Latest Developments in Turfgrass Research

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Key points: Turfgrass research is diverse. It encompasses breeding, genetic, molecular techniques, physiology, establishment, management, and new technologies. Considerable emphasis has been placed on developing improved cultivars and introducing new species with enhanced water conservation, stress tolerances, and pest resistance. Recent efforts to release a transgenic creeping bentgrass have resulted in concerns with considerable implications for future release of genetically modified grasses in the turfgrass industry. Increasing concerns and awareness for the turfgrass industry regarding water quantity and quality has lead to increased research emphasis on reduced water use, enhanced drought resistance, and improved understanding of the fate of nutrients and pesticides applied to turfgrass sites.

Key words: *Agrostis*, *Buchloe dactyloides*, *Cynodon*, *Deschampsia caespitosa*, *Distichlis spicata*, Drought resistance, *Festuca arundinacea*, Interspecific hybridization, *Lolium perenne*, Nutrients, *Paspalum vaginatum*, Pesticides, *Poa*, *Sclerotinia homeocarpa*, Transgenic, Turfgrass water use, United States Golf Association, Water quality and quantity

Introduction The discipline of turfgrass science has experienced remarkable growth and development on a world-wide basis in the past few years. A historical perspective of turfgrass research evolution in the USA can be obtained by studying the Crop Science Society of America (CSSA) Division C-5 Historian Report (Beard, 2004), and internationally, by studying the increased numbers of research papers presented at the International Turfgrass Society Research Conference (ITSRC) Journal. There were 15 turfgrass research papers presented at the first CSSA meetings in 1955 (Beard, 2004), while in 2008, this number grew to 332. In 1969, the First ITSR Conference was held in Harrogate, England, UK with 78 registrants, representing 12 countries (Beard, 2005; Thorogood, 2005). Thirty-six years later in Llandudno, Wales, UK at the 10^{th} ITSRC there were 262 registrants from 25 countries (Shearman, 2006).

Research activities in turfgrass science are quite diverse, encompassing improvement of cultivars through a better understanding of breeding, genetics and molecular genetics; new establishment and management practices and technologies; enhanced understanding of turfgrass plant physiology, biochemistry, and stress tolerances; and many other areas as well. Traditional plant breeding coupled with new technologies and approaches have resulted in dramatic changes in the numbers of new turfgrass cultivars, and the introduction of new species for the turfgrass industry. Many of these new cultivars and species offer improved water conservation characteristics, reduced nutrient and energy input requirements, and enhanced biotic and abiotic stress tolerances, all of which are traits with increasing interest to the turfgrass industry on a world-wide basis (Brilman, 2005; Morris, 2006; Shearman, 2006). In many areas of the world, water quantity and quality are concerns (Watson, 1994). Turfgrasses are ideally suited for irrigation with non-potable water sources, like effluent water (USGA, 1994). As a result, there are increasing concerns about the need for managing turfs in salt affected soils, and increasing interest in developing turfgrasses with improved salinity tolerance (Carrow and Duncan, 1998). Along with continuing improvements in turfgrass cultivars, research has advanced the development of fertilizers, pesticides and other turfgrass chemicals, like plant growth regulators, wetting agents, and biostimulants (Shearman, 2006). Technological improvements in computer controlled irrigation systems with improved sprinkler design, operation and uniformity have kept pace with research improvements and developments in other areas of the turfgrass industry. Site-specific management and precision application systems, like many other areas of agriculture, are receiving increased research emphasis for potential use in the turfgrass industry.

Species and cultivar development Future developments for turfgrass improvements are likely to emphasize enhanced performance and quality under intense use, water conservation, reduced inputs of energy and chemicals, increased biotic and abiotic stress tolerance, and better tolerance to salts and heavy metals (Brilman, 2005; Morris et al., 2005). The current emphasis on developing new species and improving cultivars for the turfgrass industry has increased over the past two decades (Shearman, 2006). As a result, there is a growing number of species and cultivars for turfgrass managers to use. The increase in numbers of improved cultivars available to the turfgrass industry is extremely beneficial, but some times leads to difficulties in identifing the best grasses to use under specific environments and management conditions. This situation is particularly true for countries with developing turfgrass industries. Species and cultivar evaluation trial information is not as readily available to end users as it may be in countries with a more developed turfgrass industry and research support base.

