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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 1983, the USGA has funded more than 290 projects at a cost of $25 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***.

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Buffalograss: Tough Native Turfgrass

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SUMMARY

The buffalograss breeding and genetics program at the University of Nebraska-Lincoln began in 1984 with a goal to develop turf-type cultivars with the potential to conserve water and require reduced inputs of fertilizers, pesticides, and energy. In the past two decades, the buffalograss breeding program at UNL has been quite successful. Among its accomplishments are:

- The release of five vegetative and four seeded cultivars with improved turfgrass color, quality and performance.
- The training of 11 Ph.D. and 14 M.S. students in plant breeding, genetics, and molecular genetics.
- The return of more than $1 million in royalties to UNL and the USGA.
- The acquisition of an extensive germplasm collection that varies in ploidy levels, is diverse geographically, and has excellent turfgrass characteristics.
- The contribution to the fundamental understanding of buffalograss biology and genetics.

In 1984, the United States Golf Association (USGA) Turfgrass and Environmental Research Committee was interested in finding and developing turfgrasses that would meet the future needs of the golf course industry. They were particularly interested in grass species that would offer potential water conservation, and perform well with reduced inputs, such as fertilizers, pesticides, and energy. With these goals in mind, the University of Nebraska-Lincoln (UNL) and the USGA entered in to a joint project to develop buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.] as a turfgrass species for potential use on golf course roughs, fairways, and tees.

In its first 22 years, the buffalograss breeding program at UNL has been quite successful, releasing nine cultivars (Table 1) that have returned well over $1 million in royalties to UNL and the USGA, and training 11 Ph.D. and 14 M.S. students (Table 2). The success of this program has been a team effort involving faculty, staff, and students in agronomy, entomology, biochemistry, biological engineering, horticulture, and plant pathology (27). The program was under the leadership of Terrance P. Riordan for nearly 18 years. It was under his leadership that the majority of cultivar releases were made, and most of the students were trained. In 2002, a Buffalograss Breeding Program Working Group (Table 3) was formed, and Robert C. Shearman took on the role of working with this group and facilitating the buffalograss breeding program.

Buffalograss is dioecious, having male (left) and female (right) plants. It is a native, perennial, low-growing, stoloniferous species that spreads rapidly and forms and excellent ground cover. It withstands cold, heat, and drought stress, while maintaining its integrity as a sod forming turfgrass species

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Cultivar	Year Released	Propagation Method	Ploidy Level
609	1993	Vegetative	Hexaploid
315	1993	Vegetative	Pentaploid
378	1995	Vegetative	Hexaploid
Tatanka	1995	Seed	Pentaploid
Cody	1997	Seed	Hexaploid
Legacy	1997	Vegetative	Hexaploid
Bowie	2001	Seed	Hexaploid
Prestige	1997	Vegetative	Tetraploid
SWI-2000	2006	Seed	Hexaploid

Table 1. Cultivars released by the University of Nebraksa Buffalograss Breeding Program since its inception in 1984

Why Buffalograss?

Buffalograss is native to the North American Great Plains, and is found naturally growing from central Mexico to Alberta, Canada, making it one of only a few native turfgrass species (33). It is a tough plant species known for it drought resistance, water conservation, high temperature performance, winter hardiness, and low maintenance characteristics.

Buffalograss is a perennial, low-growing, stoloniferous species that spreads rapidly and forms an excellent ground cover. It withstands cold, heat, and drought stress, while maintaining its integrity as a sod forming turfgrass species. In the1930s, buffalograss was recognized as a grass species with considerable agricultural and conservation importance due to its surviving the combined effects of plowing, overgrazing, and drought stress (3). Its dense sod-forming growth habit made it a species that helped prevent wind and water soil erosion, making it an ideal conservation species.

Beard and Kim (2) demonstrated that buffalograss had an evapotranspiration rate that was lower than most warm- and cool-season turfgrasses. In most of our selection studies, we maintain buffalograss germplasm with 25 mm (1 inch) of water per month, whether from rainfall, irrigation, or both. Its deep and extensive root system, relatively slow vertical canopy elongation rate, leaf hairs, and leaf rolling characteristics contribute to its ability to avoid drought and recover after long periods of drought stress. Buffalograss has the ability to go dormant sooner and revive more quickly than other turfgrasses under drought stress conditions. It can be established readily from plugs, sprigs, sod, or seed. These characteristics give buffalograss an excellent potential for use as a turfgrass species, and were the reasons that piqued our interest for improving it for use as a golf course turfgrass species.

