Research Accomplishments to Meet the Present and Future Water Use Needs of Golf

Dr. Michael P. Kenna, Director
USGA Green Section Research

Thirty years ago, the USGA organized the Turfgrass Research Committee with the primary purpose to develop minimal maintenance turfgrass cultivars that conserve water, as well as tolerate temperature extremes, salinity and pests. New cultivars were introduced, water use efficiency was improved, and new irrigation technology was developed. More importantly, this program redirected university research to focus on water conservation, while improving the adaptation and management techniques of the turfgrasses used on golf courses.

Since 1921, the USGA Green Section has worked with universities and the US Department of Agriculture to improve our major turfgrass species used on golf courses. More recently, an emphasis was placed developing turfgrasses that survive periods of high heat, extreme cold, drought or tolerance of poor quality water. During the past 30 years, the USGA has helped golf courses make significant accomplishments toward conserving water through improved turfgrass water use and adaptation, soil management, and irrigation scheduling. The ultimate goal of this USGA supported research is to provide quality playing surfaces for golf while conserving and protecting our water supply

Figure 1. Droughts in the late 1970´s made this scene increasingly common on golf courses throughout the country.

Responding to an Urgent Need

In the 1970´s, there were a series of droughts throughout the entire United States. Severe water restrictions were placed on golf courses which had dire consequences on appearance and playability. Brown, dormant or dead turf on rough and fairways, as well as empty irrigation ponds, were becoming increasingly common on golf courses throughout the country.

In the Southwest, progress was being made using recycled water for landscape irrigation. The USGA, along with allied golf associations, conducted a symposium on using recycled water and published the proceedings in 1978. However, the droughts around the U.S., and need to deal with future water shortages, prompted the USGA to organize the Turfgrass Research Committee in January 1982. A year later, a slate of straight forward objectives was laid out which inspired the USGA and golf courses around the country to fund research at several universities with turfgrass research programs (see Table 1). Early research efforts focused on two general questions: 1) how much water do turfgrasses on golf courses use? and, 2) how do the major turfgrass species used on golf courses respond to heat, cold, drought, and salinity?

Early Research Efforts on Turfgrass Water Use

In the 1980´s, a series of laboratory and greenhouse experiments to measure turfgrass water use, and how turf plants respond to drought were conducted. Evaluating turf root growth, and how long plants would go before leaf firing, dormancy, or death occurred, were common experiments conducted in greenhouse and field trials.

During the 80′s and 90′s, the Penman–Montieth equation used to predict evapotranspiration, or Et_o, was calibrated for turfgrass. This equation estimates the amount of water that evaporates from the soil, plus the amount that transpires from, or is used by, the turfgrass plant. The key weather measurements needed for this equation are solar radiation, air temperature, wind speed, and humidity. This method of estimating Et_o is accepted world–wide, not only for turfgrass, but for all crops.

Several experiments measured actual turfgrass water use in field experiments (See Table 2). Weighing lysimeters were commonly used to estimate actual evapotranspiration, or Et_a. Lysimeters are simply closed buckets, small or large, that are weighed after an irrigation event, and then weighed daily during a dry down cycle. The ratio of Et_a and Et_o is used to develop crop coefficients, or K_c values. The use of K_c values, or some fraction of estimated Et_o, is the corner stone for developing deficit irrigation programs (See Table 3).

Predicted Et_o and K_c values provided a benchmark for turfgrass water needs; however, field experiments revealed that the turf could get by with even less water and still remain green. There was some leaf firing or brown color at greater water deficits, but the turf recovered quickly when rainfall or irrigation occurred. Some of the new cultivars were tested in field trials to determine how they would reduce water use and still provide acceptable playing surfaces. Through education efforts by USGA Green Section staff, superintendents used this information to conserve water by making better decisions about when and how much to irrigate.

The leadership and direction of the USGA enabled turfgrass breeders to evaluate turfgrasses for their ability to survive periods of high heat, extreme cold, drought or salinity. The USGA also was

Table 2. Summary of Mean Summer Daily Rates of Turfgrass Evapotran–spiration (ET_0).

