rice blast disease resistance. We have constructed the CRISPR-gene editing vector (pRD302) with the expression of the guide RNA (gRNA) targeting *AsCPK12* under the control of the wheat U6 promoter and the monocot codon-optimized Cas9 nuclease gene under the control of maize ubiquitin promoter. We have also constructed vector pRD578 to KO *AsNPR3*, another gene involved in negative immunity regulation. We utilized biolistic bombardment method to deliver the CRISPR vectors into embryogenic calli of the creeping bentgrass cultivar "Crenshaw". We have produced many pRD302- and pRD578-transgenic plants and identified multiple *AsCPK12* and *AsNPR3* gene-edited plants. Detached leaves from these mutant plants were inoculated with *C. jacksonii* mycelium on water agar. Smaller lesion length from the *AsCPK12* and *AsNPR3* gene-edited plants compared to the non-edited wild type plants indicated their resistance to *C. jacksonii*. Inoculation of *AsCPK12* gene-edited plants with *C. jacksonii* and qPCR quantitation of the fungus using the fungal ITS (internal transcribed spacer)-specific primers and the host actin gene as the endogenous control, showed that the *AsCPK12*-edited plants had much lower fungal levels compared to the non-edited wild type plants.

Plant non-specific lipid transfer proteins (nsLTPs) are classified as pathogenesis-related (PR) proteins which function as part of the innate immune system. nsLTPs are small cysteine-rich proteins with the consensus sequence C-Xn-C-Xn-CC-Xn-CXC-Xn-C-Xn-C which forms four conserved disulfide bridges. The best characterized nsLTP is DEFECTIVE IN INDUCED RESISTANCE1 (DIR1) in *Arabidopsis* which plays a role in the systemic acquired resistance (SAR) response. nsLTPs have been recognized as possessing potent antifungal properties and have been linked with both biotic and abiotic stress reduction. nsLTPs have been found to bind lipids using *in vitro* assays and this lipid binding functionality is central to the antifungal nature of these proteins. The Arabidopsis AtLTP4.4 and wheat TaLTP9 have been found to be effective *in vitro* against four major turf fungal pathogens, summer patch (*Magnaporthe poae*), snow mold (*Monographella nivalis*), brown patch (*Rhizoctonia solani*), and dollar spot (*C. jacksonii*). We have constructed vectors to over-express heterologous *AtLTP4.4* and *TaLTP9* in Crenshaw creeping bentgrass and produced several transgenic lines for each vector including the empty control vector. RT-qPCR analysis showed the *AtLTP4.4* and *TaLTP9* transgenes were highly expressed in these transgenic plants. Results from the detached leaf inoculation assay with *C. jacksonii* indicated that these *AtLTP4.4* and *TaLTP9* over-expressing transgenic creeping bentgrass were more resistant to *C. jacksonii* than the empty vector-transformed plants. These results demonstrate that nsLTPs in creeping bentgrass and likely in other turfgrass can serve as targets for CRISPR activation (CRISPRa) to highly up-regulate their expression and generate novel disease resistance in turfgrass plants.

Creeping bentgrass (*Agrostis stolonifera* L., *As*) is stressed by heat and drought during summer months, besides being susceptible to dollar spot disease. Using the same CRISPR-KO platform as mentioned above and the vector pRD303 by both gene gun and *Agrobacterium* transformation methods, we have produced many edited Crenshaw creeping bentgrass plants in *AsDREB* (dehydration responsive element binding 2) gene which has been shown to be a negative stress regulating transcription factor. Selected *AsDREB* mutant and non-edited Crenshaw plants were tested for their drought and salt tolerance under the controlled growth chamber condition. The plants were visually rated and plant health data including weight, leaf color and the NDVI (normalized difference vegetation index) were collected. Some *AsDREB*-gene edited mutant Crenshaw plants were shown to be less stressed by drought and salt compared to the non-gene edited plants. Our developed CRISPR-gene editing platform can be applied to other turfgrass species and used to improve other agronomically important traits.

Assessing Establishment of Kentucky Bluegrass with Remote Sensing

Bradley S. Park[1], Daniel Coogan[1], Chis Kahn[2], Hiranthi Samaranayake[1], and James A. Murphy[1]

[1]*Department of Plant Biology, Rutgers University*
[2]*AlphaRTK, Furlong, PA*

Turfgrass establishment and quality are typically visually assessed by human evaluators and may contain subjectivity, especially for inexperienced evaluators. Multi-spectral sensors that generate index products, including normalized difference vegetation index (NDVI) and normalized difference red edge (NDRE), are used to quantify vegetation. Specifically, NDVI indicates how much green is visible in an image, which is useful in differentiating between varying levels of healthy green vegetation when vegetative cover is not too dense. In denser vegetation, NDRE is less prone to saturation and can give better insight into permanent or later-stage crops because it can measure farther down into the canopy. Unmanned aerial systems (UASs), or drones, can be equipped with multi-spectral sensors to collect NDVI and NDRE data with minimal labor input.

This research compared visual ratings of turfgrass establishment and quality with the NDVI and NDRE indices of plots during the grow-in of the 2023 NTEP Kentucky Bluegrass Test. Three replications of 56 entries were seeded on a loam in September 2023 at Rutgers Hort Farm No. 2 in North Brunswick, NJ. Turfgrass establishment was visually evaluated on 17 April and 30 May 2024 using a 0 to 100% scale, with 100% representing complete soil cover by turfgrass. Multi-spectral data were collected with a UAS (DJI Mavic Enterprise 3 equipped with multispectral RTK and a high-quality RGB mapping sensor) on 19 April and 28 May 2024 and within 3 days before or after visual ratings for monthly turfgrass quality (1 to 9 scale; 9 = best quality) from June through October 2024. Multi-spectral data was used to calculate the plot average NDVI and NDRE. All data were subjected to ANOVA and means for entry were separated using Fisher’s protected LSD test at $p \leq 0.05$. Pearson product movement procedures were used to determine correlations of visual assessments of turfgrass establishment and quality with NDVI and NDRE (n =168) and visual turfgrass quality and NDVI and NDVI (n = 168).

