USGA

Turfgrass and Environmental Research Online

...Using Science to Benefit Golf

The USDA-ARS Forage and Range Research Lab (FRRL) in Logan, Utah continues their work to identify and develop drought-tolerant turfgrass germplasm. FRRL staff have collected over 350 accessions from eight different grass genera from Russia and Uurasia and are evaluating them for various low-input traits.

Volume 9, Number 2
January 15, 2010

PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 400 projects at a cost of $30 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

Editor

Jeff Nus, Ph.D.
1032 Rogers Place
Lawrence, KS 66049
jnus@usga.org
(785) 832-2300
(785) 832-9265 (fax)

Research Director

Michael P. Kenna, Ph.D.
P.O. Box 2227
Stillwater, OK 74076
mkenna@usga.org
(405) 743-3900
(405) 743-3910 (fax)

Developing Drought Tolerant and Salt Resistant Turfgrasses

Kevin Morris and Shaun Bushman

SUMMARY

Potable water used for turfgrass irrigation is either being reduced or eliminated in many areas of the U.S. In some areas, turfgrass managers must use low quality, often saline, non-potable water for irrigation. Therefore, the development of drought tolerant and salt resistant grasses is extremely important for the turfgrass industry.

- The USDA-ARS Forage and Range Research Lab (FRRL) in Logan, UT is actively involved in many aspects of the identification and development of drought tolerant germplasm. In 1999, they released an improved crested wheatgrass cultivar, 'RoadCrest', and are working on the development of an improved cultivar, 'RoadCrest II'.
- Recently, the lab investigated the salt tolerance of Kentucky bluegrass and identified Kentucky bluegrasses that tolerate irrigation water with a salt content of up to 5 d Sm^{-1}. In addition, they are researching the genetic mechanisms that control salt tolerance and are working to develop genomic tools for Kentucky bluegrass.
- To further enhance turfgrass germplasm, the FRRL staff has collected unique drought tolerant germplasm from Russia and Eurasia. Over 350 accessions from eight different grass genera are being evaluated for various low input traits in Logan, UT. The most promising of these plants will be used to develop enhanced drought tolerant germplasm.

Reducing the water, pesticide, and fertilizer inputs needed to manage golf courses, lawns, parks, and athletic fields is one of the great challenges of the turfgrass industry. Irrigation of turfgrass is probably the most scrutinized practice currently faced by turf managers, and the use of recycled (or effluent) water is increasing because of need, availability, or regulations to do so.

According to Fender (6), a greater percentage of Americans (84% in 2000 vs. 70% in 1970) are reliant on a public water supply than ever. Increasing public water use means more water is needed in summer to meet peak demand (water for outdoor uses such as landscape irrigation, car washing, etc.). Peak demand in summer causes water use to increase by 50% or more. This great reliance on public water strains, even more, water purveyors (public water utilities) as they are strive to have water available to meet peak demand.

If public water utilities are to increase the amount water available to satisfy a growing population, their options are to: 1) build additional infrastructure (meaning higher costs), 2) locate and/or develop new water sources, or 3) regulate the amount of water available for outdoor uses. In some cases, water utilities are paying homeowners to remove turfgrass from lawns in the name of water conservation (15). These "cash for grass" programs result in landscapes that use no turfgrass, instead utilize native vegetation, rocks, mulch, and other ground covers. In other instances, municipalities are proposing limits on the amount of landscape irrigated, or the types of species planted. These proposals are not only emerging in arid states, but also in "water-rich" areas, such as the Northeast U.S. (10).

Even the federal government is considering the business of outdoor water use reduction.

'RoadCrest-II' spreading-type crested wheatgrass will maintain green color under irrigation, go dormant without water, and completely recover year after year.

KEVIN MORRIS, President, National Turfgrass Federation, Inc., Beltsville, MD; and SHAUN BUSHMAN, Ph.D. Research Geneticist , USDA-ARS, Forage and Range Research Lab , Logan, UT.

USGA Turfgrass and Environmental Research Online 9(2):1-7.
TGIF Record Number: 160026

Greenhouse evaluations of Kentucky bluegrass salt tolerance found several accessions that maintained green color under salty irrigation as much as tall fescue and perennial ryegrass varieties.

