TURFGRASS AND ENVIRONMENTAL RESEARCH ONLINE
USING SCIENCE TO BENEFIT GOLF

The availability of water for irrigation is arguably the most serious issue affecting the future of the turfgrass industry, including golf courses. For decades, USGA's Turfgrass and Environmental Research Program has invested millions of dollars in research to address this issue. This paper briefly outlines the multi-faceted, USGA-funded research that addresses this critical issue. *(Photo credit: Bud White, Director, Mid-Continent Region, USGA Green Section).*

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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 1921, the USGA has funded more than $40 million for research at universities. 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***.

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Addressing Turfgrass Water Shortages

Jeff Nus

SUMMARY

USGA has invested millions of dollars in research addressing the issue of water shortages for turfgrass irrigation. USGA-funded research included the identification of drought resistance mechanims, assessments of water use of several cool- and warm-season turfgrass species, investigating soil factors and other management aspects affecting water use, and research to understand water storage and movement in rootzones. USGA-funded research also included the assessment of turfgrass water use when using recycled water and the management techniques necessary to avoid salt build-up in the soil. The USGA has invested significant funds to improve the drought and salt resistance of currently used turfgrass species, as well as the development of several alternative species including buffalograss, inland saltgrass, seashore pasapalum and various western native grasses. USGA has invested heavily in research using biotechnology and molecular genetic approaches to understand the genetic control of drought, salinity, and heat tolerance. As biotechnology continues to advance, marker-assisted selection becomes commonplace, and entire turfgrass genomes are eventually sequenced, turfgrass stress resistance will be maximized which will allow the greatest potential for conserving water.

The availability of water for irrigation is arguably the most serious issue affecting the future of the turfgrass industry (20, 59). As the human population continues to grow, demand increases for freshwater supplies. As a result, the use of municipal water is prioritized during prolonged droughts, and those prioritized uses do not include irrigation for home lawns and golf courses. During drought, reservoirs, lakes, and other sources for turfgrass irrigation are also threatened. The USGA realizes the jeopardy in which this places the golf course industry, so since the early 1980s, the USGA Turfgrass and Environmental Research Program has provided research funding for numerous research projects that address this issue (99). This paper outlines the numerous research projects that the USGA Turfgrass and Environmental Research Program has funded that address the issue of water shortages for turfgrass irrigation.

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The breadth and number of projects that have received funding is testament for the appropriateness of a multiple-strategy approach for this challenge. These strategies include developing turfgrasses that have greater drought resistance and lower irrigation requirements than those currently in use. Other strategies include improving cold tolerance of warm-season turfgrasses, and developing management options and technological advancements to improve the efficiency of applied irrigation, as well as the use of alternative, better-adapted turfgrass species.

Drought Resistance Versus Water Use

Research has shown that water use varies widely among turfgrass species and, as a rule, water use among warm-season turfgrass species is lower than that of cool-season turfgrass species (12, 20, 58, 91). USGA provided research funding to quantify water use for both warm-season turfgrasses like bermudagrass (39, 40, 41, 102), zoysiagrass (44), buffalograss (27-29), inland saltgrass (102) and seashore paspalum (102), as well as cool-season turfgrass species including Kentucky bluegrass (31, 32, 33), perennial ryegrass (58, 91), and others.

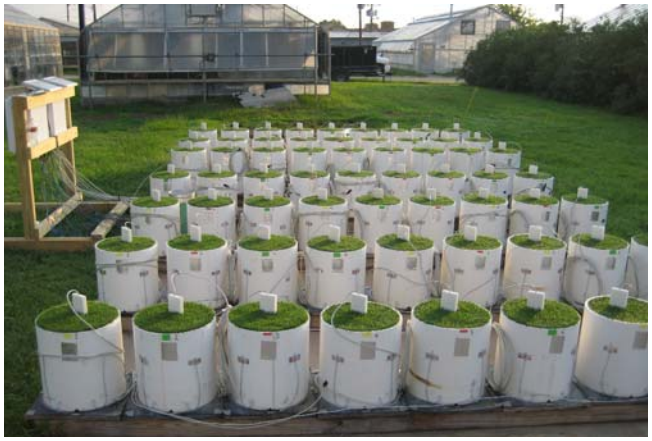
The availability of water for irrigation is arguably the most serious issue affecting the future of the turfgrass industry. *(Photo credit: Pat Gross, Director, Southwest Region, USGA Green Section).*

During drought, reservoirs, lakes, and other sources for turfgrass irrigation are threatened. *(Photo credit: Bud White, Director, Mid-Continent Region, USGA Green Section).*

Besides turfgrass species, water use can vary significantly among cultivars of the same species (12, 31-33). Other factors affecting water use rate include canopy resistance, turf density, leaf area, mowing height, nitrogen nutrition, soil moisture level (12, 43, 48-50, 68). USGA has also provided funding to explore various other management options such as soil aeration methods to maximize infiltration and minimize irrigation requirement (42, 45-47).