Turfgrass establishment ratings (17 April 2024) had strong positive correlation with NDVI (r=0.73; $p < 0.0001$) on 19 April 2024. Ten entries ranked among the entries with the best establishment rating and highest NDVI value during April 2024: DLF-KB-3633, DLF-KB-3634, DLF-KB-3635, DLF-KB-3640, Jersey, PVF-A17-842, Barserati, PST-K22-11, Lightning, and PST-K19-206. Entries with the best visual rating of establishment in April ranged from 80 to 93% cover of the soil. Turfgrass establishment and NDRE in April had a moderately positive correlation (r=0.33; $p < 0.0001$); 5 entries had the best establishment and highest NDRE: DLF-KB-3634, Barserati, PST-K22-11, Lightning, and PST-K19-206. Turfgrass establishment ratings taken visually on 30 May 2024 had a moderate positive correlation with NDVI values acquired on 28 May 2024 (r=.30; $p < 0.0001$); however, turfgrass establishment was not correlated with NDRE (r=0.08; $p = 0.33$). Entries with the best visual rating of establishment in May ranged from 87 to 98% cover of the soil.

Visual evaluations of turfgrass quality had moderate to strong positive correlations with NDVI for each month ($p < 0.0001$) during June through October 2024 (June: r = 0.42; July: r = 0.62; August: r = 0.69; Sep.: r = 0.66; Oct.: r = 0.60). Similarly, the average turf quality and average NDVI from June through October 2024 had a strong positive correlation (r = 0.65; $p < 0.0001$). Turfgrass quality had a weak to moderate positive correlation with NDRE measured in June (r = 0.16), July (r = 0.36), August (r=0.49), Sep. (r=0.37), and Oct. (r=0.34). The average turfgrass quality and average NDRE from June through October 2024 had a moderate positive correlation (r=0.36; $p < 0.0001$).

Overall, visual ratings of turfgrass establishment and quality had stronger correlations with NDVI than NDRE. Further study of the relationship between multi-spectral data and visual ratings will likely provide a more comprehensive understanding of turfgrass persistence. These results indicate value in incorporating UAS-based acquisition of multi-spectral data to evaluate the establishment and quality of turfgrasses in field trials.

Leveraging GIS for Extraction and Visualization of Multispectral Statistics from Drone Data

Chris Kahn

Alpha RTK

The Rutgers University Center for Turfgrass Science monitors tens of thousands of plot trials, combining cultivars & varieties to find the most effective profiles resistant to heat, foot traffic, and disease. Plot trials are small (3' x 5') and variations in color & health are quite subtle. Comparing plot trial health via imaging at the resolution and precision required for reliable research results was previously a roadblock.

Rutgers has combined its access to AlphaRTK's cm level precision with a DJI Mavic 3 Enterprise Multispectral drone, ArcGIS Field Maps, and Pix4D photogrammetry to produce weekly multi-spectral statistical analytics for plot trials. During the 2024 season, GIS geometry was created for the majority of Hort Farm 2 and Adelphia farm plot trials. Multispectral statistics were calculated for each plot, for each week of the season, and aggregated into GIS dashboards for each farm. The dashboards display maps of the aerial imagery (color) and multispectral imagery for each week. The dashboards also display graphs that are filterable of mean NDRE values by field and by plot across the season. Additionally, researchers can view & download the tabular multispectral statistics from the dashboard to conduct further analysis. This scalable, innovative use of geospatial data will accelerate statistical insights into turfgrass responses to stressors.

The 2024 season was a learning curve on establishing accuracy, quality control, scale, computing power, and consistency of analysis. For 2025, Rutgers Turfgrass has procured more sophisticated equipment to advance its remote sensing capabilities even further. The Center is acquiring an industrial DJI M350 drone, capable of carrying a variety of advanced sensors. To this end, the Center will also acquire a DJI L2 lidar system (for precisely measuring plant heights) and a Sony ILX-LR1 multispectral sensor (capable of capturing many more MS bands at a higher resolution than the current model). The 2025 season will be a learning curve for exploring more advanced analysis capabilities provided by the new hardware. Additionally, new computing hardware will be installed at Adelphia to begin to perform the extensive processing locally at the farm, by farm staff.

Using Computer Vision to Phenotype Turfgrass at Scale

Juan M. Gonzalez, Mark Labarge, Stacy Bonos

Department of Plant Biology, Rutgers University

Turfgrasses are vital in urban and sports settings, offering benefits such as soil erosion prevention, carbon sequestration, recreational surfaces, and stormwater runoff reduction. Traditional phenotyping methods are labor-intensive, subjective, and imprecise, limiting breeding efficiency. TurfAnalyzer, a tool developed for analyzing turf images using image boxes, does not perform well with drone images and only produces nine features, which is insufficient for machine learning applications. To address these challenges, we developed TurfCV, a computer vision application that extracts quantitative information from images captured by unmanned aerial vehicles. TurfCV can analyze RGB and four-band multi-spectral images, generating over 1000 image features, broadly categorized into color, texture, density, and uniformity. Unlike conventional methods that use fixed segmentation thresholds, TurfCV takes a heuristic, dynamic approach to segmenting grass from non-grass pixels.