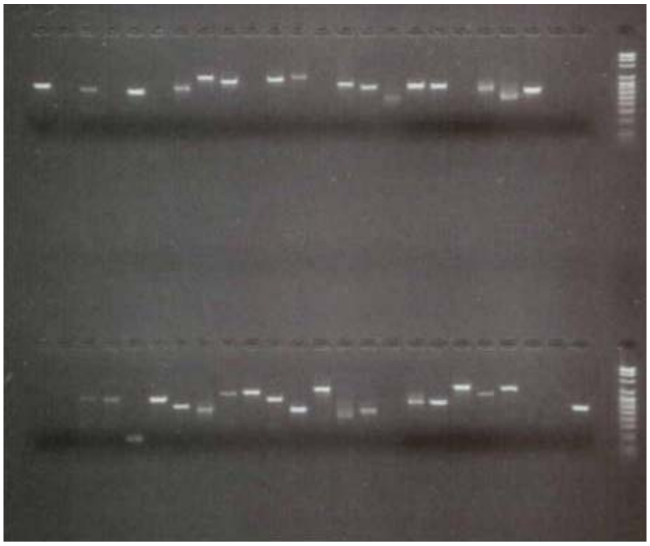
The Environmental Protection Agency's (EPA) WaterSense® new homes program is suggesting either a 40% limit on turfgrass planting or a water budget based on 70% ET_o (potential evapotranspiration) for the entire landscape (5). The purpose of the program is to encourage water conservation outside, as well as inside the home. Even though WaterSense® is a voluntary program, many municipalities and water utilities will likely use this program as a model to develop locally-implemented regulations on water use. These proposals are already starting to surface based only the draft new home Water Sense® specification (10).

In short, gazing into the turfgrass crystal ball shows less potable water available for turfgrass nationwide. In addition, the public is less amenable to the use of potable water to irrigate turfgrass, especially when public drinking water supplies are in greater demand for basic household uses.

Developing Water Saving Turfgrasses

Thanks to the National Turfgrass Research Initiative (NTRI), funding for turfgrass research within the United States Department of Agriculture's Agricultural Research Service (USDA-ARS) has increased to about $1 million per year. In addition, NTRI is designated as a high-priority research initiative in the 2007 Farm Bill under the Specialty Crops label (8). One of the six major objectives of NTRI is to improve the water efficiency of turfgrass and turfgrass systems (9). Water efficiency can be accomplished by reducing the amount of water used, improving the delivery and effectiveness of the water currently used, or utilizing non-potable/poor quality water (non drinking sources) for turfgrass.

The USDA-ARS Forage and Range Research Lab (FRRL) is dedicated to reducing potable (drinking) water use of turfgrass. FRRL is located in Logan, UT on the Utah State University campus. Although traditionally studying dryland



Kentucky bluegrass genes conferring salt tolerance can be separated based on DNA fragment size, as shown above by white 'bands' in an agarose gel matrix. Each band represents a different gene whose expression is induced by salt stress. These genes can be sequenced, and often their function identified.

grasses and legumes with an emphasis on forage production, low water use turfgrass research at the FRRL has been underway since the early 1990s. Currently, of the twelve scientists in the FRRL, six have research projects concerning at least one of three turf species and have formed an internal turfgrass working group. In the Intermountain West of the U.S., the lab's main challenge is to maintain or improve turf quality under environmental stresses such as water deficits, saline irrigation, and heat. Their research encompasses disciplines from plant breeding to molecular genetics to address challenges in turf science from several perspectives.

Breeding Low Water Use Species For Turf

Research on water-saving turfgrasses actually began at FRRL back in the 1990's when Dr. Kay Asay and others evaluated spreading-type wheatgrasses for turf quality, and subsequently released 'RoadCrest' crested wheatgrass in 1999. This initial focus toward drought tolerant turfgrass development has continued, with research recently expanded to include Kentucky bluegrass and fescues.

Crested wheatgrass (*Agropyron cristatum* L. Gaertn.) is a persistent, long-lived perennial native to Russia and Siberia (11). Wheatgrasses are well adapted to the semiarid temperate regions of the Western U.S., where 10 to 20 inches of annual rainfall is the norm (1). Like many perennial grasses that evolve in semi-arid environments, often drought tolerance in the plant is manifested through summer dormancy. However, in lawn situations, long-term drought induced dormancy is undesirable (3), therefore, wheatgrass must be improved for its color retention during drought. Also, crested wheatgrasses must be developed that are lower-growing, more dense, and generally more attractive in a turf setting.