Plants resist drought in various ways. USGA-funded research in the 1980s sought to define plant stress mechanisms including how plants react to drought (12-18). The three major strategies that plants have evolved to resist drought are avoidance, tolerance, and escape, and each of those strategies are represented in turfgrasses. Deep rooting allows turfgrasses to ***avoid*** dehydration (68-71). Osmotic adjustment allows turfgrasses to maintain leaf turgor and ***tolerate*** increasing water stress (145, 146). Even some turfgrasses, like annual bluegrass, ***escape*** drought by using an annual life cycle and surviving periods of drought as seed (12).

Although this information, combined with the knowledge of genetic control of these and other mechanisms, is critical for the development of more drought resistant turfgrasses, it is important to understand that there is not a direct relationship between water use rate and drought resistance (12). Although low water use can contribute to overall drought resistance, there are many other factors affecting drought resistance. Because of this, a higher water use does not always mean decreased resistance to drought. Tall fescue is a good example of a cool-season turfgrass with good drought tolerance, but it also has a relatively high water use rate (12). Tall fescue's good drought tolerances comes, in part, from its deep root system which allows additional moisture to be absorbed from the moister, deeper rootzone depths compared to more shallow-rooted cool-season turfgrasses (68).



USGA provided research funding to quantify water use for both warm-season turfgrasses like bermudagrass, zoysiagrass, buffalograss, inland saltgrass, and seashore paspalum, as well as cool-season turfgrass species including Kentucky bluegrass , perennial ryegrass, and others.

This same deep-root advantage is evident in most warm-season turfgrasses, as well (12). Research has shown that the ability to extract moisture from deep in the soil profile allows deeper-rooted turfgrasses to go longer intervals between irrigations (69-71, 76). And since the rate of water loss is greatest immediately after irrigation (or rain) and decreases daily the longer turf is allowed to go between irrigations, the amount of supplemental irrigation required is generally lower for turfgrasses that are more deeply rooted whether you're comparing warm- versus cool-season turfgrasses, turfgrass species, or even cultivars within the same species (31-33).

Golf course superintendents, who are trying to conserve irrigation water as much as possible, irrigate based on the onset of wilt. In other words, superintendents allow some areas of their courses, most notably fairways and roughs, to develop wilt symptoms before those areas receive irrigation. In this way, the minimum amount of supplemental irrigation can be applied and still maintain playable turf. Recent studies designed to quantify water use have also taken this approach (31-33) compared to earlier water-use studies that quantified turfgrass water use under less stressful conditions.

Use of Recycled Water

More and more golf courses are using recycled water for irrigation. However, the use of recycled water for irrigation brings with it additional challenges for turfgrass managers. Because of the additional salt content of recycled water, USGA has provided research funding necessary to determined irrigation requirements for turf irrigated with recycled water (34, 35, 117, 118). USGA research funding also supported research to determine the long-term effects of irrigating with recycled water on soil properties and the management techniques that are necessary to avoid salt build-up and the deleterious effects of sodium accumulation in the soil (165-167).

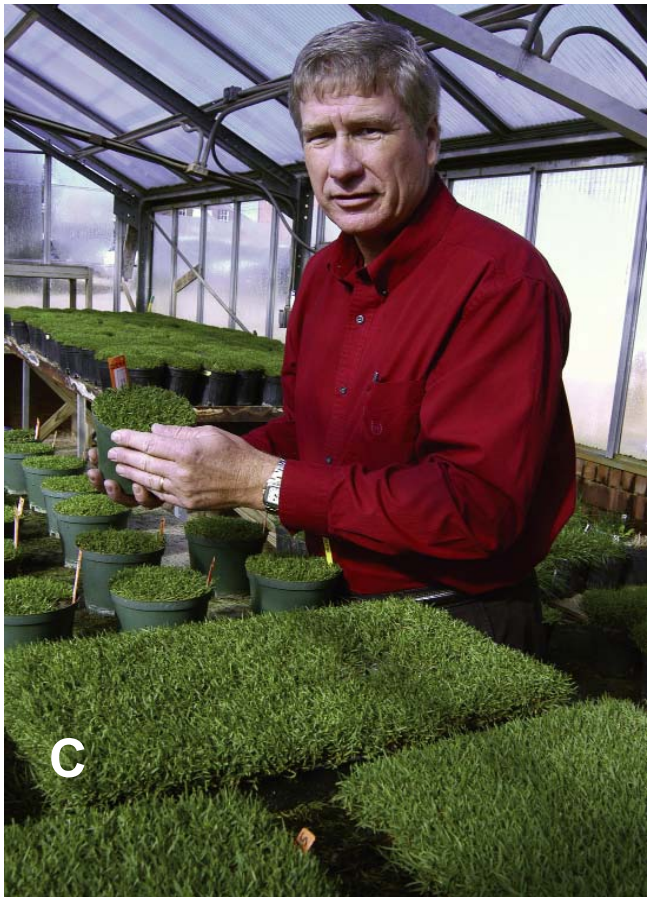
Because of the greater salinity of recycled water, turfgrasses exposed to this increased salt stress need greater salt resistance. USGA has funded several projects to evaluate both cool- and warm-season turfgrasses for their salinity tolerances (25, 26, 96, 97, 107, 144), as well as developing new turfgrass cultivars with greater salt tolerance through turfgrass breeding programs (52-54, 56, 57, 62-67, 85-90, 100, 101, 138, 140-144, 161-163, 168-173).

