1. **What was accomplishments relative to project goals?**

Project Objectives:

1. Continue effective functioning of CAP team

* During the reporting period (09/01/2020 and 08/31/2021), the CAP team including industry advisory panel hold an annual virtual meeting at December 2020, several monthly teleconferences and sub-objective teleconferences.

1. Improve our understanding of turfgrass performance under drought

* TAMU: 1) A 2000 sq. ft. lysimetry field facility has been constructed in College Station Texas and data are being collected over the 2021 season to develop crop coefficient values for the advanced experimental lines. 2) College Station is in the final stages of grow-in of St. Augustinegrass pots in the greenhouse for drought mechanisms experiments. A severe hailstorm came through in February 2021, which damaged a large part of the greenhouse, but final repairs are being completed. These experiments should be initiated by late summer 2021. 3) Data has also been collected monthly using UAV equipped with a multi-spectral sensor in Dallas TX.
* OSU: 1) Established a field trial for bermudagrass, zoysiagrass, St. Augustinegrass and seashore paspalum genotypes under a rainout shelter. 2) Evaluated the rooting characteristics of bermudagrass genotypes under controlled environment condition. 3) Initiated a greenhouse trial to study the root and shoot response of bermudgrass genotypes under drought stress.
* UGA: 1) Data collection has begun under rain-out shelters to assess minimum water use requirements. 2) An initial run looking at drought tolerant seashore paspalum lines and commercial check cultivars have been performed in growth chamber conditions to assess physiological mechanism responsible for improved drought tolerance. Measurements have included water use and photosynthetic traits, as well as antioxidant metabolism, accumulation of protective solutes, and rooting characteristics. 3) UAS images are being collected on replicated field trial and single space plant nursey regularly at Georgia, North Carolina, Texas, and Oklahoma locations using the shared protocol. Subsequent image analysis and data extraction are being conducted at the UGA Tifton campus. Planning meeting to provide project updates and training for conducting flight and image analysis. Traveled to Florida to help set up new equipment and prepare the field for phenotyping.
* UF: Lysimeters were established in the greenhouse and installed in the field. Data is being collected to determine the water use of selected lines.
* NCSU: 1) Plant materials have been established in lysimters. Preliminary run of water use research to quantify reduced water requirements has been collected. 2) Breeding plots were setup with permanent ground control markers for use in the geometric rectification of the drone imagery. A RTK-GPS survey was performed to precisely locate the ground control markers. Additional storage was added to a computer dedicated to image processing and analysis. Standardized flight plans were developed, tested, and saved in flight control software. Three UAV flights were conducted to collect year 1 data on establishment and growth rate. Radiometric calibration panels were created and tested. Software code was developed to automate the creation of breeding plots for use in geospatial analysis (GIS). Initial code was developed to calculate common vegetative indices from multispectral imagery.