To demonstrate the usefulness of this application, we applied an unsupervised machine learning approach to assess the informativeness of TurfCV's features. Using a dataset of 58 plots, we achieved a moderate prediction of quality scores, indicating that the feature space holds potential for phenotypic prediction and captures meaningful quantitative signals.

Overall, our findings demonstrate the feasibility of developing quantitative phenotypes using computer vision, with TurfCV providing a robust, scalable, and efficient method for rapid trait assessment. This approach offers objective, reproducible feature extraction, facilitating the selection of superior genotypes and the training of machine learning models to predict relevant phenotypes. In the future, we will leverage a large, labeled image training dataset to explore supervised machine learning and deep learning techniques for improved phenotype prediction.

Remote-Sensing Evaluation of Creeping Bentgrass Responses to Variable Drought Stress Levels in a Linear Gradient Irrigation System

Haoguang Yang and Bingru Huang

Department of Plant Biology Rutgers University

Remote-sensing technology is a promising approach to monitor and detect turfgrass drought status and develop prevision irrigation programs. In this study, we intend to develop an Unmanned Aircraft System (UAS)-based, precision turfgrass management system for water conservation for creeping bentgrass (Agrostis stolonifera) . To test the performance of different levels of drought stress, a linear gradient irrigation system (LGIS) was used to create a varying degree of drought stress along the irrigation gradient. Remote sensing data were collected using multispectral and RGB camera to determine vegetation indices that are sensitive to drought stress for early stress detection and that are correlated to ground measurements that can serve as physiological indicators to evaluate levels of drought tolerance. The experiment was conducted in the summer of 2023 and 2024. The result indicates high correlation and predictability of vegetation indices including Plant Senescence Reflectance Index (PSRI), Structural Independent Pigment Index (SIPI), Normalized Difference Vegetation Index (NDVI) and Normalized Difference Red Edge (NDRE) with turf quality and soil water content. Such information will be used for development of predictive machine learning model for monitoring drought stress and guiding precision irrigation in cool season turfgrass species.

POSTER PRESENTATIONS

Metabolic Responses to Elevated Night Temperature in Creeping Bentgrass

Amir Abbas, Stephanie Rossi and Bingru Huang

Department of Plant Biology, Rutgers University

Air temperature is increasing, and nighttime temperature (NT) increases faster than daytime temperature (DT) according to global climate change prediction. Greater increases in NT relative to DT can be detrimental to the growth of cool season turfgrass species. The objective of this study was to investigate the impact of higher elevation of NT temperature relative to DT on the metabolism of creeping bentgrass (*Agrostis stolonifera* 'Penncross'). Plants were grown in an environmentally controlled growth chamber subjected to three temperature regimens: non-stress control (25/15 ºC, day/night), moderate heat stress (30/25 ºC, day/night), and severe heat stress (35/35 ºC, day/night). Turf quality and chlorophyll fluorescence parameters (photochemical efficiency and non-photochemical quenching) were monitored weekly for 35 days. Metabolomic analysis was performed to determine metabolites and metabolic pathways differential responsive to different levels of elevated NT and DT. Metabolic analysis revealed a significant decrease in carbohydrates and organic acids under heat stress conditions. These findings indicate that greater increasing in NT could disrupted carbon balance by suppressing photosynthesis and enhancing respiration, and ultimately caused decline in turf quality. A deeper understanding of these metabolic alterations will aid in developing strategies to mitigate the negative impacts of climate change on turfgrass ecosystems.

Development of Molecular Methods to Examine Major Ectotrophic Root-Infecting Fungal Pathobiome in Cool-Season Turfgrasses

Chase Bauberger and Ming Yi Chou

Department of Plant Biology, Rutgers University

Recent studies found emerging ectotrophic root infection (ERI) fungal pathogen *Slopeiomyces cylindrosporus* causing root disease in cool-season turfgrass and being prominent in the Northeast of the U.S. and Canada. To conduct a large-scale survey to examine the prominence of the root disease caused by *S. cylindrosporus* in relation to *Gaeumannomyces avenae* and *Magnaporthiopsis poae,* a molecular tool that is more sensitive, reliable, and rapid than the conventional cultural-dependent technique is needed. In addition, accurately distinguishing between and quantification of ERI pathogens in cool-season turfgrass allows for proper identification of the causal agent and provides the best possible recommendations for management in a shorter time frame. In this study, we aim to develop species-specific primers and fluorescent probes to be used in multiplex digital PCR, which can be a helpful tool for reliable pathogen identification and quantification. Primers and probes that are specific to *G. avenae, M. poae, S. cylindrosporus* targeting virulence genes are being developed. With the successful development of the genetic markers to be used in dPCR, we could verify the causal agent of cool-season turf root disease within three hours.

Leveraging Fungicide Synergy with Entomopathogenic Nematodes and Insecticides to Optimize Turfgrass Pest Management

Matthew S. Brown [1], Ming-Yi Chou [2], Tarikul Islam [1], and Albrecht M. Koppenhöfer [1]

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Fungicides are widely used in turfgrass management to control fungal pathogens and diseases. Beyond their antifungal activity, fungicides can influence insect pests by disrupting development, suppressing immune responses, and increasing susceptibility to natural enemies and insecticides. This dual impact offers opportunities to enhance pest management strategies.

Entomopathogenic nematodes (EPNs) are natural enemies employed to control turfgrass pests. If fungicides increase pest susceptibility to EPNs and insecticides, integrating these agents with fungicides could improve pest control efficacy. This study investigated the synergistic interactions between fungicides, EPNs, and insecticides for managing key turfgrass pests, including the annual bluegrass weevil, black cutworm, and white grubs.