Certainly improvements with traditional turfgrass species, like Kentucky bluegrass (*Poa pratensis* L.), perennial ryegrass (*Lolium perenne* L.), tall fescue (*Festuca arundinacea* Schreb.), creeping bentgrass (*Agrostis stolonifera* L.), and bermudagrass (*Cynodon* spp.) continue to remain as strong components for a large portion of the international turfgrass industry. Recently, buffalograss [*Buchloe dactyloides* (Nutt.) Engelm], seashore paspalum (*Paspalum vaginatum* Swartz), and inland saltgrass [*Distichlis spicata* (L.) Greene] have been introduced as new species for turfgrass use. The United States Golf Association (USGA) Turfgrass and Environmental Research Program has been instrumental in supporting the development of these new species. Buffalograss is a C_4 grass that is native to the Great Plains of North America. It is noted for its excellent high temperature tolerance , and drought resistance , and its ability to perform under reduced input conditions , such as little to no fertilizers , pesticides , energy , or water (Shearman et al ., 2004) . Buffalograss has been used as a forage , rangeland , and conservation species in the past , but most recent efforts to improve this species has come from turfgrass interests . Seashore paspalum , a C_4 grass , has multiple stress resistant traits , but is best known for its salinity tolerance (Duncan , 2003) . Seashore paspalum can tolerate exposure to ocean salt water levels of ECe = 54 dSm^{-1} and low nitrogen inputs . Its primary adaptation falls between 30 to 35 N-S latitudes and its low temperature tolerance is thought to be similar to hybrid bermudagrasses (Duncan and Carrow , 2000) . Inland saltgrass , like buffalograss , is also native to the Great Plains of North America (Pessarakli and Kopec , 2005) . It is a vigorous species with excellent salt tolerance , and drought resistance , and a strong potential for development as a turfgrass species . Turfgrass research programs at the University of Arizona and Colorado State University have jointly lead the way in developing a breeding and selection program to improve this species for turfgrass use . Other grass species such as annual bluegrass [*P . annua* f . *reptans* (Hausskn .) T . Koyama] , tufted hairgrass [*Deschampsia caespitosa* (L .) P . Beauv .] , velvet bentgrass (*A . canina* L .) , Highland bentgrass (*A . castellana* Boiss . and Reuter) , and Idaho bentgrass (*A . idahoensis* Nash) are also receiving attention for improvement as turfgrasses .

Interspecific hybridization offers potential for turfgrass improvement . Certainly the benefits derived from hybrid bermudagrasses [*C . dactylon* (L .) Pers .) x *C . transvaalensis* Burt-Davy] are well documented and known . Recently hybrid bluegrasses (HBG) have been developed from crosses between Kentucky bluegrass (*P . pratensis* L .) and Texas bluegrass (*P . arachnifera* Torr .) . The desirable HBG cultivars have the appearance of Kentucky bluegrass , but have improved high temperature performance and drought stress tolerance compared to Kentucky bluegrass cultivars (Read et al ., 1994 ; Abraham et al ., 2004 ; Bremer et al ., 2006) . The HBG appear to have potential , but they are new and have received only limited testing to date . Current HBG cultivars have demonstrated improved high temperature performance , but they may not have the improved drought resistance characteristics at this point as desired by the breeders utilizing this hybridization technique (Bremer et al ., 2006) . Enhanced drought resistance might depend on proper selection of parental genotypes from both species as well as the potential and anticipated contribution from the Texas bluegrass among these interspecific crosses . Interspecific hybrids between tall fescue (*Festuca arundinacea* Schreb .) and annual ryegrass (*L . multiflorum* L .) or perennial ryegrass (*L . perenne* L .) have been studied for forage purposes (Meyer and Watkins , 2003) . Most of these crosses result in hybrids that lack desirable turfgrass traits , but they may have specific traits of interest , like disease resistance that could prove useful to improving either or both species turfgrass performance . Similarly , research with hybrids of creeping bentgrass (*Agrostis stolonifera* L .) and colonial bentgrass (*A . capillaris* L .) has been conducted in an effort to incorporate the inherent dollar spot (*Sclerotinia homeocarpa* F .T . Bennett) resistance from colonial into creeping bentgrass (Belanger et al ., 2005) . The hybrids from these crosses are fertile both through the pollen and egg , and therefore , have potential for improving dollar spot resistance in creeping bentgrass or through the potential use of hybrids as well . They have used a population generated from a cross with a dollar spot resistant colonial x creeping bentgrass hybrid and a creeping bentgrass to develop a genetic linkage map for colonial bentgrass . These researchers feel this approach will lead to new creeping bentgrass cultivars with improved dollar spot resistance . It is thought that dollar spot infestations on creeping bentgrass turfs results in more fungicide treatments and expense than any other pathogen attacking creeping bentgrass .