1. Continue pipeline of germplasm development and evaluation of advanced lines

* TAMU: 1) Establishment and evaluation of the SSPNs and advanced trial for all four warm-season turfgrasses planted at Dallas in July 2020. 2) Drought stress will only be imposed on the advanced trials in 2021 (starting August) and not on SSPNs due to slower rate of establishment of some entries. 3) Data has been collected from the SSPNs and advanced trials monthly in Dallas TX for establishment, turfgrass quality, spring greenup, and other seasonal traits. 4) Shade trial (80% shade) to evaluate elite St. Augustinegrass hybrids were planted in July 2020 at Dallas TX. Following unusually cold winters experienced in Dallas Texas in 2021, most of the entries were winter killed. Data is being collected on any surviving plots.
* OSU: 1) Production of new bermudagrass breeding lines: approximately 10,000 seedlings were developed from the seed. The best 440 seedlings were grown in a selection nursery on June 25, 2021. 2) 2020 SSPN seashore paspalum and St. Augustine nursery were winter killed, substantial winterkills were observed in the 2020 SSPN bermudagrass and zoysiagrass nursery. Data are continuously collected in these latter nurseries. 3) Collected data in the two replicated field tests in Approach C planted in 2020 for bermudagrass and zoysiagrass plots. Drought data will be collected based on progress of drought stress in 2021. 4) Established two field shade trials for bermudagrass and zoysiagrass in accordance with the proposal. 5) Initiated greenhouse shade physiology and morphology studies including evaluation of light use efficiency of selected St. Augustinegrasses and bermudagrasses. 6) Established two field sod trials for bermudagrass and zoysiagrass in accordance with the proposal.
* UGA: 1) Four SSPN field trials and four replicated field trials (RFTs) of advance lines planted in 2020 for evaluation of drought tolerance were maintained and reached establishment (> 80% coverage) by mid-summer 2021. Irrigation to these trials was discontinued July 1, 2021. Data collection from all trials using a combination of monthly drone images and visual scores began at green-up and has continued throughout the growing season. 2) An ancillary shade trial for seashore paspalum was planted in 2020 and allowed to establish until May of 2021 under full sun. Shade cloth (65%) was applied to the structure over the plots in mid-May. Plots were maintained according to protocols and digital images and turf quality data were collected monthly. 3) Salinity: all entries in the four RFT trials were increased in the greenhouse during 2021 to provide adequate plant materials for the greenhouse salt tolerance screening. Actual salt screens of St. Augustinegrass and bermudagrass are planned for fall and winter of 2021. Salt tolerance screenings for seashore paspalum and zoysiagrass are planned for 2022. 4) Sod: plant materials were received and have been propagated for establishment of sod strength field trials.
* UF: 1) New progenies were produced in the breeding program. 2) Trials were planted and are now established for SSPN and Approach C bermudagrass, St. Augustinegrass, seashore paspalum and zoysiagrass. 3) The field shade study was established for zoysiagrass and seashore paspalum. 4) The sod trial was established at WFREC
* NCSU:
* UCR: Data on establishment and turfgrass quality are being collected starting Fall 2020. In 2021, the salinity and restricted irrigation field studies were initiated on all four investigated species. Irrigation with saline water at electroconductivity (EC) level of 4.0 dSm-1 started on July 6th, 2021. Watering in the restricted irrigation trial was withheld on July 12, 2021. Data are being collected to evaluate changes in turfgrass quality under drought and salinity stress, and for recovery after restoring irrigation.

1. Develop marker-assisted breeding systems:

* TAMU: 1) Developed an *in vitro* method for quantification of salt secretion in zoysiagrass, 2) and has been used to evaluate salt secretion trait in major zoysiagrass cultivars. 3) Characterized candidate genes of sodium transporters in zoysiagrass. 4) Zoysia genome: performed comparative genomics analysis between zoysiagrass and other major grass lineages, and identified major evolutionary events. We are summarizing our results and preparing a manuscript.
* NCSU: 1) Conduct drought evaluation for new mapping population of St. Augustinegrass in greenhouse. 2) Constructed genotyping sequencing library of new Augustinegrass population. 3) RNA-Seq data analysis of St. Augustinegrass under drought stress to identify candidate genes. 4) Identified QTL of morphological traits associated with water usage in Augustinegrass, the manuscript has been submitted for review.
* OSU: 1) The nursery of 1,000 plants from nine polycrosses established on the OSU Agronomy Farm in 2020 was maintained to collect turf performance data. 2) A genetic analysis in African bermudagrass was completed to quantify genetic variability and identify QTL associated with winter survivability and drought resistance. The manuscript of this study is ready for submission to a peer-reviewed journal. 3) African bermudagrass OKC 1163 plants were delivered to Dr. Susana Milla-Lewis and Dr. Amanda Hulse-Kemp at USDA ARS for generating whole genome sequence.
* USDA: 1) St. Augustinegrass cultivar Raleigh was sequencing and assembled to chromosome scale. An additional assembly to chromosome scale was produced for a PI line St Augustinegrass. 2) An annotation pipeline for St. Augustinegrass is in development. 3) Flow cytometry has been completed for samples targeted for genome sequencing to determine genome size. 4) Lines have been identified for sequencing for African Bermudagrass. A draft genome assembly has been produced for one line of African Bermudagrass. 5) Additional long-read sequencing has been performed on hybrid bermudagrasses.
* UGA: 1) Generation of a new F2 mapping population. Tested additional accessions that can be used as parents in crosses. 2) Improvement of the seashore paspalum genome assembly, version 3.1, has been publicly released on Phytozome (https://phytozome-next.jgi.doe.gov/info/Pvaginatum\_v3\_1). 3) RNA was extracted, libraries generated and sequenced. Differential gene expression analyses are ongoing. 4) Metabolism: Plant materials for the target species (bermudagrass, seashore paspalum, St. Augustinegrass, and zoysiagrass) have been established in pots, and initial experiments screening plant drought responses and tissue collection for further analysis have begun. Preliminary trials for selected species (seashore paspalum and bermudagrass) were performed, and a protocol for metabolomic analysis has been tested.