Field experiments evaluated annual bluegrass weevil densities under various fungicide treatments (untreated control, propiconazole, and pyraclostrobin) combined with EPNs (untreated control and *Steinernema carpocapsae*). Results showed that fungicides did not affect the susceptibility of annual bluegrass weevils to EPNs.

Laboratory experiments assessed black cutworm and masked chafer survival and development when exposed to fungicide mixtures with EPNs or insecticides. Fungicides tested included propiconazole, pyraclostrobin, chlorothalonil, *Bacillus amyloliquefaciens*, fluazinam, iprodione, and tebuconazole at two rates each. *Steinernema carpocapsae* was used for black cutworm experiments, and *Heterorhabditis bacteriophora* was used for masked chafer experiments. Insecticides included bifenthrin for black cutworms and clothianidin and trichlorfon for masked chafers. Some fungicides, including fluazinam, iprodione, and tebuconazole, increased black cutworm larvae’s susceptibility to EPNs and insecticides, while most fungicides delayed larval development (increasing time to pupation).

These findings indicate that fungicides may already exert sublethal effects on turfgrass insect pests. A deeper understanding of specific fungicide impacts on insect pests can enhance pest management strategies. Integrating EPNs or insecticides with select fungicides can improve pest control efficiency. This research highlights the potential to optimize turfgrass pest management by leveraging synergistic effects between fungicides, EPNs, and insecticides, offering practical solutions for integrated pest and disease management on golf courses.

Comparison of Genotype Calling Methods for Kentucky Bluegrass

Ryan Earp and Stacy Bonos

Department of Plant Biology, Rutgers University

Kentucky bluegrass (Poa pratensis L.) is a cool-season perennial turfgrass widely used across the U.S. and Canada, particularly on sports fields and golf courses (Huff, 2010). Performing genomic analyses has been difficult due to its apomictic reproduction, polyploidy, and large genome size. However, the recent publication of a reference genome by Phillips et al. (2023) has helped reduce this complexity. This study evaluates methods for analyzing genotyping-by-sequencing data to perform a Genome-Wide Association Study (GWAS) on a Kentucky Bluegrass population.

A population of 62 individuals from 8 cultivars was analyzed using two alignment tools, BWA and Bowtie2, and two variant callers, Freebayes and GATK. BWA was able to align a higher percentage of total and unique reads to the reference genome compared to Bowtie2. GATK identified more variants with higher quality, while Freebayes showed higher read depth.
Since GWAS software cannot handle mixed ploidy, GATK calls were compared using both uniform diploid and respective ploidy approaches. The diploid method resulted in 2,130,151 SNPs, with a median quality of 192 and depth of 48, while the polyploid method yielded 1,148,481 SNPs, with median quality of 551 and depth of 30. Both methods were able to cluster cultivars together using PCA and genetic diversity trees.

A GWAS on Rust disease data, collected in 2023, was conducted using the uniform diploid call, scaling to the highest sample ploidy, and incorporating ploidy as a cofactor in GWASpoly, following Yang et al. (2020). After filtering, 6,698 SNPs were used, identifying a potential SNP on scaffold 43. This study outlines a potential method for GWAS in mixed ploidy Kentucky bluegrass populations. Further research is needed to refine the model for larger populations and more traits to assist in improving breeding selection.

Mycobiome Associated with *Sphagnum* Moss in the New Jersey Pine Barrens Ecosystem

Alexis Faulborn, Emily Walsh, Jing Luo, Ning Zhang

Department of Plant Biology, Rutgers University

Mosses are commonly referred to as 'sponges' due to their ability to soak up rainfall, maintain moisture and temperature around themselves. This enables other neighboring plants to thrive in environments that may have once not been ideal, for example, the pine barren ecosystem with acidic, dry, and low nutrient soils. Previous studies in our lab have revealed that the mycobiomes associated with roots of pine, grasses, and other vascular plants in the pine barrens are unique, diverse, and rich in undescribed fungi. Mycobiomes associated with the *Bryophyta* mosses, however, have been less studied. The objective of this study was to characterize the mycobiome associated with the non-vascular sphagnum mosses (*Sphagnum* spp.) in the pine barrens ecosystem. Fungal isolates were identified by morphological attributes and fungal ITS DNA barcoding. Phylogenetic analysis also was performed for accurate fungal identification. A diverse mycobiome that include *Sordariomycetes*, *Leotiomycetes*, *Mucoromycotina*, as well as *Dothideomycetes* was observed, and several isolates were identified as potentially new fungal lineages. This study also provides fungal cultures for future plant-fungal interaction studies in order to understand the functions of these plant associated fungi in nature. This study at New Jersey Pine Barrens is part of a National Science Foundation supported project of investigating the impact of climate variation on mycobiome dynamics along a latitudinal transect from Maine to Florida.

Leaf Senescence with Dehydration and Rehydration of Kentucky Bluegrass

Devan Gladden, Stephanie Rossi, and Bingru Huang

Department of Plant Biology, Rutgers University

Kentucky bluegrass (*Poa pratensis* L.) is a cool-season turfgrass used in residential lawns, livestock pastures, athletic fields, and golf courses. Drought is a major limiting factor to Kentucky bluegrass growth and aesthetics. Drought-induced senescence is known to reduce chlorophyll content of Kentucky bluegrass plants but the mechanisms underlying this reduction, specifically the activities of chlorophyll degradation and chlorophyll synthesis enzymes, are not well understood. Two Kentucky bluegrass cultivars, 'Baron' and 'Bewitched' were grown in an environmentally controlled growth chamber at (25/15 ºC) with control plants fully irrigated regularly and drought plants receiving no irrigation for 14 days then rewatered for 13 days. Turf quality, chlorophyll content, chlorophyll fluorescence, and leaf relative water content were monitored approximately every 5 days over the 27 days of study. Chlorophyll degradation and chlorophyll synthesis enzymes were extracted to elucidate the effect of drought-induced senescence on chlorophyll metabolism. Physiological parameters turf quality, chlorophyll content, chlorophyll fluorescence, and leaf relative water content were reduced in response to drought and increased upon rewatering. Investigating the effect of drought on chlorophyll metabolism in Kentucky bluegrass may provide further insight on producing more drought tolerant cultivars.