Recent water use studies, such as the one shown above at Kansas State University comparing the water use rates of several Kentucky bluegrass cultivars, have based irrigation on the development of visual wilt symptoms. At the start of a dry-down cycle, well-watered plots (A) are allowed to dry down until they exhibit wilt symptoms (B) before plots are irrigated. This approach more closely matches how golf course superintendents strive to minimize water use on fairways and roughs.

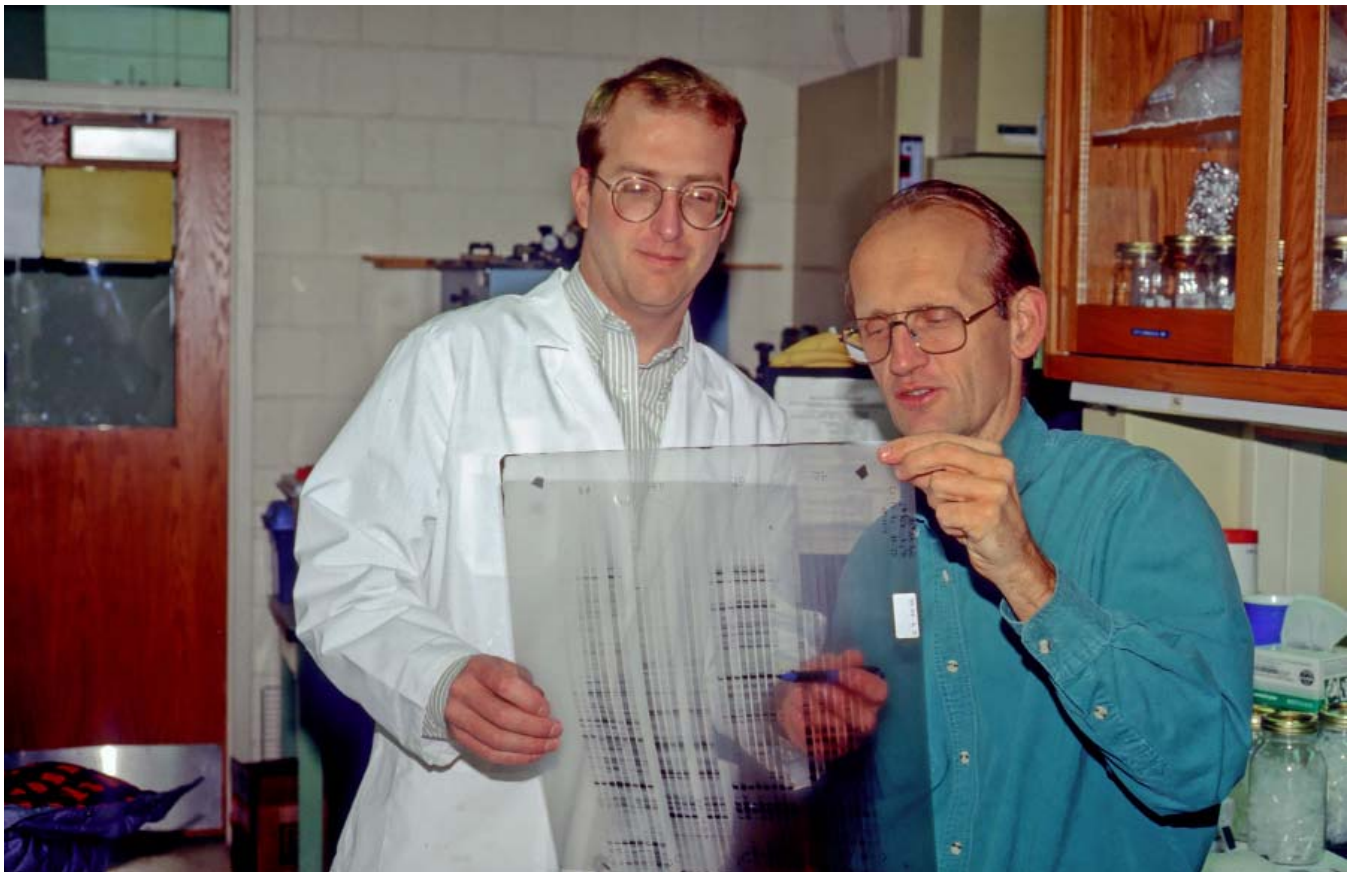
Management Adjustments

In an effort to conserve as much water as possible, it is important for golf course superintendents and other turfgrass managers to understand how other aspects of turfgrass management affect water use. USGA has provided funding to understand how incipient soil moisture affects turfgrass water use (43, 48, 49). USGA-sponsored studies also have investigated how nitrogen fertilizer and traffic affect water use (44) and how overall water use is affected by the frequency of irrigation events (95).

Improving irrigation efficiency requires effective infiltration into the rootzone and knowledge of water storage and movement in the rootzone. USGA funded research to compare various cultivation methods to maximize water infiltration on compaction-prone sites (41, 45-47) and other management strategies (137). USGA-funded research also compared water storage and movement in putting green rootzones built using different construction methods (61,127-132,164) or rootzone amendments (133). USGA also funded research to test whether sub-surface irrigation might be a feasible alternative to above ground irrigation for putting greens (108-114) and whether manufacturer claims regarding water savings as a result of using various water conditioners in the irrigation system are valid (115, 116, 125).



The USGA has made significant investment in the development of many alternative turfgrass species to reduce water use and improve resistance to drought and salinity. These species include the development of buffalograss at the University of Nebraska (A), inland saltgrass at Colorado State University (B), and seashore paspalum at the University of Georgia (C).



The continued improvement of turfgrass cultivars increasingly depends on the use of biotechnology and molecular genetics. The USGA has funded numerous projects designed to understand the genetic control of stress tolerance, gene discovery and expression, and the improvement of both biotic and abiotic stress resistance in turfgrasses. As biotechnology continues to advance, marker-assisted selection becomes commonplace, and entire turfgrass genomes are eventually sequenced, turfgrass stress resistance will be maximized which will allow the greatest potential for conserving water.

Using Better Adapted Grasses