1. Extension, outreach and impact:

* TAMUS: 1) Dr. Segars presented a total of 37 presentations and Dr. Bowling has presented a total of 24 presentations in 2021 that touched on newly developed cultivars by the SCRI project. 2) Dr. Segars conducted three county agent trainings and 10 master gardener presentations in 2021 that included updates on newly developed cultivars from the SCRI project and how they best fit into the Texas landscape. Dr. Bowling has conducted 5 master gardener trainings and 6 trainings for green industry professionals that have included updates on new cultivars from the SCRI project.
* OSU: 1) Seven Turfgrass Master Gardener Programs with a total of 98 attendees were conducted during fall of 2020 through spring of 2021 which included a revised segment covering use of bermudagrass having improved drought resistance. Cultivars Tahoma 31 and TifTuf bermudagrass were emphasized in the bermudagrass selection component of these programs. 2) Preliminary discusses were conducted with landscape leaders concerning potential semi-permanent installation of demonstration plots of the new bermudagrasses and zoysiagrasses that have been developed by the project. The plans are expected to be finalized during 2022 and installations started at that time. 3) Conducted a consumer survey to estimate homeowners’ preferences and tradeoff values between aesthetic quality attributes and low-input uses. 4) Collected turfgrass professionals’ virtual networking data via social media focusing on their social networking, new variety adoption, and socio-demographic information. The data have been analyzed to estimate the impact of consumers’ social networking on their new turfgrass adoption.
* UGA: 1) Media Professional Steering Committee operational. Turfgrass Specialist Steering Committee members operational. Steering committee focus group perceptions research underway, data collected, one article submitted. SCRI Turf project website established for education and communication of findings (<https://site.caes.uga.edu/scriturf/>). Social media channels created (Instagram, Facebook, Twitter). 2) Finished CNN inferencing for Atlanta, Orlando and Oklahoma City. Created labels for training the model for Raleigh

1. **What opportunities for training and professional development has the project provided?**

* TAMU: Training and professional development of Baoxin Chang (post-doctoral researcher), Reagan Hejl (PhD student/techician), Jose Diaz (MS Student) in physiology studies, Haomin Lyu and Zixiao Zhao (post-doctoral researchers) in genomics and plant molecular biology, Tianyi Wang and Meghyn Meeks (post-doctoral researcher and scientists) in turfgrass breeding and high-throughput phenotyping.
* OSU: 1) Two graduate students from Wu lab have been trained to work in breeding and genomics research. Shuhao Yu graduated in December, 2020. Ryan Earp helped on data collection. Two MS graduate students from Fontanier lab (Alyssa Counce and Anmol Kajla) have been trained on work related to shade physiology, with both graduated August 2021. Two MS graduate students from Moss lab (Charanpreet Kaur and Sehijpreet Kaur) have been trained to work related to drought performance cultivar evaluation. Charanpreet Kaur graduated in August 2021. Sehijpreet Kaur helped in data collection. Two Ph.D. students from Chung’s research team (Hyojae Jung and Joohun Han) have been trained for estimating economic effect of new turfgrass development and factors affecting the effect. 2) Colten Martin and Kellen King worked on this project. Three undergraduate research interns (Ashton Franks, Abigail Hobbs, Peyton Baggs) contributed to shade and sod field trials. Ms. Baily Lockhart, Ms. Brooklyn Evans, Ms. Gracie Hladik and Ms. Kailyn Twyman worked on the controlled environment and field trials. 3) Dr. Lakshmy Gopinath (post-doc) worked on data collection from the controlled environment physiology and field trials.
* UCR: The project has provided training in conducting field studies for our graduate student and information about advantages and possibilities of using warm-season turfgrass species in Southern California for landscapers, other professionals and general audience through a webinar at the Landscape Expo Academy in January 2021.
* UGA: Provided training and professional development for 3 graduate students (Qianqian Fan, Ravneet Kaur, Krishna Katuwal) in establishment of plants for both field and pots studies, experimental design, data collection, and analysis of data. One graduate student (Katherine Catching) in experimental design and field layout, organization of plant materials, field maintenance, data collection, and greenhouse propagation. Program technical staff and student workers also received similar training. One technical staff received training on image capture using a UAV. One PhD student, Shreena Pradhan, and one post-doc, John Spiekerman, in genomic projects. Barbara Worley (graduate student) and Edy Copeland (Undergraduate student)– Receiving training on Focus Group research methods, qualitative research methods, qualitative sampling, symposium presentation, conference presentation, research article written.– Received training on Focus Group research methods, qualitative research methods, qualitative sampling, poster creation, symposium presentation, conference presentation. Dr. Nick Fuhrman – Consultation with Dr. Taylor Ruth (author) of seminal article used as theoretical framework for this study.
* NCSU: Postdoc Beatriz Tome Gouveia was hired in breeding program to analyze field and research data. MS student Greta Rockstad was trained to working on developing mapping population and high-throughput phenotypic tools. Rotation Ph.D student Nico Lara was trained to collect morphological data from field trials. MS Student Cory Ketchum on water use and drought tolerance data collection training. Ph.D student Ashley Schoonmaker was trained to generate high-quality reference genome assemblies, perform linkage mapping and proper experimental design. In addition, multiple graduate students and research technicians were trained in the safe and proper use of UAV technology, best practices and proper workflows to operate and collect data using drone technology, process imagery in photogrammetry software, use GIS and image classification to summarize results, use programming languages such as R and python to view and process imagery.