Turfgrass species[1]		Mean Summer ET rate[2]	Relative ranking
Cool Season	Warm Season		
		mm per day	
	Buffalograss	5.0 – 7.0	Very low
	Bermudagrass hy–brids	3.1 – 7.0	Low
	Centipedegrass	3.8 – 9.0	
	Bermudagrass	3.0 – 9.0	
	Zoysiagrasst	3.5 – 8.0	
Hard fescue		7.0 – 8.5	Medium
Chewings fescue		7.0 – 8.5	
Red fescue		7.0 – 8.5	
	Bahiagrass	6.0 – 8.5	
	Seashore paspalum	6.0 – 8.5	
	St. Augustinegrass	3.3 – 6.9	
Perennial ryegrass		6.6 – 11.2	High
	Carpetgrasss	8.8 – 10.0	
	Kikuyugrass	8.5 – 10.0	
Tall fescue		3.6 – 12.6	
Creeping bent–grass		5.0 – 10.0	
Annual bluegrass		> 10.0	
Kentucky blue–grass		4.0 > 10.0	
Italian ryegrass		> 10.0	

[1] Based on the most widely used cultivars of each species.
[2] Mean rates of water use based on research from several studies

Table 3. Fraction of ET_0 (K_c value) for acceptable turfgrass appearance in various landscape settings.

Intended Use	Required minimum ac–ceptable ap–pearance	*Fraction of ET_o for accept–able appearance (+/– 0.05)	
		Cool–season	Warm–season
Industrial, Roadside, etc.	Low	0.60	0.40
Homeowners Asso–ciation, Typical Lawn, Municipal, etc.	Traditional	0.70	0.60
Parks and Sports Fields, Commercial, etc.	High–performance	0.80	0.70

[1] Based on the most widely used cultivars of each species.
[2] Mean rates of water use based on research from several studies

instrumental in providing research funds to turfgrass management and physiology experts to assess the progress that the breeding programs were making. The USGA provided funding to develop turfgrasses native to North America, and, in collaboration with the US Department of Agriculture, breeders had the opportunity to collect interesting grasses from around the world. The foresight of the USGA Turfgrass Research Committee was quite remarkable, and, without those early efforts to organize a focused research effort, where would we be today?

New Turfgrass Cultivars Arrive

The turfgrass industry started to see new warm- and cool-season grass cultivars in the late 1980's, all throughout the 1990's, as well as today. More than 30 cultivars were developed since 1983 and have returned $4 million in royalty income to the USGA's research program. Warm-season grasses, particularly new bermudagrass and zoysiagrass cultivars, are significant solutions to reduce as much as half the amount of water needed for golf course fairways during the summer. Improved heat tolerance in cool-season grasses, such as bentgrass and perennial ryegrass, demonstrated the value of breeding programs directed toward improving their performance and persistence during the summer. A few native grasses were developed that were highly adapted to lower rainfall regions of the Western United States (See Table 4).

In cooperation with allied golf associations, the USGA's book, *Wastewater Reuse for Golf Course Irrigation,* greatly improved the confidence of course decision makers to use recycled water. Salt tolerant grasses, like seashore paspalum and inland saltgrass, provide alternatives when poor quality water high in salts is the only source available for irrigation. National Geographic in *A Special Issue on Water* penned seashore paspalum, "A humble turfgrass (that) has won the golf trifecta, earning raves from duffers and greenkeepers as well as environmentalists." Seashore paspalum is not a perfect turfgrass, though it is a positive step in dealing with poor quality water in the Southern United States. All of the turfgrass species used on golf courses have been evaluated for salt tolerance (See Table 5). Additional research continues today on improving salinity tolerance of several cool-season species such as perennial ryegrass and Kentucky bluegrass.

Biotechnology and Molecular Approaches

For the last 20 years, the USGA has supported plant biotechnology that uses cellular and molecular levels of plant biology to better understand turfgrass genetics, and as a tool to supplement traditional plant breeding efforts. While significant advances have been made for traditional agricultural crops such as corn, wheat, and soybeans, progress using molecular approaches to improve stress tolerance in turfgrass is not as readily apparent. In this regard, the lack of success is partially due to the genetic complexity of perennial turfgrasses, as well as the differences in resources being committed to the improvement of turfgrasses compared to other agricultural crops.

Biotechnology is very basic and long-term research that is expensive to conduct. The USGA has played an important role to provide seed money to get projects underway. Several USGA sponsored scientists have received grants from the National Science Foundation or the US Department of Agriculture (USDA). For significant progress to be made in the field of turfgrass biotechnology, scientists will need to compete and receive large, multi-million dollar grants from federal research programs.

One interesting example of turfgrass biotechnology is evaluating the heat tolerance of grass species related to creeping bentgrass. These "grass cousins' thrive in the thermal soils at Yellowstone National Park. The soil temperatures run as high 113 degrees Fahrenheit, and, molecular studies are conducted to determine which genes are involved in this natural thermal tolerance of the Yellowstone grasses.