What's the Breeding History for Buffalograss?

The breeding and development history for buffalograss is really recent history compared to other turfgrass and crop species. A study of buffalograss seed availability conducted about 60 years ago found no commercially available cultivars (33). At that time, seed sources were harvested primarily from native buffalograss stands.

The first described strain of buffalograss was ‘Hays’ in 1950 (3). ‘Texoka’ buffalograss was released in 1974, and was one of the first improved commercially available, cultivars (36). Its most significant attribute was its potentially high seed production rate. Until the 1980s, cultivar development was primarily for forage or conservation use. In the early 1980s, ‘Sharps Improved’, ‘Comanche’ and ‘W2F2’ were released. ‘Comanche’ and ‘W2F2’ are closely related re-selections from ‘Texoka’.

‘Prairie’ buffalograss was developed and

Ph.D.	Year
Jeffrey Klingenberg	1992
Jennifer Johnson-Cicalese	1995
Charles Rodgers	1996
Dan Beran	1998
Shuizhang Fei	1998
Kevin Frank	2000
Tiffany Heng-Moss	2000
Osman Gulsen	2004
Thomas Eickhoff †	---
Songul Severmutlu †	---
Desalegn Serba †	---
M.S.	**Year**
Sarah Browning	1990
Debbie Schwarze	1990
Jeana Svoboda	1990
Ron Moore	1991
Rob Hilton	1991
Katherine Kerner	1993
Matt Giese	1995
Kevin Frank	1996
Tiffany Heng-Moss	1997
Tom Eickhoff	2002
Jeff Carstons	2003
Songul Severmutlu	2003
Wyatt Anderson	2004
Luciana Toda †	---

† Students currently working on their degree program.

Table 2. Graduate students receiving degrees and training in the University of Nebraska-Lincoln Buffalograss Breeding Program since 1984

released in 1989 by Texas A & M University (10). It was the first cultivar released primarily for its turfgrass characteristics. It was released as a vegetatively propagated cultivar that was sold as sod. It was recommended for use on minimal maintenance turfgrass sites like roadsides, industrial grounds, parks and other non-irrigated turfs. Selection, hybridization, and clonal plant evaluation are approaches used to identify superior vegetative genotypes. Once a superior type is identified, sod, sprigs, or plugs can be used to increase the cultivar. 'Prairie' was the result of this approach to buffalograss improvement.

'Bison' buffalograss was released by Oklahoma State University and the USDA-ARS in 1990 as a seeded cultivar (35). 'Bison' had a greater seed yield than 'Texoka', and was recognized for its forage, conservation, and general turf use potential. 'Bison' was a four clone synthetic cultivar developed from two male and female clones which were selected plants in 'Mesa' and 'Texoka' buffalograss stands. Synthetic cultivars take advantage of additive gene response and accumulation of favorable alleles in the new population to develop superior new lines (33). Most recent improvements in buffalograss have been for turfgrass rather than for forage or other uses.

UNL Breeding and Development Program

The University of Nebraska-Lincoln received funding from the USGA in 1984 to support a buffalograss breeding and development program for golf course turf. Starting in 1984,

Working Group Member	Area of Expertise
Bob Shearman	Facilitator
Bekele Abeyo	Project Coordinator
Fred Baxendale	Entomology
Hikmet Budak	Molecular Biology
Roch Gaussoin	Weed Science
Loren Giesler	Plant Pathology
Osman Gulsen	Molecular Biology
Tiffany Heng-Moss	Entomology
Don Lee	Genetics
Gautam Sarath	Molecular Biology
Desalegn Serba	Breeding
Songul Severmutlu	Physiology
Paul Twigg	Molecular Biology
Ken Vogel	Breeding and Genetics
Lannie Wit	Project Management

Table 3. In 2002, a Buffalograss Breeding Program Working Group was formed. Individuals and their areas of expertise are listed above.