Natural Selection of Elements for Plant Nutrition, Darwin's Diner Cartoon for Teaching

Joseph Heckman and Adrianna Scuderi

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Art and humor may serve as instruments to enhance communication of science. In this way (Fig. 1) cartoons can be used as a teaching tool. Students enrolled in Soil Fertility are expected to build new knowledge on a foundation in Chemistry, Physics, and Biology. The cartoon on display is intended as a teaching tool to transition students from previously acquired knowledge of science and inspire curiosity about the chemical elements associated with Soil Fertility and Plant Nutrition. With these images the stage is set to raise many questions that are intended spark student interest such as: Which set of elements on the periodic table are essential to plants? What defines a plant nutrient? How is an element classified as essential to life? What special properties of a chemical element makes it essential to life? Does abundance of an element on planet Earth influence its usefulness to support life? Why is an element such as Aluminum, which is abundant in soils, often toxic and has no known essential life function? Which elements do plants acquire from the atmosphere and which from soils? How do chemical properties of an element (metal vs non-metal, oxidation reduction, electrical charge, atomic size and weight) influence its biological function in a living organism? What is the nature of nutrient cycles for each essential element. And how can farmers manage the cycles of these elements for production of healthy plants and animals? Such questions are intended to prompt student thought, curiosity, and engagement for subject matter to be covered in a semester long Soil Fertility/Plant Nutrition course.

Dual Benefits: Silicon Fertilization Enhances Turfgrass Resistance to Black Cutworms and Nematode-Induced Cutworm Mortality

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The black cutworm (*Agrotis ipsilon*) is a destructive global pest of many plants, including turfgrasses. Silicon (Si) accumulation confers physical resistance to plants by making tissues tougher and more abrasive, reducing their digestibility and palatability for insect herbivores. However, the effects of Si on turfgrass insect pests remain largely unexplored. It is also unknown whether Si interacts with other sustainable pest management strategies, such as biological control using entomopathogenic nematodes (EPNs). We examined the impacts of Si fertilization of creeping bentgrass (*Agrostis stolonifera*), a widely cultivated turfgrass, on black cutworm performance, larval susceptibility to the EPN *Steinernema carpocapsae*, and EPN reproduction. In greenhouse experiments, grasses were treated with wollastonite, a calcium silicate mineral, at rates of 1221 kg/ha, 2442 kg/ha, and 4884 kg/ha. Si fertilization increased leaf Si concentrations and decreased cutworm larval performance, with the highest application rate reducing larval weight by up to 45% and head capsule width by 20%. Si also enhanced turf cover and quality under herbivory. All Si rates increased EPN-induced larval mortality, and larvae fed clippings from high-Si grass were killed faster than those fed untreated grass clippings. However, fewer infective juveniles (IJs)—the free-living stage of EPNs—emerged from cadavers of larvae fed Si-treated grass clippings, correlating with decreased cadaver length and weight. Si treatment negatively affected IJ emergence, independent of cadaver size. We provide novel evidence that Si fertilization enhances EPN-based biological control of cutworms. Although decreased IJ emergence may inhibit long-term EPN persistence, this trade-off is unlikely to limit initial biological control success, as EPNs are commonly applied as inundative biopesticides.

Evaluating Cold Hardy Bermudagrass and Zoysiagrass in New Jersey

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The effects of climate change are impacting turfgrass grown in New Jersey and the northern transition zone. Improvements made by plant breeders in the cold hardiness of bermudagrass (*Cynodon* spp.) and zoysiagrass (*Zoysia* spp.) have widened their use range. Improved bermudagrass and zoysiagrass have not been extensively evaluated for use in New Jersey. A series of studies is being conducted to evaluate the potential benefits and shortcomings of bermudagrass and zoysiagrass grown in New Jersey. Promising entries are being used in a field-based comparison to creeping bentgrass (*Agrostis stolonifera* L).

An initial evaluation trial was established via sprigs (500 US bu/acre rate) on June 30, 2022, and concluded on July 1, 2024. The trial included seven zoysiagrass cultivars, twelve bermudagrass cultivars, six zoysiagrass experimental selections, and four bermudagrass experimental selections. Maintenance inputs including irrigation, fertilizer, pesticides, and labor were recorded during the trial period. Visual establishment (percent green cover), turfgrass quality (1-9 scale), fall color retention (percent green cover), spring green-up (percent green cover), and winter kill (percent damaged cover) ratings were taken throughout the trial. Digital images were collected using a Canon PowerShot G15 with an enclosed lightbox (0.5 x 0.6 m) with four fluorescent bulbs. Digital image analysis was conducted using Turf Analyzer software (Green Research Services, LLC). Visual establishment ratings were analyzed using non-linear regression with a sigmoid variable slope model in GraphPad Prism version 10 (GraphPad Software Inc., La Jolla, CA). All visual ratings and Turf Analyzer data was analyzed using SAS 9.4 software (SAS Institute Inc., Cary, NC). Additionally, a principal component analysis of visual ratings was conducted using GraphPad Prism version 10.