1. **How have the results been disseminated to communities of interest?**
   * Presentations
     1. C. Segars. Offered at least 37 outreach presentations involving cultivar performance and variety selection.
     2. C. Segars. Offered three county agent trainings and 10 master gardener presentations.
     3. B. Wherley. 2021. Technologies & Tools for Improving Lawn Irrigation Management. Texas Nursery and Landscape Association Water & Pest Workshop. Virtual. May 14. Invited.
     4. B. Wherley. 2020. Deficit Irrigation as a Strategy for Golf Course Water Conservation. West Texas GCSA/ TCEQ Irrigators Education Session. October 28. Invited.
     5. B. Wherley. 2020. Turfgrass Research at Texas A&M that Benefits the Golf Course Superintendent. West Texas GCSA/ TCEQ Irrigators Education Session. October 27. Invited.
     6. B. Wherley. 2020. Texas A&M Turfgrass Research Update for Sports Field Managers. Texas Turfgrass Association Summer Meeting. July 21. Invited.
     7. Yu, Q. 2020. Genome evolution in zoysiagrass. Oct. 28, 2020, Department of Plant Pathology & Microbiology Seminar Series, Texas A&M University, College Station, Texas, USA
     8. B. Bowling. Offered at least 24 outreach presentation involving cultivar performance and variety selection.
     9. B. Bowling. Offered 5 Master Gardener presentations and 6 presentations specifically for green industry professionals including landscape architects, turfgrass producers and other land care operators.
     10. Kajla, A., C. Fontanier, L. Zhang, Y.Q. Wu, A. Chandra, B. Schwartz, and S. Milla-Lewis. 2020. Effect of low light conditions on photosynthetic parameters of selected warm-season turfgrasses. ASA-CSSA-SSSA Meetings.
     11. Kaur, C, J. Moss, Y. Wu, and D. Martin. 2020. Differences in rooting characteristics of bermudagrass cultivars and OSU experimental genotypes. ASA-CSSA-SSSA Meetings.
     12. Jung, H., and C. Chung. 2021. Estimating Consumers’ Preference on Improved Turfgrass Attributes Considering Adverse Effects on Aesthetic Values. AAEA Annual Conference, Austin, TX, August 1-3.
     13. Han, J., C. Chung, and Wu. 2021. Effects of Social Networking on the Adoption of New Turfgrass Varieties. AAEA Annual Conference, Austin, TX, August 1-3.
     14. Zhang, J., Austin, R., Wang, T., Maleski, J., Milla-Lewis, S.R., Chandra, A., Moss, J.Q., Wu, Y., Kenworthy, K., Raymer, P., and B.M. Schwartz. Developing UAS Based High-throughput Phenotyping Tools in Turfgrass Variety Trials. SCRI fall meeting. Virtual. December 2020.
     15. Zhang, J., J. Maleski, and B. Schwartz. 2021. Precision Agriculture and Object Recognition in Turfgrass. UGA Office of Government Relations Congressional Staff Tour. August 19th. Athens, GA.
     16. Schwartz, B. 2021. Drought Tolerant Turfgrasses Can Reduce Urban Water Use in Georgia. Greater Atlanta Home Builders Association Stop Watering and Start Saving: TifTuf Bermudagrass. Georgia Association of Water Professionals – NG Turf Meeting. August 19th.
     17. Schwartz, B. 2021. Stop Watering and Start Saving: TifTuf Bermudagrass. Georgia Association of Water Professionals Annual Conference – Georgia Water Wise Council. July 13th.
     18. Schwartz, B. 2021. Are Newly Developed Drought and Shade Tolerant Grasses Really What Golf Course Superintendents Need To Be Successful In The Future? GGCSA Bentgrass/Bermudagrass Forum. March 22nd.
     19. Schwartz, B. 2021. TifTuf Bermudagrass, a Good Steward of Georgia’s Water Resources. Georgia Water Wise Council Meeting. February 15th.
     20. Using Key-Player and Decision-Making Models to Increase Diffusion of Innovations in Turf. Round Table Session Southern Region American Association for Agricultural Education Conference. Virtual
     21. Annual Grant Team Update: Using KeyPlayers and Decision-Making Models to Increase Diffusion of Innovations in Turf. December, 2020 SCRI Grant Annual Meeting