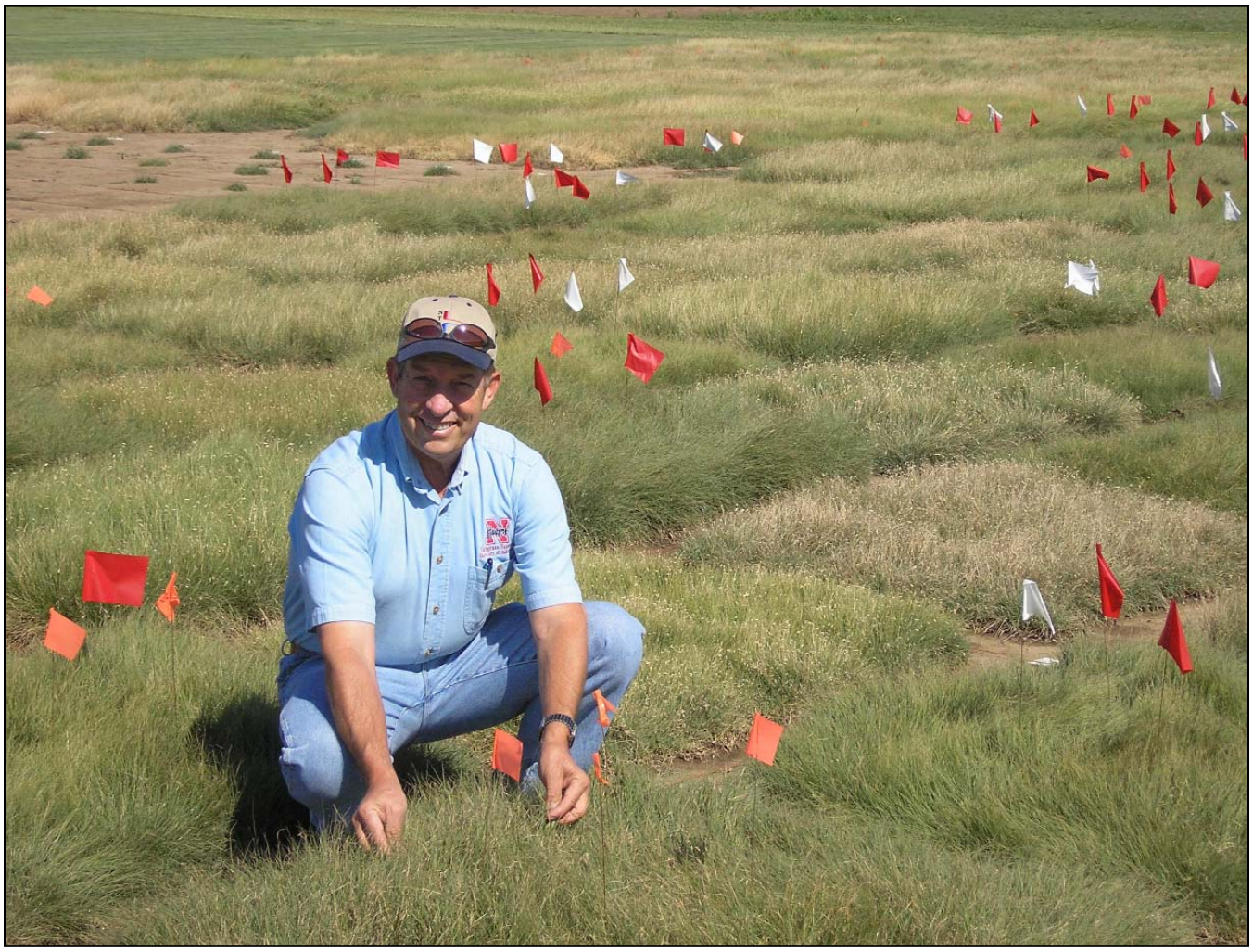

Figure 1. Selection and evaluation are key components used by the University of Nebraska-Lincoln Buffalograss Breeding and Development Program to enhance germplasm development.

extensive collections of buffalograss germplasm were made throughout the Central Great Plains (Figure 1). The emphasis for these plant collections was placed on ecotypes that expressed desirable turfgrass characteristics. At the same time, plant material from a Texas A & M University collection was obtained (27). This germplasm collection was planted in the field at the John Seaton Anderson Turfgrass Research Facility located near Mead, Nebraska. It was quickly identified that many of the selections expressed desirable turfgrass characteristics. The following spring, 48 genotypes expressing turfgrass characteristics were planted in a replicated study for evaluation. These selections served as the first of several selection and evaluation processes used to identify superior turfgrass types. Improvements concentrated on turfgrass quality, color, density and growth habit; and mowing tolerance, sod strength, and sex expression.