A fundamental approach to address abiotic stresses is to develop grasses that have greater genetic resistance to that stress. USGA funded numerous studies with the goal of improving the drought and/or salt tolerance of a broad range of grass species in addition to those currently used on a broad-scale basis. These species include buffalograss (60, 61-66, 175), alkali grass (36), inland saltgrass (53-55, 86-91, 101, 102, 163-163), seashore paspalum (37, 38, 56, 57, 168-173), prairie junegrass (183), poverty grass (139), curly mesquite (119-123), annual bluegrass (77-84, 134-136, 184-194), and various other western native grasses (55, 102-105).

Warm-season turfgrasses, such as bermudagrass, exhibit lower water use rates and require less supplemental irrigation than cool-season turfgrasses due to their deeper root system. It can be reasoned that water use on golf courses in the transition zone may be reduced if significant improvements can be attained in bermudagrass cold hardiness, although the original goal of improving winter hardiness of bermudagrass was to reduce winter damage in locations where bermudagrass is already grown (182).

However, bermudagrasses with significantly greater cold tolerance may survive at sites farther north in the transition zone, possibly replacing cool-season species currently in use on transition zone fairways not unlike the water-use advantage that the use of zoysiagrass offers those transition zone golf courses now. USGA has invested heavily in the development of more cold-tolerant, fine-textured bermudagrasses (30, 126, 179-182, 195) and continues to fund research to understand the basic science of cold hardening of this important warm-season turfgrass (1-3, 6, 7, 8-11).

Basic Science and Molecular Genetics

Knowledge of the fundamental processes that plants have evolved to endure environmental stresses is essential in developing turfgrasses that have improved stress tolerance. It is also vital to combine this knowledge with the understanding the genetic control of these processes. USGA has supported research to understand the genetic control (functional genomics) of stress tolerance of both cool- and warm-season turfgrasses (4, 5, 9-11). USGA also has invested significantly in research to identify genetic components associated with drought and heat tolerance (72-75, 92-94) and multi-gene transfer strategies to improve stress resistance (176-178).

A basic-science approach often leads to gains in understanding that have far-reaching benefits. Nowhere is that more evident than with the rapid gain in knowledge being acquired in the field of molecular genetics. USGA has funded and continues to fund research designed to understand the genetic control of stress tolerance (4, 92-94), gene discovery and expression (7-11, 73-75, 147-160), and the use of biotechnology to improve both biotic and abiotic stress resistance in turfgrasses (21-23, 177-178). As biotechnology continues to advance, marker-assisted selection becomes commonplace, and entire turfgrass genomes are eventually sequenced, turfgrass stress resistance will be maximized which will allow the greatest potential for conserving water.

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