     22. Extension communications on the importance of selecting water saving turfgrasses at local agent trainings and industry updates (+10 meetings); Radio interview [WSB 95.5 FM]
     23. Maleski, J., Zhang, J., and B.M. Schwartz. Turf Survey Update. SCRI fall meeting. Virtual. December 2020.
     24. Cory Ketchum – Water use in turfgrasses. The Mid-Atlantic Turfgrass Expo Jan 19, 2021.
     25. Grady Miller – Blades of Green, Shades of Ecology. The Mid-Atlantic Turfgrass Expo Jan 19, 2021.
     26. Grady Miller – Drought tolerant turfgrasses for NC. Extension Agent and Master Gardener Training. Raleigh, NC. May 6, 2021.
     27. Grady Miller – Drought tolerant turfgrasses for NC. Master Gardener Training. Charlotte, NC. March 5, 2021.
     28. Grady Miller – Turfgrasses for NC. Landscape Conference. Rocky Mount, NC. Feb 14, 2021.
     29. Gouveia, B., Raymer, P.L., Schwartz, B.M., Kenworthy, K.E., Fontanier, C., Porto, A.C., Rios, E.F., Unruh, J.B., and Milla-Lewis, S.R. 2020. Performance and Genotype-By-Environment Interaction in Seashore Paspalum (Paspalum vaginatum) Evaluated Under Shade Conditions. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Phoenix, AZ. Nov 8-11.
     30. Porto, A.C., Paudel, D., Gouveia, B.T., Kenworthy, K.E., Kruse, J.K., Munoz, P.R., Schwartz, B.M., Novaes, E., Milla-Lewis, S.R., and Rios, E.F. 2020 Multi-Environment Evaluation of St. Augustinegrass Genotypes Under Shade. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Phoenix, AZ. Nov 8-11.
     31. Rockstad, G.B., Austin, R., Yu, X., Carbajal, E.M., Dunne, J.C., Miller, G.L., Jespersen, D., and Milla-Lewis, S.R. 2020. Evaluation of UAV-Based Imagery for Drought Stress Traits in St. Augustinegrass. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Phoenix, AZ. Nov 8-11.
   * Field days
     1. TAMU field day in Dallas Texas. October 7, 2020, Cancelled due to COVID-19.
     2. OSU: Field tour with Jon Brown of Bethel Farms on Sept 29, 2020.
     3. OSU: Field tour with Paul Jacobs of US Golf Association on April 21, 2021.
     4. OSU: Field tour with US Golf Association visitors on July 6, 2021.
     5. OSU: Field tour with Chad Adcock of Sod Production Services on August 2, 2021.
     6. Schwartz, B.M. 2021. An Overview of the Turfgrass Breeding Program at the University of Georgia – Tifton Campus. Buy Sod Field Tour. July 1st. Tifton, GA
     7. Schwartz, B.M. 2021. An Overview of the Turfgrass Breeding Program at the University of Georgia – Tifton Campus. Bethel Farms Turf Tour. April 16th. Tifton, GA
     8. Fox, J. and B.M. Schwartz. 2021. An Overview of the Turfgrass Breeding Program at the University of Georgia – Tifton Campus. Woerner Turf Tour. January 7th. Tifton, GA
     9. NCSU 2021 Turfgrass Field day. August 11, 2021.
   * Social media
     1. The TAMU Extension Team has delivered Extension/outreach education through multiple platforms:
        + AggieTurf Website: https://aggieturf.tamu.edu – which also houses all Extension publications for the AggieTurf program.
        + AggieTurf Facebook Page: 2,633 Followers
        + AggieTurf Twitter: 1,877 Followers
        + Segars Twitter: 682 Followers
        + Bowling Twitter: 1,082 Followers
        + Constant Contact Email Listserv (~1600 subscribers)
     2. Twitter: Yanqi Wu tweeted multiple times on the project field operations and Tahoma 31 bermudagrass released from the previous SCRI project. The information has been disseminated to more than 1600 professionals in the turf industry.
   * Other
     1. Dennis Martin conducted 10 golf course, 5 municipal park, 5 professional landscape installer, and 23 residential consultations alerting end users concerning the availability and benefits of using either Tahoma 31 or TifTuf bermudagrass (products of this multi-state grant) at time of next bermudagrass install. Winterkill was serious in the region and many end-users were considering options for regressing of damaged sites in spring of 2021.
2. **What do your plan to do during the next year to accomplish project goals?**