In 1991, '609' buffalograss was released, and was the first buffalograss cultivar released by UNL as a result of support from the USGA (26). It was darker green and showed improved turfgrass quality compared to cultivars available at that time. Recently, '609' has been used as a standard cultivar in National Turfgrass Evaluation Program (NTEP) trials for comparison with new releases and experimental lines (Table 4). Results from NTEP trials demonstrated that '609' was a southern-adapted cultivar, having extended green color into the fall. In warm-season species like buffalograss, this extended fall green response is often associated with increased winter injury. In 1993, '315' buffalograss was released by UNL (28). It produces a fine textured, low-growing

Entry	Mean Quality †
378	5.8
315	5.7
Buffalawn	5.5
NE 84-436	5.4
Bowie (NTG-5)	5.4
NTG-2	5.4
AZ 143	5.3
NTG-3	5.3
609	5.2
Tatanka	5.2
NTG-4	5.2
Prairie	5.2
Highlight 4	5.0
NE 84-45-3	4.9
Highlight 15	4.9
Top Gun	4.9
Sharps Improved	4.9
Highlight 25	4.8
Plains	4.8
Texoka	4.8
Rutgers	4.8
Bison	4.8
LSD	0.2

† Data are from the 1991 National Turfgrass Evaluation Program Buffalograss Trial 1991-1996 Final Report.

Table 4. Mean Turfgrass quality ratings of buffalograss entries grown at 28 locations in the USA. Turfgrass quality ratings are based on a 1 to 9 visual rating system with 1= poorest and 9= ideal. Data are a summary of those collected monthly from 1991 to 1995.

attractive turf that tends to green up quicker in the spring, but goes dormant earlier in the fall than most other cultivars. The earlier fall dormancy expressed by '315' is associated with its improved winter hardiness compared to '609'. The cultivar '315'is a northern-adapted selection. It had one of the highest mean quality ratings in the 1991 NTEP trial final report (Table 4).

Data demonstrate that turfgrass quality improvements have been made when compared to 'Texoka' (base standard) and '609' (improved, turf-type standard) in the past few years (Tables 4, 5, 6). Thus, improvements in developing dense, low-growing, and dark green cultivars with extended growing seasons has been demonstrated. These improvements were particularly evident with the early vegetative releases from the UNL program.

'Tatanka' was the first seeded release from the UNL Buffalograss Breeding Program. It was released in 1995 through a cooperative effort with the Native Turfgrass Group (20). 'Tatanka' was a maternal half-sib generated from a modified back-cross of male selections on '315', which was a single female clone adapted to the northern Great Plains. It demonstrated improved turfgrass quality, density, and leaf spot (*Helminthosporium spp.*) resistance when grown in central and northern portions of the range of adaptation for buffalograss.

'Tatanka' showed promise as a seeded turf-type, but was inconsistent in its seed yield potential and rate of establishment. Later it was identified that 'Tatanka' was a pentaploid (17). The unbalanced chromosome number likely attributed to its poor seed production potential and lack of seedling vigor. This response identified the importance of ploidy level to the enhancement of buffalograss breeding improvements. After the release of 'Tatanka', ploidy level was determined for all genotypes making it to the advanced evaluation level in the program.

'Cody' buffalograss was also released by UNL as a seeded type in 1995 (31). It was derived from a four-clone synthetic consisting of two male and two female clones, and was developed through cooperation with the Native Turfgrass Group. These materials were selected from a large heterogeneous population growing at the John Seaton Anderson Turfgrass Research Facility. These materials were obtained from germplasm collected from a broad geographic representation. 'Cody' had similar turfgrass characteristics as 'Tatanka', but its seed yield and seedling vigor were much better than those identified for 'Tatanka'. 'Cody' is a hexaploid.

'Legacy' (i.e. 61) buffalograss was released as a vegetative, turf-type buffalograss by UNL in 1997 (18). It is a dark green, low-grow-

Figure 2. 'Prestige' buffalograss, a recent release from the University of Nebraska-Lincoln Buffalograss Breeding Program, forms a dense turf at 15.6 mm moving height and 25 mm of water from rainfall, irrigation or both per month.

ing, and very dense vegetative female clone with excellent turfgrass quality (Tables 5, 6). It is noteworthy for its reduced canopy height and rapid lateral spread, making it an excellent turf-type buffalograss. 'Legacy' is a hexaploid with central and northern Great Plains adaptation. It has excellent winter hardiness.