Entries of both bermudagrass and zoysiagrass showed increased fall color retention with limited winter kill over two growing seasons. Eight bermudagrass and five zoysiagrass entries exhibited an average of approximately 30% or less winterkill over the two-year study period. All established selections did grow back to full coverage in both years despite any level of winter kill. Spring green-up was variable among entries but almost all entries showed improved spring green-up during their second green-up period. The most desirable characteristics for the region are improved fall color retention, quicker spring green-up, and limited winter kill which was exhibited by several entries. The results of this study informed the selection of DALZ 1701, Lobo, and Meyer zoysiagrass along with Tahoma 31, Tiftuf, and Ironcutter bermudagrass for further evaluation in New Jersey.

Two fairway trials (low and high maintenance) were established in July of 2024 to evaluate these promising selections alongside creeping bentgrass. The top 2 creeping bentgrass cultivars (Spectrum and Coho) and a standard (007) were selected from previous trials conducted in NJ. All species and plots were established as sod. For both trials, plots are arranged in a strip plot design (by species) with three replications of each entry. Management programs for each species and maintenance level were developed through literature reviews, interviews with turf managers, and collaboration with experts in turfgrass maintenance. Management programs were implemented in the fall of 2024 and will continue through 2026. In the low maintenance trial, the best plot from each species will be maintained at a turf quality threshold of 6. In the high maintenance trial, the best plot from each species will be maintained at a turf quality threshold of 9. All inputs will be recorded and utilized for environmental and economic comparisons within and between species. The same entries are being utilized in a water use trial. The trial was established from sod in July of 2024 in a rainout shelter at the Adelphia Plant Science Research Station. Plots are arranged in a Randomized Complete Block Design with three replications. After establishment, each plot will be irrigated individually and the amount of water needed for acceptable turf quality will be recorded for each entry.

Investigating the Compatibility between Synthetic and Biological Fungicides in Turfgrass

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Fungicides are commonly used to control turfgrass diseases. Rotating or tank-mixing multiple active ingredients helps prevent disease breakthrough and development of fungicide resistance. Increasingly stringent pesticide regulations and concerns about environmental and human health have elevated the importance of using synthetic fungicide alternatives. Biological fungicides, when used correctly, could suppress diseases while having minimal environmental impacts. Weaving biological fungicides into disease management may be a potential option. However, the interactions between biological fungicides and synthetic fungicides are not well understood. The goal of this research is to facilitate fungicide efficacy while taking advantage of the biological agents in turfgrass disease management through understanding the interactions between synthetic and biological fungicides. Compatibility of 44 synthetic fungicides for turfgrass from 20 modes of action and two living-bacterial biological fungicides, Rhapsody (*Bacillus amyloliquefaciens*) and Actinovate (*Streptomyces lydicus*), were investigated. The growth curves of the two bacteria were examined and compared in liquid cultures with and without synthetic fungicide amendments under pH 6 and 28°C. Bacterial growth and survival varied when interacting with different synthetic fungicide active ingredients and modes of action. The persistence of synthetic fungicides when mixed with biological agents will be further investigated.

Creeping Bentgrass Response to Winter Wear

Eric MacPherson

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Milder winters in the northeast are leading to golf courses staying open longer into the winter season. Many of these courses have bentgrass greens and fairways that go dormant. Utilizing a wear machine to simulate golfer traffic during the winter months was conducted over the course of two winters to see how different creeping bentgrass varieties responded. The Rutgers wear machine was used on winter days above 30°F to simulate when courses would have play from the months of December through March. Winter wear damage and winter wear recovery were then measured on a scale of 1-9 with 9 being better winter wear tolerance and better spring recovery. Several varieties exhibited strong tolerances to having simulated winter play on them. Several varieties exhibited delayed spring green up and winter recovery after winter traffic was applied.

Long-term Effects of Topdressing Creeping Bentgrass with Three Sand Sizes

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Topdressing turf has been practiced since the 19th century when Old Tom Morris was thought to have discovered its benefits for managing organic matter accumulation. However, sand topdressing of golf course putting greens is often avoided or applied at very low application rates (dusting) during the growing season due to the potential of coarse sand particles interfering with play and dulling mower blades. Topdressing with finer sand enhances incorporation and greatly reduces interference concerns, which could enable superintendents to keep pace with thatch accumulation in putting greens during the summer and reduce problems associated with excess organic matter. A long-term topdressing trial was initiated in May 2016 on a 19-month-old 'Shark' creeping bentgrass grown on a sand-based root zone to evaluate the long-term effects of topdressing with sand lacking coarse sand particles. Another objective of this research was to assess the impact of backfilling cultivation holes with medium-coarse sand on the physical properties of a putting green surface.

The experimental design of the trial was a 3 x 2 x 2 factorially arranged randomized complete block design with four blocks. The topdressing factors included sand size (medium-coarse, medium-fine, fine-medium) and quantity of mid-season topdressing (50- or 100-lb per 1,000-ft^2 every 10 to 14 days, totaling ten applications from June through early October). The cultivation factor was either non-cultivated or hollow tine cultivation in April and October, which disrupted approximately 10% of the surface area each year. During the spring of 2023 – after seven years of hollow tine cultivation – solid tines (0.625-inch o.d.) were used to apply cultivation in the trial. Controls (no mid-season topdressing) at each cultivation level were included for comparisons, resulting in 14 treatments. The medium-coarse sand used in this trial meets the USGA particle size recommendation for construction. In contrast, the medium-fine and fine-medium sands exceeded USGA construction recommendations for fine and very fine sand content and contained little to no coarse or very coarse particles. The trial was mowed at a 2.8-mm bench setting 5 to 6 days weekly from late April through October. Fertilization was applied every 1 to 2 weeks at 0.1 to 0.3 lb. of N per 1,000 sq ft and achieved an annual total of 2.4 lb. N per 1,000 sq ft. Irrigation was applied at 50 to 80% ET_o. During select periods irrigation by handheld hose was initiated on an individual plot when the plot exhibited incipient wilt stress. Each handheld hose watering event and the gallons of water applied were recorded. Pests were preventively managed with pesticides.