Future Research and Partnerships

Turf response to drought and deficit irrigation research continues today using experimental techniques developed more than 25 years ago. More emphasis is now placed on evaluating the differences among cultivars within a turfgrass species. For example, several bermudagrass cultivars were tested for their response to 99 days without water. Based on preliminary analysis in this experiment, there are a few cultivars with significantly better tolerance among the 16 that were tested. Similar research has been conducted for Kentucky bluegrass and creeping bentgrass that will identify existing cultivars that use significantly less water.

University breeding programs supported by the USGA received two USDA Specialty Crop Research Initiative (SCRI) grants of more than $5 million. Turfgrass scientists at universities in Florida, Georgia, North Carolina, Oklahoma, and Texas received $3.8 million to develop warm-season grasses with better drought and salinity tolerance. In the midst of severe drought in Oklahoma and Texas, the USGA/USDA supported research has evaluated hundreds of bermudagrass, zoysiagrass, and seashore paspalum selections for their ability to survive with less water. A similar SCRI grant for $2.1 million was awarded to universities in Minnesota, New Jersey, and Wisconsin

Table 4. Summary of Turfgrass Cultivars Developed by Universities Receiving USGA Funding.

Turfgrass	University	Cultivars or Varieties
Creeping Bentgrass *Agrostis stolonifera var. palustris*	Texas A&M University	´Crenshaw´, ´Cato´, ´Mariner´, ´Century´, ´Imperial´, and ´Backspin´.
	University of Rhode Is–land	´Providence´
	Pennsylvania State Uni–versity	´Pennlinks´
	Rutgers University	Heat tolerant and dollar spot resistant pa–rental lines are under development.
Colonial Bentgrass *Agrostis tenuis*	DSIR–New Zealand and University of Rhode Island	BR–1518
Bermudagrass *Cynodon dactylon* *C. dactylon X C. trans–vaalensis*	New Mexico State Uni–versity	´NuMex Sahara´, ´Sonesta´, ´Primavera´, and ´Princess´.
	Oklahoma State Uni–versity	Two seeded types, ´Yukon´ and ´Riviera´, three vegetative types, ´Patriot´, ´Northbridge´, and ´Latitude 36´.
	University of Georgia	´Tifton 10´, ´Tifsport´, ´Tifeagle´, and ´Tifgrand´.
Buffalograss *Buchloe dactyloides*	University of Nebraska	Five vegetative varieties ´Legacy´, ´Prestige´, 609, 315, and 378; three seeded varieties ´Cody´, ´Tatanka´, and ´Bowie´. Vegetative NE 95–55 under evaluation.
Alkaligrass *Puccinellia* sp.	Colorado State Univer–sity	Ten improved families were developed.
Blue grama *Bouteloua gracilis*	Colorado State Univer–sity	Elite, Nice, Plus and Narrow populations were developed.
Fairway Crested Wheat–grass *Agropyron cristatum*	Colorado State Univer–sity	Narrow leafed and rhizo–matous popula–tions were developed.
Curly Mesquitegrass *Hilaria belangeri*	University of Arizona	'Fine' and 'Roa–dside' popula–tions were developed and made available for further improvement.
Annual bluegrass *Poa annua* var. *reptans*	University of Minnesota	DW–184 (MN#184).
	Pennsylvania State Uni–versity	Several promising lines, but nothing re–leased to seed production problems.
Zoysiagrass *Zoysia japonica* and *Z. matrella*	Texas A&M University	´Diamond´, ´Cavalier´, ´Crowne´ and ´Palisades´.
Inland Saltgrass *Distichlis spicata*	Colorado State Univer–sity University of Arizona	Vegetative A–49, A–50 and A–138 con–sidered for release. Seeded varieties are be–ing developed.
Seashore Paspalum *Paspalum vaginatum*	University of Georgia	Vegetative ´Seaisle 2000´, ´Seaisle I´, ´Seaisle Supreme´, and seeded ´Seaspray´. More seeded and vegetative cultivars near–ing release.

Table 5. Relative Salt Resistance of Several Turfgrass Species Used in the United States .

Cool-Season	Warm-Season	Ranking
Alkaligrass	Seashore paspalum	Excellent
	Bermudagrass	
	Bermudagrass hybrids	Good
	St. Augustinegrass	
Creeping bentgrass	Zoysiagrass	
Tall fescue	Bahiagrass	Fair
Perennial ryegrass	Centipedegrass	
Fine fescues	Carpetgrass	Poor
Kentucky bluegrass	Buffalograss	

*Based on the most used cultivars of each species.

to improve fine fescues for golf courses and lawns. University scientists also have partnered with their counterparts at USDA Agricultural Research Service laboratories in Utah and Maryland to collect and evaluate new and existing turfgrass species for drought and salinity tolerance.