In 1997, 'Prestige' (i.e. 118) was also released by UNL (29). 'Prestige' is a tetraploid, vegetative cultivar that is lighter green than 'Legacy', and tolerates mowing heights of 15.6 mm (Figure 2). It has demonstrated an extended green cover over the growing season by greening up early in the spring, similar to '315', and staying green longer in the fall. It also has demonstrated good winter hardiness, and is adapted for use in southern to northern Great Plains. 'Prestige' has excellent chinch bug (*Blissus occiduus*) resistance (12, 15).

In 2001, UNL released 'Bowie', a seeded, turf-type buffalograss (32). This release was made in conjunction with the Native Turfgrass Group. It is a four-clone synthetic with a wide range of adaptation and very good turfgrass quality characteristics (Table 4). 'Bowie' was comparable to 'Tatanka' and '609' for turfgrass quality, but is darker green than either of those cultivars. It has very good bur yields, similar or better than 'Texoka'. 'Bowie' has excellent winter hardiness and excellent mealybug [*Tridiscus sporoli* (Cockerell) or *Trionymus spp.*] resistance (16).

In 2005, the UNL program released 'SWI-2000' in cooperation with Seeds West Incorporated. 'SWI-2000' is an open-pollinated variety developed by three cycles of selection for heavier caryopsis weight in two elite experimental genotypes, 'NE-501', and 'NE-503'. 'NE-501' and 'NE-503' are both four-clone synthetics. The

parent clones of these two genotypes were selected on the basis of multiple trait selection index, using turfgrass quality, bur yield, evapotranspiration, fall dormancy, false smut resistance, and seed set from a diverse collection of germplasm from the UNL collection. 'SWI-2000' has similar turfgrass performance characteristics as 'Bowie' (Table 6), but has higher bur yield characteristics.

Buffalograss is quite variable, and is a relatively easy species to improve using traditional plant breeding techniques. Our research results indicate that cultivars can be developed with improved turfgrass quality, color, and density, as well as extended greenness and increased bur yield potential. As water conservation continues to become an issue for the turfgrass industry, buffalograss will become even more important and its acceptance as a golf course turfgrass species will continue to increase.

Entry	Mean Quality †
Prestige	5.6
Cody	5.4
Tatanka	5.3
BAM-1000	5.2
Legacy	5.2
Bonnie Brae	5.2
Texoka	5.1
86-120	5.1
609	5.0
378	5.0
UCR-95	4.9
Bison	4.8
Midget	4.8
Stampede	4.8
LSD (0.05)	0.2
C.V. (%)	21.1

† Data are from the 1996 National Turfgrass Evaluation Program Buffalograss Trial 1996-2000 Final Report.

Table 5. Mean turfgrass quality ratings for buffalograss entries grown at 12 locations in the USA. Turfgrass quality ratings were based on a 1to 9 visual rating scale with 1= poorest and 9= best. Data were collected monthly from all locations from 1996 to 2000.

Adding to the Base Knowledge of Buffalograss Genetics

Our collection of buffalograss germplasm is a broad, genetically diverse resource with a strong potential for use in improving low-input, drought resistant golf course fairway, tee, and rough turfs. Our research has indicated that sequence-related amplified polymorphism (SRAP) markers could be used to estimate genetic relationships among the genotypes in our germplasm collection (6, 8, 14). The use of PCR-based technologies is an effective approach for estimating genetic diversity, identifying unique genotypes, and for analyzing evolutionary and historical development of buffalograss as a species. Using these techniques, we have identified the depth and breadth of genetic diversity in our germplasm collection. Only a few genotypes in our germplasm collection were closely related (14). However, identifying these few closely related genotypes helped us streamline our breeding, improve breeding efficiency, and avoid duplication of efforts.

The implications of buffalograss evolution are not clear. The center of origin for buffalograss is thought to be central Mexico. It is speculated that this population survived the ice age, and buffalograss spread across the Great Plains to its current southern and northern range of adaptation by herbivores feeding on its forage (23, 24). The female flower is located in the sward canopy. These herbivores, primarily buffalo, subsequently dispersed seed in their feces from burs that were digested while eating the forage.

Our evaluation of buffalograss evolution revealed that comparisons of sequence data from the mitochondrial and plastid genome suggested that all genotypes contained the same cytoplasmic origin (7). Thus cytoplasmic incompatibility is not an issue for buffalograss breeding programs. The buffalograss genome appears to have evolved through the rearrangement of convergent subgenomic domains. The sequence information obtained in these studies can be used as genome-specific markers for investigation of the buffalograss polyploidy complex, and testing of plastid

and mitochondrial mode of transmission in the genus (5, 13).