Data collection during April 2023 included removing undisturbed 3-inch diam. cores of the mat layer of each plot to determine the surface bulk density, pore size distribution, organic matter content, and sand size distribution of the mat layers. Data collection during 2024 included visual ratings of turf quality and residual sand after topdressing, volumetric water content (VWC) of the surface 0- to 3-inch depth zone; Clegg soil impact values, ball roll (GS3 device), normalized difference vegetation index (NDVI), and documentation of the number of hand-watering events and amount of water applied to individual plots. Dual-head infiltrometers were used to measure field-saturated hydraulic conductivity of select plots.

The analyses of the organic matter content, bulk density, and pore size distribution of mat layer samples collected in 2023 indicate that seven years of topdressing and hollow tine cultivation clearly affected organic matter content, bulk density, and porosity of mat layers on creeping bentgrass turf. The sand rate was the only topdressing factor affecting the organic matter content of the mat layer. Applying a greater topdressing rate (100-lb) reduced the organic matter content more than topdressing sand applied at the lower rate (50-lb); this effect was most evident when the turf was not cultivated with hollow tines. The organic matter content was always lower (1.2 to 1.6%) when turf was cultivated twice a year with hollow tines compared to no cultivation. Accordingly, the bulk density of the mat layer responded to topdressing and cultivation treatment combinations. The mat layer was densest when turf was cultivated with hollow tines (and organic matter content was reduced) compared to non-cultivated turf. Topdressing at the greater rate (100-lb) developed a denser mat layer than the lower (50-lb) rate, and this effect was greatest when turf was not cultivated. The coarsest topdressing sand was or was among the sand sizes that produced the greatest bulk density of the mat layer under non-cultivated conditions. In contrast, the finest topdressing sand (fine-medium) produced the mat layer with the lowest bulk density.

Air-filled and capillary porosities of the mat layer were clearly affected by the size of the topdressing sand; however, the effects depended on the topdressing rate and cultivation factors (2 two-way interactions). Under non-cultivated conditions, air-filled porosity was reduced as the size of the sand became finer. In contrast, only the fine-medium sand reduced air-filled porosity when plots were hollow tine cultivated. Under non-cultivated conditions, capillary porosity increased as the sand size became finer, and the increase with fine-medium sand was 7.1 and 9.4%—only the fine-medium sand increased capillary porosity when plots were hollow tine cultivated. The interaction with the topdressing rate indicated that air-filled porosity declined the most as sand size became finer under the greater topdressing rate (100-lb) than the lower (50-lb) topdressing rate. Capillary porosity increased the most as sand size became finer under the greater topdressing rate (100-lb) compared to topdressing at the lower (50-lb) rate. Capillary porosity was greatest under topdressing with the fine-medium sand regardless of the topdressing rate.

Bulk density measured *in situ* with a Troxler moisture density gauge during 2024 also indicated that sand size and topdressing rate effects depended on the cultivation factor. Plots treated with cultivation (14 hollow tine and three solid tine events) had a greater bulk density than non-cultivated plots. Additionally, under non-cultivated conditions, plots that were topdressed with fine-medium sand had the lowest bulk density compared to plots topdressed with medium-coarse or medium-fine sand. The greater topdressing rate increased bulk density compared to the lower topdressing rate under the non-cultivated conditions; however, this effect was not evident when plots were cultivated.

Data collection during 2024 also included visual ratings of turf quality, routine volumetric water content (VWC) of the surface 0- to 3-inch depth zone; Clegg soil impact values, ball roll measurements (GS3), normalized difference vegetation index (NDVI), dual-head water infiltration, and documentation of the number of hand-watering events and amount of water applied to individual plots. Additionally, we used a DJI Mavic 3 Multispectral drone to collect remote sensing data from the trial. Statistical analyses and summarization of these data are in progress.

Work planned for 2025 includes continuing treatments and data collection. A peer-review publication on the surface characteristics during the first seven years of this trial is in review for Agronomy Journal. And we are drafting a second publication focused on the physical properties within the mat layer during the first seven years of this trial and plan to submit it for review in Agronomy Journal.

Ecological Dynamics of Kentucky Bluegrass and Tall Fescue Turfgrass Swards

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Mixtures of tall fescue (TF) (*Festuca arundinacea* Shred.) and Kentucky bluegrass (KB) (*Poa pratensis* L.) during seeding is gaining popularity in the transition and northern climatic zones of the United States. Species mixtures provide better genetic diversity, improved disease tolerance, and reduced management inputs like fertilization and irrigation. Tall fescue is drought-tolerant and requires fewer inputs when compared to KB. Kentucky bluegrass has good establishment and recuperative potentials; however, genetic variability exists among cultivars, requires high inputs and spreads aggressively. Homeowners and turfgrass practitioners need information on population shift of KB in mixtures with TF. Repeated field experiments at Kansas State University were conducted in 2022 and 2023 to understand the ecological dynamics of KB classifications (e.g., Shamrock, Compact etc.) or growth aggressiveness labels (high, medium, and low) in a 95:5 (TF:KB w/w) mixture ratios over 2 years. Field was seeded in September and maintained in a lawn standard, and at 9, 12, 20, and 24 months after planting (MAP), a 58-cm^2 plug cutter was used to remove three plugs from plots. Percentage TF and KB tillers per plug were visually counted. Results revealed that KB growth aggressive label influenced ecological dynamics over 2 years. At 24 MAP, medium-aggressive cultivars ‘Bolt’, ‘Fullback’, and ‘Martha’ had more tillers spread with a 25–32% population increase. However, most low-aggressive cultivars had <10% population increase. Findings assist turfgrass breeders and practitioners with more information on cultivars when mixing TF and KB, in creating a sward that is chiefly TF, which saves management costs.