‘RoadCrest’ crested wheatgrass was selected for rhizomatous growth habit, short stature, and fine leaves under low maintenance conditions (2). Turf quality and color of ‘RoadCrest’ are not as good as Kentucky bluegrass, tall fescue, or perennial ryegrass under optimum environmental conditions. However, ‘RoadCrest’ is adapted and will survive without irrigation in areas receiving only 10 to 20 inches of annual precipitation. In semiarid climates, ‘RoadCrest’ greens-up in early spring, remains green until mid-summer dormancy, and greens back up as temperatures decline in the fall. Besides roadsides, ‘RoadCrest’ is used in more traditional low-maintenance turf settings, such as summer cabins and golf course roughs (often in seeding mixtures with streambank wheatgrass and fine fescue), in the Northern Plains and western U.S.

Additional research showed that there is significant variation within crested wheatgrass populations to improve characteristics such as turf quality, spring regrowth, summer color, and spread rate (7). Robins et al. (12) found that heritability estimates for crested wheatgrass were generally high for turf quality traits, suggesting that breeding improvements could be made within this species. From those promising results, Dr. Blair Waldron of FRRL is currently developing ‘RoadCrest-II’, an improved derivative of RoadCrest with shorter stature, finer leaves, better turf quality, and greater rhizome production. ‘RoadCrest-II’, and additional future improved


Kentucky bluegrass plots receiving 50% ET_0 replacement of water, and minimal fertilization. The photo was taken in late September after temperatures cooled.

crested wheatgrass cultivars should provide turf managers with new options for low-maintenance landscapes to help meet the growing need for water conservation.

Improving Salt and Drought Tolerance in Kentucky Bluegrass

According to Carrow and Duncan (4), about 10% of the Earth's total land surface contains salt-affected soil, with 33 to 50% of all irrigated land being influenced by salinity. Low quality, non-potable water, including wastewater, is increasingly being used for irrigation. These waters are often high in various salts. Therefore, there is a great need to improve salt tolerance in many turfgrass species. As a result, the FRRL team decided to evaluate bluegrass for variation to environmental stresses, including salt tolerance. The initial project began two years ago, in collaboration with Dr. Paul Johnson of Utah State University and the U.S. Golf Association, by evaluating Kentucky bluegrass accessions housed in the National Plant Germplasm System (NPGS) for salt tolerance. The NPGS includes over 300 accessions of Kentucky bluegrass that have been collected worldwide.

Drs. Joe Robins, Shaun Bushman, and Paul Johnson chose a subset of those accessions and evaluated their ability to maintain acceptable green color while being subjected to increasing levels of salt over time (13). The solution salt levels used started at EC (electrical conductivity) of 3 dS m^{-1} and gradually increased to 33 dS m^{-1}. They found substantial variation for salt tolerance, with some Kentucky bluegrass accessions as tolerant as tall fescue and perennial ryegrass standard varieties. They are now in the process of

Year	Location	Genus (Number of Collections)
2008	Ural Mountains, Russia	*Agrostis* (12), *Festuca* (18), *Poa* (23)
2007	Northwestern Russia	*Agrostis* (18), *Festuca* (25), *Koeleria* (12), *Poa* (17)
2006	Inner Mongolia, China	*Agropyron* (14), *Agrostis* (25), *Festuca* (4), *Leymus* (27), *Poa* (36), *Zoysia* (40)
2006	Kyrgyzstan	*Agrostis* (25), *Festuca* (18), *Koeleria* (2), *Poa* (65), *Puccinellia* (3)

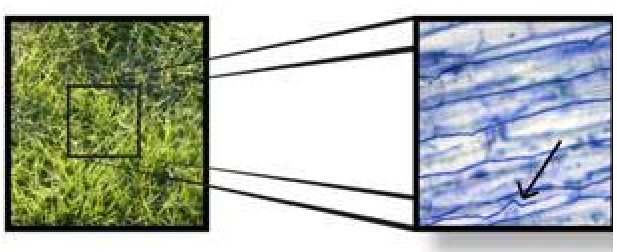
Table 1. Recent germplasm collection trips conducted by Douglas A. Johnson from the USDA-ARS Forage and Range Research Lab at Logan, UT targeting turf genera.

expanding the evaluation of the most tolerant plants for turf quality and seed production.