Peroxidase activity has been associated with chinch bug resistant (i.e. 'Prestige') and susceptible (i.e. '378') buffalograss cultivars (12, 15). Plant peroxidases are a family of related proteins possessing highly conserved domains. Degenerate oligonucleotide primers based on these conserved domains can be used to amplify DNA sequences coding for peroxidases, using buffalograsses with unsequenced genomes. We studied polymorphisms of peroxidase genes among buffalograss genotypes. We also investigated the potential evolutionary relationships among the genotypes studied, using this approach. Targeted-PCR amplification of genomic DNA yielded polymorphisms that differentiated diploids from polyploids within buffalograss.

A total of 11 peroxidase gene fragments, seven belonging to buffalograss and four to the other grass species studied were sequenced during these studies. Five of these sequences were clustered with rice ascorbate peroxidases, which were known to have chloroplast origin. The results from these studies demonstrated that primers targeting the peroxidase gene family could be used to study genotypic diversity and evolutionary relationships within and between species. The PCR-based peroxidase markers may also have potential for use in linkage mapping and differential gene expression studies in grasses.

Recently, chinch bug (*Blissus occiduus*) has become an important insect pest of buffalograss in Nebraska (1, 12). Germplasm screening conducted so far found considerable variation among buffalograss genotypes, indicating the presence of genetic resistance, tolerance, or both to chinch bugs (12, 15). However, the mechanisms of resistance and their mode of inheritance have not been determined. The insect resistance variability observed did not show trends associated with ploidy level. Fortunately, this response suggests that any technology developed for the lower ploidy level buffalograss genotypes (i.e. diploids) should be applicable to the higher ploidy level genotypes (i.e. tetraploids and hexaploids).

To bring different desirable turfgrass quality traits into one genotypic background, it is imperative to understand the genetic basis of the traits (19). Chinch bug resistance is an important

Entry	May †	June	July	August	September	October	Mean
Legacy	7.7	7.3	6.7	7.7	3.7	3.0	6.0
NE 95-55	7.7	8.0	7.0	7.3	3.0	1.7	5.8
378	7.0	7.3	6.7	7.0	2.3	2.3	5.4
Bowie	7.0	6.7	6.7	6.3	3.0	2.7	5.4
Density	4.3	4.0	5.0	6.0	6.0	5.3	5.1
SWI-2000	6.3	6.0	5.7	5.3	4.0	1.7	4.8
Bison	3.3	6.3	6.0	5.7	4.0	2.7	4.7
Texoka	4.7	6.0	5.3	5.0	3.3	2.7	4.5
609	1.7	2.0	5.0	5.0	5.7	4.3	3.9
Frontier Turfallo	1.0	2.0	3.7	3.0	4.3	3.7	2.9
LSD	1.2	1.5	1.1	2.0	1.8	2.3	1.0
CV (%)	4.4	16.4	12.3	21.5	28.6	47.1	12.5

† Data are from the 2000 National Turfgrass Evaluation Program Buffalograss Trial 2005 Progress Report.

Table 6. Mean turfgrass quality ratings for buffalograss entries evaluated at the John Seaton Anderson Turfgrass Research Facility located near Mead, NE. Turfgrass quality ratings were based on a 1 to 9 visual rating scale with 1= poorest and 9= best. Data were collected monthly during the 2005 growing season.

trait for buffalograss turf. Resistant cultivars are more desirable than those that might require some pesticide input for chinch bug management. We need to improve our understanding of the genetic basis and mode of inheritance for chinch bug resistance. This information would be helpful to employing marker assisted selection, and tagging of the genomic region responsible for resistance (4, 19). Putting these markers in relative order is a prelude to understanding the genome structure and for manipulating the gene of interest.

With these aspects in mind, we started mapping a diploid buffalograss population. The male and female parents of this population were diverse for chinch bug resistance, turfgrass quality, and seed yield characteristics. We have constructed cDNA libraries for the parents. Identifying markers that are linked to the resistant gene(s) and that can be used in marker-assisted selection (MAS) would be beneficial to our buffalograss improvement efforts.