Tulipalins: A Natural Herbicide from a Tulip Bulb Waste Stream

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There is interest amongst the public in reducing 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 indicates that tulipalin which is a lactone found in tulip bulbs, has herbicidal properties both as a pre-emergent and as a post-emergent.

While almost 70% of all newly registered active pesticide ingredients have their origins in natural products research, only 8% of conventional herbicides are derived from natural compounds and only 7% of biochemical biopesticides (natural compounds) approved by the U.S. Environmental Protection Agency are bioherbicides. Tulip bulbs contain tulipalin lactones. They are stored in the bulbs in the form of a sugar conjugate called tuliposide. Tulipalin is released from the bulbs by acid hydrolysis. Early results indicate that tulipalin hydrolysed from its precursor tuliposide is also phytotoxic. We have found that synthetic tulipalin has herbicidal effects against crabgrass, clover, kyllinga, Palmer amaranth, and perennial ryegrass. There is more activity seen with sedges and dicots than with grasses and activity is greater in sand than in soil. Unlike mesotrione, synthetic tulipalin does not have residual activity.

Mowing and Plant Growth Regulators Affect Competition of *Eleusine indica* Ecotypes in Turfgrass

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The objective of this research was to determine the effects of mowing height, nitrogen (N) fertilizer, and plant growth regulator (PGR) on the competitiveness of two different goosegrass (*Eleusine indica*) ecotypes in Kentucky bluegrass (*Poa pratensis*) and annual bluegrass (*Poa annua*) turf. This experiment was conducted at the Rutgers Horticulture Farm No. 2 in North Brunswick, NJ from 2023 to 2024. Treatments consisted of four cultural management programs: 1) nontreated, 2) urea at 25 kg N ha^{-1} (N), 3) trinexapac-ethyl at 190 g ai ha^{-1} (PGR), and 4) N+PGR; applied every 21 d from May to September to whole plots planted with turf-type or crop-type goosegrass ecotypes. Goosegrass ecotypes were selected from New Jersey populations with distinct heritable morphological traits determined from greenhouse garden experiments; a turf ecotype collected from a golf course fairway and a crop ecotype collected from bare soil on a cranberry farm. Goosegrass ecotypes were transplanted into the field as leaf-stage seedlings in July. Sub-plot strips of mowing height (2.0 cm and 6.0 cm) were imposed to form a strip-plot RCB design. Monthly turfgrass density was evaluated visually on a 1 (i.e., no cover) to 9 (i.e., complete density) scale and percent green cover was calculated from lightbox photos using TurfAnalyzer software. At 10 weeks after planting, aboveground goosegrass biomass was harvested. Data were analyzed in SAS (v 9.4) and Fishers protected LSD test (α=0.05) was used to separate means. The dry weights of each goosegrass plant harvested were analyzed as a sub-samples. Significant effects of cultural management program and goosegrass ecotype were detected for goosegrass biomass, turfgrass quality and percent green cover in 2023 and 2024. Mowing height effects were significant for goosegrass biomass in 2023 and 2024. The interactions of mowing height and cultural management was significant in 2023. The highest order interaction of each year is presented.

In 2023, N-only and N+PGR programs had greater turfgrass density and green cover compared to nontreated and PGR-only programs. The PGR-only programs reduced density and green cover only temporarily in June 2023. N+PGR treatments had greater cover and density compared to all other programs throughout 2023 and until July 2024, when the PGR-only program had greater density and green cover. PGR and N+PGR were then similar for the rest of the experiment. In 2024, green cover and density declined in N-only treatments in July and was then like the nontreated from August onward. Green cover was similar for all treatments in September 2024 when the experiment concluded.

In 2023, crop-type goosegrass subjected to nontreated and N-only cultural management had the lowest biomass regardless of mowing height. The PGR-only program increased crop-type goosegrass biomass to 422% and 622% of the nontreated in the low and high mowing strips, respectively. N+PGR treatment increased crop-type biomass to 500% and 234% of the nontreated at low and high mowing, respectively. Biomass for the nontreated turf-types was greater than the crop-types. The N-only treatment reduced turf-type goosegrass biomass (45-50% of the nontreated) at both mowing heights. The PGR-only treatment increased turf-type goosegrass biomass to 115% and 148% of the nontreated at low and high mowing, respectively. Goosegrass biomass for the nontreated turf-type was greater than the nontreated crop-type.

In 2024, all goosegrass ecotypes accumulated more biomass at high mowing compared low. Across factors of mowing height, nontreated turf-type biomass was greater than the nontreated crop-type biomass. N-only treatment increased turf-type biomass to 117% of the nontreated. Turf-type goosegrass biomass was reduced by both PGR and N+PGR treatment (64% and 79% of the nontreated, respectively). In 2024, all cultural management programs increased crop-type biomass compared to the nontreated. Biomass of crop-types were 148%, 181% and 209% of the nontreated for N-only, PGR-only and N+PGR programs, respectively.

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