Although development of salt tolerant plants is important, the team is also determining the genetic mechanisms behind salt tolerance (14). They are selecting salt tolerant and susceptible plants and identifying genes that are expressed in tolerant plants but not in susceptible plants. Kentucky bluegrass, with its apomixis (clonal production of seed) and high polyploidy (more than two sets of chromosomes), has never been what could be called a model research plant from a genetics standpoint. Thus, most of the genes found are unique or currently unidentified.

The goal is to use these genes as DNA markers to quickly and efficiently screen plants and select those with the best salt tolerance. Additionally, by understanding the molecular response of Kentucky bluegrass to salt, help can be given to turf managers, sod producers, and extension specialists to better understand turf management in saline environments.

For tolerance of Kentucky bluegrass to water deficits, evaluations of over 250 NPGS Kentucky bluegrass accessions are being conducted in a field location near Logan, UT. These plants have been establishing for two years with 50% ET (evapotranspiration) replacement irrigation, using minimal fertilization, and no pest treatments. As might be expected, most accessions have poor turf quality under these conditions. However, some accessions appear to be maintaining color and density above and beyond current cultivar checks. The goal is to identify the best plants, assess their turf quality and seed production, and cross them into high performance lines.



Fungal endophytes (arrow) naturally infect grass and are maintained through the seed during reproduction. They usually grow between cells and provide a defense against insects and other diseases. Some endophytes have been shown to make plants more tolerant of drought conditions.

Finally, a severe limitation on research of Kentucky bluegrass is the lack of genomic tools. An example of an essential genomic tool would be a large 'library' of Kentucky bluegrass DNA sequences that could be used to test relationships of varieties and/or germplasm, find DNA markers associated with important traits, test plants for apomixis, and find genes that confer traits of interest (e.g., drought or salt tolerance). These libraries of DNA sequences are crucial tools and have been developed for many crop plants and grasses, except for Kentucky bluegrass. One goal is to develop more of these genomic tools in order to facilitate efficient research and management of Kentucky bluegrass.

Collecting New Species and Novel Germplasm

Another recent aspect of research conducted at the USDA-ARS FRRL is the collection of promising reduced-input turfgrasses from Eurasia. The vegetation of many parts of Eurasia has a wide diversity of grass species that grow in low-fertility soils and are adapted to semi-arid conditions. As a result, many Asian grasses have potential for reduced-input, drought tolerant turf in the western U.S. Dr. Doug Johnson at the FRRL has joined with staff from the Vavilov Institute of Plant Industry in St. Petersburg, Russia to collect seeds of turfgrass species in Kyrgyzstan, northwestern Russia, and the southern Ural Mountains of Russia (Table 1).

These collection trips seek to identify novel germplasm for reduced-irrigation turf applications in the western U.S. Plant species collected have included those in *Agrostis* (bentgrass), *Agropyron* (wheatgrass), *Festuca* (fescue), *Trisetum* (oatgrass), *Koeleria* (junegrass), *Poa* (bluegrass), and *Puccinellia* (alkaligrass). A small amount of seed of each collection is used at Logan for field evaluation trials to determine their potential for use in reduced-input turfgrass applications in the western U.S. The bulk of the seed (and accompanying collection data) has been sent to Pullman, WA where it will be increased for distribution through the NPGS. The most drought-tolerant collections of *Poa*, with favorable turf quality characteristics, will be identified and incorporated into the breeding and selection program at Logan.

Drs. Jack Staub and Richard Wang are identifying novel grass-endophyte associations in the fine fescues from these collections. Endophytes are not new to turfgrass science, as many commercial fescues and ryegrasses are naturally infected with these fungi. Endophytes can produce chemicals that provide protection to the plants against insects, diseases, and drought. The goals are to identify novel endophytes in recently collected germplasm from Eurasia, develop inoculation procedures, and introduce potentially novel endophytes into high performance turfgrass germplasm to further improve their economic potential.

In summary, the ARS lab at Logan, UT is committed to the identification and improvement of drought and salt tolerant turfgrass germplasm. This is long-term research that we feel will significantly benefit the turfgrass managers and others in the years to come. We welcome input from, interaction with, and cooperation of the turfgrass industry concerning this research and future endeavors.

Acknowledgements

The authors wish to thank USGA's Turfgrass and Environmental Research Program for their support of this project.