Molecular markers are based on differences in the DNA nucleotide sequences of chromosomes of different individuals (39). These differences are referred to as DNA polymorphisms, and they result from insertions, deletions, duplications, and substitutions of nucleotides (21). DNA polymorphisms can be visualized using a wide variety of molecular marker methodologies (19, 34). All types of molecular markers detect sequence polymorphisms and monitor the segregation of a DNA sequence among progeny of a genetic cross, which helps to construct a linkage map (39).

Molecular markers reveal genotypic differences of phenotypically similar plants. This revelation enables plant breeders to select plants based on genotypic or DNA-based differences rather than phenotypic (i.e. whole plant) differences. This greatly improves the potential to increase selection efficiency. Molecular markers are phenotypically neutral. They can be used to map simply inherited, dominant, or recessive traits controlled by segregation at a single locus, or complex traits that are controlled by multiple loci. Molecular markers have brought about a revolutionary approach to conventional plant breeding by revealing the variation at the DNA sequence level (19). Our research efforts are the first of this kind working with buffalograss.

Putting the markers in relative order on the chromosome provide an advantage in understand-

The advanced buffalograss lines being developed at the University of Nebraska by the Buffalograss Breeding Program Working Group are a direct result of the perceived need for turfgrass species that would offer potential water conservation and perform well with reduced inputs, such as fertilizers, pesticides, and energy.

ing which region of the genome controls a trait of interest, and for tagging genes controlling the trait of interest. Several types of DNA markers have been widely used to detect sequence polymorphisms and monitor the segregation of DNA sequence among progeny of a genetic cross in order to construct a linkage map (39). The application of markers for the construction of a linkage map can be used for the estimation of recombination frequency between genetic loci and determination of the order of loci in linkage groups. Based on this, genetic linkage maps have been constructed for several economically important cereal crops, pasture and turfgrass species (11). Most of these linkage maps were constructed using F_2 populations, backcross inbred lines, or recombinant inbred lines mapping populations based on a cross between two inbred lines.

In self-incompatible species like buffalograss, it is impossible to get homozygous parents to use in crosses (37). In these types of species, heterozygous parental plants are crossed to obtain F_1 or pseudo testcross mapping populations. There are many problems associated with such mapping populations. Since the parents are highly heterozygous, as many as four alleles can segregate from a locus, and any given marker can segregate in two (1:1), three (1:2:1) or four (1:1:1:1) genotypic classes (37). Phase relationship determination among the alleles also involves a longer process to determine linkages with progeny segregation data.

Several genetic linkage mapping approaches have become possible using F_1 populations from crosses between heterozygous parents. Gebhardt et al. (11) developed a RFLP linkage map for potato (*Solanum tuberosum)* from a segregating F_1s obtained by crossing two highly heterogeneous diploid parents. Detailed description of the theoretical background was provided for RFLP linkage analysis from F_1 populations generated from crossing of heterozygous individuals (30). A one-way pseudo-testcross population was used for mapping perennial ryegrass (*Lolium perenne* L.) (19). The genetic linkage map of creeping bentgrass (*Agrostis stolonifera* L.) has been constructed from F_1 of a cross between two heterozygous parents exhibiting dramatic differences in leaf color, shoot density, root depth, and resistance to diseases (9). Furthermore, theoretical and statistical backgrounds have been given for simultaneously estimating linkage, linkage phase combinations, and gene order for a group of linked markers displaying all possible segregation patterns (22, 25, 38).

We have made significant strides in studies of molecular markers in buffalograss. Cytoplasmic and nuclear marker systems have been used to study ploidy complex and the geographic origin of the species (7). RFLP markers have been used to study chloroplast and mitochondrial DNA diversity among buffalograss genotypes from the Great Plains (13). To make use of the applications of molecular markers in buffalograss improvement for chinch bug resistance and improved turfgrass quality, we are now moving forward with the molecular genetic mapping of the buffalograss genome.

Conclusions

The acceptance of buffalograss as a relatively new turfgrass species has come along way in just a little over two decades of selection, breeding, and improvement. As water shortages become more of an issue in the future, the need to conserve water for turfgrass use will become even more essential. Certainly, a tough, drought resistant, native turfgrass species, like buffalograss, will play an important role in meeting these needs. The nine cultivars released to date by the UNL Buffalograss Breeding Program have proven track records for excellent turfgrass performance with minimal requirements for inputs. The cooperative research effort between UNL and the USGA has demonstrated that buffalograss has excellent potential for development as a golf course fairway and rough turfgrass species.

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