* **Objective 1:**
  + Planning the fall annual meeting during ASA/CSSA meeting at Salt Lake City at Nov. 2021. Planning summer meeting and monthly teleconferences.
* **Objective 2:**
  + OSU: The drought field and physiological trials will be evaluated in accordance with the project proposal and overall team discussions. Publication of drought physiology studies are expected in 2022.
  + UGA: 2A - Next year the field trial to determine minimum water requirements will continue during the 2022 growing season, for a second repeated year of data collection. 2B - Analysis of data from initial controlled environment well be performed and a repeat of the experiment will be performed in necessary. 2C - Continue collecting UAS images throughout the growing season, winter dormancy and spring green-up in all locations. Continue provide technique support for the team. Disseminate the knowledge obtained from the process to the public.
  + NCSU: 2A- Continue water use evaluation in field lysimeters. 2C- Next year we will conduct flights every two to three weeks over breeding plots.We will collect additional on-ground imagery for calibration and validation of UAV data and processing methods. We will continue to collect soil moisture and volumetric water content to help characterize seasonal changes in water availability at the site. We will develop additional tools and code to automate the processing and analysis of UAV-imagery for use in turf grass breeding programs. We will refine workflows and identify bottlenecks in UAV-based turf phenotyping. We will build relationships with collaborating universities to help guide analysis and standardize results. Continue to disseminate results are share research with stakeholders and other interested parties.
* **Objective 3:**
  + TAMU: Initiate drought stress on the 2021 SSPNs and advanced trial for all four warm-season turfgrass species; continue data collection on the SSPN, advanced and shade trials.
  + OSU: The shade field trials will be evaluated in accordance with the project proposal and overall team discussions. Publication of shade physiology studies are expected in 2022.
  + UGA: Actual salt screens of St. Augustinegrass and bermudagrass are planned for fall and winter of 2021. Salt tolerance screenings for seashore paspalum and zoysiagrass are planned for 2022.
  + UF: 1) We will continue to collect data from all trials with a goal of allowing for drought stress to occur in all SSPN and Approach C trials. 2) New populations of progeny from the breeding program will be established. 3) A graduate student will begin conducting research on management of CitraBlue St. Augustinegrass. This cultivar was developed using SCRI funding. However, additional information is needed for management.
  + UCR: Evaluation of lines in single space plant nurseries and advanced trials will continue. Salinity field trial will be continued until end of October 2021 after that irrigation with potable water will be restored for recovery over the winter. Irrigation with saline water will be initiated again in early summer 2022. If weather conditions allow, water will be restricted once more this season. After recovery over the winter, drought will be initiated again in early summer of 2022. The UCR Turfgrass & Landscape Research Field Day will take place on September 16, 2021. The salinity trial will be presented during this event to golf course superintendents and other turf professionals. The Field Day report presenting results from the first year of this study will be published on the UCR Turfgrass website.
  + NCSU: Sod production trials have been initiated, will be monitored through 2021 growing season and for green-up in 2022 before evaluating sod tensile strength in 2022.
* **Objective 4:**
  + UGA: 4A - We will complete the differential expression analysis from the generated RNASeq data, and focus on validating the expression of sodium and potassium transporters. Efforts to generate and validate additional seashore paspalum crosses between parents that differ in their salt response will also continue. 4B - Tissue harvested from current experiments will be used for metabolite and RNASeq analysis, to identify potential candidate genes and key pathways responsible for drought tolerance in improved lines.
  + NCSU: GBS will be conducted to genotype new mapping population and a linkage map will be produced. Field and greenhouse data will be taken on drought traits. Paper of drought RNA-Seq will be completed.
  + USDA: 1) We will finalize both St. Augustinegrass reference genomes and perform annotation. 2) We will sequence, assemble and annotate African Bermudagrass. We will collect RNAseq data for annotation and collect prior data from collaborators. 3) We will sequence a set of parental lines used for generating triploids from African Bermudagrass. 4) Hire a postdoc on the project to work on integration of genomics-based resources across species.
* **Objective 5:**
  + NCSU: Continue working with team on Socio-economic analysis via surveys.
  + TAMU: 1) Plans to conduct more outreach presentations on newly developed cultivars with best management practices for the Texas landscape. 2) Plans to create at least two factsheets on newly developed cultivars and best management practices for the Texas landscape. 3) Showcase SCRI plots and data at the 2021 Texas A&M Turfgrass Field Day
  + OSU: 1) Consultations will continue with prospective sod producers concerning availability of production licenses of new SCRI warm-season grass products. 2) Consultations will continue with sports field managers, golf course superintendents, turf managers and consumers concerning availability and fit of the newly commercialized warm-season turfgrasses with improved drought resistance. 3) Continuous effort will be made to investigate homeowner’s preferences for new turfgrass attributes particularly focusing on tradeoffs between low-input and aesthetic attributes; we will also develop econometric procedures to estimate the economic effect of social networking among consumers on new variety adoption; special effort will be made to consider climate change for our research.
  + UGA: 5A - Testing communication artifacts and communication channels with the Media and Turfgrass Professionals to identify communication channels and create media artifacts for different audiences: television spots, websites, social media, press releases, extension bulletins, etc. Produce a television segment on innovative tools resulting from this grant to air on Georgia Public Broadcasting and nationally through Rural Free Delivery (RFD) television. Utilize KeyPlayers that are identified to maximize the impact of educational media and trainings to increase impact on the turfgrass network and subsequent strata of the network. Utilize, test, and refine the Decision-Making Model in Agricultural and Natural Resources to create a more efficient and reusable model for turfgrass professionals to increase impact on the turfgrass network and subsequent strata of the network. Submit conference presentation to Association for Communication Excellence Conference focused on increasing impact of communication within the turfgrass network. 5C - Continue transfer learning with new labels to better generalize the model for different locations. Train on Leaf-Off imagery to better quantify area under canopy. Present work at Field Day and CSSA annual conference.