The USGA worked closely with the Council for Agricultural Science and Technology, or CAST, on a special symposium dealing with "Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes." The USGA is currently working with National Turfgrass Federation and USDA staff at the U.S. National Arboretum in Washington, DC on a turfgrass exhibit titled "Grass Roots." Due to the long history of USGA support of turfgrass water use research and introduction of improved turf cultivars, the Green Section consults with the American Society of Agricultural and Biological Engineers on the development of landscape water requirements, as well as provides review and comments for the Sustainable Sites Initiative and EPA WaterSense.

The Turfgrass Information File

An important goal set by the Turfgrass Research Committee in 1984 was to develop a "Turfgrass Research-Computer Data Base Library." This database was named the Turfgrass Information File, or TGIF, and is hosted at the Turfgrass Information Center, Michigan State University Libraries. As the internet evolved, the power of this database became more accessible to turfgrass scientists and managers. To encourage the growth and sustainability of this important tool, the USGA provided a $1 million endowment which was subsequently matched by allied associations and corporations. TGIF now has over 200,000 records, and more than 1.3 million searches are conducted annually,

The Turfgrass Information Center houses important collections from past turfgrass scientists, such as O.J. Noer, James Beard, or Fred Grau. TGIF is home to *Green Section Record* which is accessed more than 3,000 times per day. USGA *Turfgrass and Environmental Research Online*, or *TERO,* and several other digitized turfgrass publications are available through the Turfgrass Information Center at Michigan State University. More than 50% of the records are linked to the full text of the article so it can be read or downloaded using the internet. There are ten organizations (which include the Golf Course Superintendents Association, Sport Turf Managers Association, Turfgrass Producers International) that have blanket-access agreements for their members. More than 60 university subscribers worldwide use TGIF to provide access to faculty and students.

Conclusion

Thirty years ago, the USGA organized the Turfgrass Research Committee with the "primary purpose of the program to develop minimal maintenance turfgrass" which conserves water; survive periods of high heat, extreme cold, drought or tolerance of poor quality water. The USGA has been a leader in turfgrass water use research through its support of university programs on turfgrass breeding, physiology, and management. The USGA's research provides valuable information on turfgrass water use rates, minimal water requirements, and ability of turfgrass to survive periods of drought.

Some golf courses use half the water they did 30 years ago by using improved grasses, like bermuda-grass and zoysiagrass, which save water. A few native grasses, like buffalograss and fine fescues, can be used on golf course roughs to reduce water use. The increased heat tolerance of grasses, such as bentgrass and perennial ryegrass, has improved their perform-ance and persistence during the summer.

The USGA staff helps superintendents conserve water by making better decisions about when to water and how to use technology that improves irrigation precision. The turfgrass water use information is used to implement weather-based replacement of water. Due to the USGA's education efforts to improve the confi-dence of course decision makers, more recycled water is used for golf course irrigation today than ever before. Salt tolerant grasses, like seashore paspalum, provide alternatives when poor quality water high in salts is the only source available for irrigation.

The USGA has been a valuable cooperator with allied associations, government agencies, and industry to provide excellent summaries and education on water research conducted during the past 30 years. The USGA provides free, public access to all of its research and education information through the internet, and, was a leader supporting the Turfgrass Information File, or TGIF, at the Turfgrass Information Center, Michigan State University Libraries.

Golf has made significant progress; however, there is still a lot can be accomplished to conserve water, through continued improvements in turfgrass water use and adaptation, soil management, deficit irrigation programs, as well as improved irrigation control systems, sprinkler uniformity, and sensor technology. The ultimate goal is to provide quality playing surfaces for golf while conserving and protecting our water supply.

Figure 6. The droughts around the United States, and need to make plans for the future in dealing with water shortages, prompted the USGA to organize the Turfgrass Research Committee in January 1982.

The USGA Research Committee (left to right): Stephen J. Horrell, Charles W. Smith, W. H. Bengeyfield, Harry W. Easterly, Jr., Dr. Paul Rieke, James B. Moncrief, H. E. Neale, Dr. James R. Watson. Dr. Marvin H. Ferguson is not present.

The Green Section's New Turfgrass Research Committee