Transgenic creeping bentgrasses with glyphosate resistance have been developed in the USA , and are being tested and considered for release to the turfgrass industry (Turner et al ., 2003) . It was thought that these genetically modified creeping bentgrasses would be released to the industry by 2003 . To date , the glyphosate-resistant , transgenic creeping bentgrass has not been released , primarily because of concerns over gene escape to other bentgrasses (Kenna et al ., 2004) . Researchers at Rutgers University investigated the frequency of interspecific hybridization between transgenic creeping bentgrass and four related *Agrostis* species , *A . stolonifera* , *A . capillaris* , *A . canina , and A . gigantea* . They used transmission of the herbicide resistance gene as a means of identifying hybrids from these crosses . They recovered interspecific hybrids among all four species , but reported the frequency of hybridization was lower than that of the intraspecific cross (i .e . creeping bentgrass to creeping bentgrass) . These results support the concerns over the potential for gene escape to other bentgrasses . Researchers conducted a gene flow study on the landscape level using transgenic creeping bentgrass (Watrud et al ., 2004) . Their results demonstrated gene flow occurred to a distance of 21 km for sentinel plants (i .e . other creeping bentgrasses) and 14 km for residential plants (i .e . other bentgrass species) with most gene flow occurring within 2 km in the direction of the prevailing winds . This research certainly justified the concerns over gene escape from transgenic bentgrasses , but it also demonstrated how far pollen from wind-pollinated , highly outcrossing species , like creeping bentgrass , might travel . Prior to the glyphosate-resistant , transgenic bentgrass , it was difficult to tell exactly how far pollen might travel and remain viable , but by simply spraying the progeny with glyphosate , testing for the resistance gene , or both , one could determine if hybridization had occurred . These researchers indicated that additional work is needed to evaluate whether introgression will occur and whether it will influence ecosystems in which progeny may become established . At this time , there is no consensus within the turfgrass industry on a world-wide basis concerning the release and use of genetically modified grasses . In the long term , it is highly likely that genetically modified grasses will be commercially available . On the short term , the controversy surrounding these grasses will delay their commercial release at least for the near future . Since the potential for outcrossing of wind-pollinated , perennial turfgrasses is high , release of these genetically modified grasses should be carefully scrutinized , and in-depth research is needed before their release is considered .

Turfgrass stress tolerance Turfgrasses are exposed to biotic and abiotic stresses that limit their performance and require additional inputs to maintain desirable turfgrass quality . Developing an improved understanding of these stresses and how to manage them is a key emphasis in much of the current turfgrass research efforts being conducted at this time (Fry and Huang , 2004 ; He et al . , 2005) . Summer decline in cool season turfgrasses , like creeping bentgrass is a common occurrence . This decline results in a loss of turfgrass performance particularly in mid summer or in transition zones between cool and warm season grass adaptation . Researchers at Rutgers University discovered several unique heat tolerance genes from *A . scabra* , a bentgrass species , found growing near geothermal areas (Huang et al . , 2007) . They found that the expression of a gene fragment (AsExp) encoding expansin proteins in cell walls was correlated to heat tolerance in *A . scabra* and creeping bentgrasses . Their research is leading to a better understanding of high temperature tolerance mechanisms in cool season turfgrasses . Similarly , researchers studying bermudagrasses have worked to improve the low temperature tolerance this species (Anderson and Taliaferro , 1995) . These efforts have directed the released of cultivars with improved low temperature tolerance and enhanced their adaptation to more northern portions of the transition zones between warm and cool season species . This research has further improved our understanding of the adaptation and management of warm season turfgrasses where suboptimal temperature stress is a concern .