1. **Products**
   * Publications (Journal, Book, dissertation, proceedings, conference paper…)
     1. R. Hejl, B. Wherley, and C. Fontanier. 20XX. Long-Term Performance of Warm-Season Turfgrass Species Under Municipal Irrigation Frequency Restrictions. *In Press* HortScience.
     2. M. Chavarria, B. Wherley, R. Jessup, and A. Chandra. 2021. Physiological Responses to Salinity among Warm-Season Turfgrasses of Contrasting Salinity Tolerance. *In Press* Journal of Agronomy & Crop Science. <https://doi.org/10.1111/jac.12501>
     3. B. Chang, B. Wherley, J. Aitkenhead-Peterson, and J. West. 2020. Water chemistry and nitrogen source effect foliar uptake efficiency in ‘Champion’ bermudagrass. *In Press* Journal of Plant Nutrition. <https://doi.org/10.1080/01904167.2020.1783310>
     4. M. Chavarria, B. Wherley, R. Jessup, and A. Chandra. 2020. Leaf anatomical responses and chemical composition of warm-season turfgrasses to increasing salinity. Current Plant Biology 22: 100147 <https://doi.org/10.1016/j.cpb.2020.100147>
     5. Xu, Y., J. Zhang, J. Zhao, J. Song, Q. Yu. 2021. An improved virus-induced gene silencing (VIGS) system in zoysiagrass. In: RNA-based technologies for functional genomics in plants, edited by G. Tang, S. Teotia, X. Tang, D. Singh. Springer. Pp 155-168.
     6. Gopinath, L., J.Q. Moss, and Y.Q. Wu. 2021. Evaluating the freeze tolerance of bermudagrass genotypes. Agrosystems, Geosciences, & Environment. DOI: 10.1002/agg2.20170.
     7. Chhetri, M., C. Fontanier, J.Q. Moss, and Y.Q. Wu. 2021. Effect of combined shade and drought stress on bermudagrass turf. International Turfgrass Society Research Journal. 1-11. DOI:10.1002/its2.68.
     8. Gopinath, L., J.Q. Moss, and Y.Q. Wu. 2021. Quantifying freeze tolerance of putting green type bermudagrasses. HortScience. 56:478-480. <https://doi.org/10.21273/HORTSCI15606-20>
     9. Yu, S.H., T.L. Fang, H.X. Dong, L.L. Yan, D.L. Martin, J.Q. Moss, C.H. Fontanier, and Y.Q. Wu. 2021. Genetic and QTL mapping in African bermudagrass. The Plant Genome. 14: e20073. DOI:10.1002/tpg2.20073
     10. Godwin, C., T. Fang, andY.Q. Wu.2021. Genetic identity and diversity among experimental selections and cultivars of vegetatively propagated turf bermudagrass as assessed with SSR Markers. International Turfgrass Society Research Journal. 1-10, **DOI:**10.1002/its2.29.
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   * Patents
   * Others (activities, events, service, products…)
     1. Copeland, E., Peake, J., Fuhrman, N. (2021, Spring) Improving drought tolerance and sustainability of turfgrasses used in southern landscapes through the integration of breeding, genetics, physiology, economics, and outreach. College of Agricultural and Environmental Sciences Center Undergraduate Research Symposium. $500, January, 2020.
2. **FTE’s**
3. Actual FTE report (Not include NCSU team)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Role | Faculty and Non-Students | Students with Staffing Roles | | |
| Undergrad | Graduate | Post-doc |
| Scientist | 1+1.73+0.3+0.08 | 2+5+0.55+1.5 | 2+4+1.3 | 4+1+0.1 |
| Professional | 1+0.14+0.02 |  |  |  |
| Technical | 1+0.4+0.04 | 0.2 | 2 |  |
| Administrative | 0.5+0.05 |  |  |  |
| Other |  |  |  |  |