Literature Cited

1. Asay, K. H., and K. B. Jensen. 1996. Wheatgrasses. p. 691-724. *In* L. E. Moser (ed.) Cool-season forage grasses. Agronomy Monograph 34. ASA, CSSA, SSSA, Madison, Wis.

2. Asay, K. H., K. B. Jensen, W. H. Horton, D. A. Johnson, N. J.Chatterton, and S. A. Young. 1999. Registration of 'RoadCrest' crested wheatgrass. *Crop Sci.* 39:1535. (TGIF Record 62290)

3. Bushman, B. S., B. L. Waldron, J. G. Robins, . and K. B. Jensen. 2007. Color and shoot regrowth of turf-type crested wheatgrass managed under deficit irrigation. *Appl. Turfgrass Sci.* doi: 10.1094/ATS- 2007-0418-01-RS. (TGIF Record 123980)

4. Carrow, R. N., and R. R. Duncan. 1998. Salt-affected turfgrass sites. Ann Arbor Press, Chelsea, MI. (TGIF Record 43045)

5. Environmental Protection Agency. 2009. Water Sense revised draft water-efficient single-family new home specification. Available at http://www.epa.gov/OW-OWM.html/water-efficiency/docs/home_rev-draftspec508.pdf (verified 23 Sept. 2009). EPA, Washington, DC. (TGIF Record 159979)

6. Fender, D. H. 2008. Urban turfgrasses in times of a water crisis: benefits and concerns. p. 11-31.

In J. B. Beard et al. (eds.) Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes. CAST Spec. Publ. 27. Counc. for Agric. Sci. and Tech., Ames, IA. (TGIF Record 133433)

7. Hanks, J. D., B. L. Waldron, P. J. Johnson, and K. H. Asay. 2000. Genetic variation for important low-maintenance turf traits in a rhizomatous crested wheatgrass population. Amer. Soc. of Agron. Annual Meeting Abstracts. p. 159. (TGIF Record 71049)

8. Library of Congress. 2008. Food, conservation, and energy act of 2008. Public Law No: 110-234. Available at http://thomas.loc.gov/cgibin/query/f?c110:6:./temp/~c110ckengc:e26696 (verified 23 Apr. 2009).

9. Morris, K. N. 2003. The National Turfgrass Research Initiative. Available at http://www.turfresearch.org/pdf/turfinitiative.pdf (verified 23 Sept. 2009). Natl. Turfgrass Federation, Beltsville, MD. (TGIF Record 90068)

10. Otto, J. 2009. Increasing your outdoor water efficiency. Available at http://www. wickedlocal.com/lexington/news/lifestyle/x702313490/Increasing-your-outdoor-water-efficiency (verified 23 Sept. 2009). Pub. 28 May 2009. Lexington Minuteman, Lexington, MA. (TGIF Record 159983)

11. Robins, J. G., B. L. Waldron, D. W. Cook, K. B. Jensen, and K. H. Asay. 2006. Evaluation of crested wheatgrass managed as turfgrass. *Appl. Turfgrass Sci.* doi: 10.1094/ATS-2006-0523-01-RS. (TGIF Record 111518)

12. Robins, J. G., B. L. Waldron, and P. G. Johnson. 2007. Potential for improvement of turf quality in crested wheatgrass for low-maintenance conditions. *HortSci.* 42(7):1526-1529. (TGIF Record 131830)

13. Robins, J.G., B. S. Bushman, B. Waldron, and P. J. Johnson. 2009. Variation within *Poa* germplasm for salinity tolerance. *HortSci*. 44(6):1517-1521 (TGIF Record 157202)

14. Shridhar, S., S. B. Bushman, and P. B. Johnson. 2008. Molecular responses to salinity stress in *Poa pratensis* L. by subtractive hybridization analysis. p. 44036. *In* 2008 Agronomy Abstracts. ASA, Madison, WI. (TGIF Record 145522)

15. Southern Nevada Water Authority (SNWA). 2008. Water smart landscape rebates. Available at http://www.snwa.com/html/cons_wsl.html (verified 23 Sept. 2009). SNWA, Las Vegas, NV. (TGIF Record 159982)

16. Waldron, B. L., K. H. Asay, K. B. Jensen, and P. G. Johnson. 2001. RoadCrest: A grass for semiarid regions. *Golf Course Management* 69(6):71-74. (TGIF Record 73316)