The demand for water for residential , industrial , and agricultural purposes is increasing and concerns are on the rise over water quantity and quality issues (Watson , 1994) . Turfgrasses are often a center of focus for these concerns , and these issues are of considerable importance to the turfgrass industry . Research is being conducted on turfgrass water use , conservation , and drought resistance (Ebdon and Kopp , 2004 ; Fry and Huang , 2004 ; Da Costa and Huang , 2005 ; Shearman , 2006) and most researchers agree that more effort is needed in this regard . Water use , conservation and drought are affected by environmental conditions and management factors as well . Under deficit irrigation turfgrasses may use significantly less water than well-irrigated plants (Da Costa and Huang , 2005) . Drought and heat stress are often interactive and difficult to separate among stressed cool season turfgrasses (Fry and Huang , 2004 ; Wang and Huang , 2004) . Turfgrass nutrition , irrigation and mowing are also highly interactive in affecting turfgrass water use and drought resistance (Shearman , 2006) .

Turfgrass cultural practices can impact biotic stresses and are important factors in pest management approaches . Certainly , turfgrass species and cultivar resistance and tolerance mechanisms play important roles in reducing pest problems (Shearman , 2006) . Numerous research projects have been conducted on factors that reduce or enhance disease incidence and weed competition in turfgrasses . Managing biotic stresses and improving pest management practices are of particular interest to the turfgrass industry , primarily due to the emphasis of turfgrass quality and performance on intensively used turfgrass sites , like golf course greens and sports turfs .

Environmental concerns Turfgrasses have been criticized for polluting surface and ground water supplies with nitrogen and phosphorus fertilizers , and pesticides by the media and environmental groups . Much of this criticism comes without direct evidence of such negative contributions to these environmental concerns . There have been claims that all of the fertilizers and pesticides applied to golf course turfs move into local water supplies have been made without concerns of the lack of any substantiation . This lack of evidence does not mean that problems are not present nor that they have not occurred , but often accusations are being made without justification or documentation . The USGA initiated a research effort to address some of these concerns in late 1980s . Kenna and Snow (2002) summarized much of this research . Their report indicated that under most conditions only very small amounts of nutrients and pesticides move from turfgrass sites and these levels are well below the health and safety standards established by the United States Environmental protection agency . They also indicated that this research found that the important factors influencing the fate of pesticides and nutrients applied to turfs are : 1) the filtering properties of the thatch and canopy , 2) soil texture , 3) stand maturity , and 4) solubility and adsorption properties of the chemicals applied . Their report is an excellent synopsis of a host of research addressing these concerns . The research they reported has been published in reputable , peer-reviewed scientific journals . More research is needed to further identify and substantiate the best management practices needed to prevent or reduce potential sources of pollutants from turfgrass sites . The turfgrass industry needs to increase it educational efforts to provide turfgrass managers with the most appropriate practices that include a holistic approach that minimize potential pollution problems .

Conclusions The turfgrass industry is one of the most rapidly developing areas in agriculture on an international basis . As a result , there has been increased emphasis of research and development efforts to address the needs facing turfgrass managers . Plant breeders have used cutting edge technologies to release improved cultivars and new species with enhanced water conservation , stress tolerance , and pest resistance characteristics . Researchers have increased our understanding of turfgrass physiology and stress tolerance mechanisms , and have developed an improved comprehension of the fate of nutrients and pesticides applied to turfgrass sites .

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