1. Student Count

How many undergraduates, grad students and post-docs were trained or paid by the grant?

* + TAMU: 3 undergraduate students.
  + OSU: 6 graduates and 5 undergraduate students
  + UGA: 1 Post-doc; 6 Graduate students; 6 Undergraduate students.
  + UF: 4 Graduate students
  + UCR: 1 graduate student.
  + NCSU: 3 graduate student, one postdoc.
  + Total: More than 10 undergraduate students, 15 graduate students, 4 postdoc

1. **Changes or problems**
   * TAMU: 1) Covid 19 university shutdown at TAMU led to delays in progress towards year 1 project goals, but things are beginning to catch back up, and we should be in decent shape to meet our assigned objectives after this season. 2) A severe hailstorm damaged the turf greenhouses at TAMU, and are finally being repaired. This has delayed initiation of drought mechanisms research, but we should be able to catch up by late fall 2021.
   * OSU: As all plants of the SSPN seashore paspalum and St. Augustinegrass nurseries were completely winterkilled, data collection in the two nurseries has not been continued since the spring of 2021.
   * UGA: 1) Several delays have occurred (largely due to the pandemic), these have included field trials started later in the year than originally planed (due to materials that had late planting dates in the previous year needing to finish establishing in field plots), as well as delays in hiring graduate students to work on specific objectives (i.e. candidate gene identification). While there have been some delays in the completion of experiments, we still believe we can accomplish the proposed objectives. 2) All crosses between PI 299042 and HI10 failed, indicating that a crossability barrier exists between these two lines. We are now attempting to generate crosses between other parental lines that vary in leaf structure, including papilla size and salt tolerance. 3) Identifying timelines for steering committees’ meetings in the spring will pose challenges as turfgrass professionals face heavy time constraints in the spring of each year. It is likely that with COVID-19 limiting travel and time constraints that these committee meetings will continue to be held virtually.
   * UF: Drought and salinity trials were initiated later than planned due to slower establishment of zoysiagrass and pest infestation.
   * NCSU: Due to conronavirus affecting labs, scaffolding to generate pseudomolecules had to be changed from completion with BioNano technology to scaffolding with linkage maps for St. Augustinegrass. Savings from this effort will allow for sequencing a second St. Augustinegrass which is included in the disease resistance study.