1993 TURFGRASS RESEARCH SUMMARY

THE USGA®

UNITED STATES GOLF ASSOCIATION 1894

BEARD COLLECTION

1993
Turfgrass
Research Summary

SUBMITTED BY:

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Statement of Intent

It is the intent of the United States Golf Association (USGA) Executive Committee, through the USGA Foundation, to collect and disseminate substantial amounts of money for support of research to: 1) improve turfgrasses which substantially reduce water use, pesticide use, and maintenance costs: 2) develop management practices for new and established turf which protect the environment while providing quality playing surfaces; and 3) encourage young scientists to become leaders in turfgrass research.

It is anticipated that funds for this purpose will be derived, in major part, from contributions to the USGA Foundation. Additional funds may be derived in the future from royalties attributed to marketable discoveries. The USGA presently intends to return any income received from royalties to the support of turfgrass research.

Historically, the sport of golf has maintained a leadership role in the development of improved turfgrasses through the activities of the USGA Green Section. While those developments have helped to provide better playing areas for golf, they have had a far-reaching impact on turfgrass improvement for other uses. Home lawns, parks, school grounds, highway rights-of-way and all other turfgrass uses have been improved by developments which were pioneered by the USGA.

The USGA expects to support research at numerous institutions. In some cases, several institutions will be involved with the development of grasses and maintenance practices where the research may interact and overlap.

In view of this Statement of Intent, it is expected that recipients of grants will embrace a spirit of cooperation and engage in a free exchange of information with other investigators.

USGA Turfgrass Research Summary - 1993 through 1997

Project/Subproject	University/Investigator	1993	1994	1995	1996	1997	Total
TURFGRASS BREEDING:							
Bentgrass	TAMU/Engelke	60,000	63,000	66,150	69,458	72,930	331,538
Cool Season	Rutgers Univ./Funk	8,000	8,000	8,000	8,000	8,000	40,000
Bermudagrass	USDA/Burton	8,000	8,000	8,000	8,000	8,000	40,000
Bermudagrass	OK State Univ./Talifaferro	60,000	63,000	66,150	69,458	72,930	331,538
Buffalograss	Univ. of Nebraska/Riordan	60,000	63,000	66,150	69,458	72,930	331,538
Colonial Bentgrass	Univ. of RI/Ruemmele	20,000	21,000	22,050			63,050
Seashore Paspalum	Univ. of GA/Duncan	20,000	21,000	22,050			63,050
Poa annua	Univ. of Minnesota/White	40,000	20,000	10,000			70,000
Zoysiagrass	TAMU/Engelke	60,000	63,000	66,150	69,458	72,930	331,538
	Subtotal	336,000	330,000	334,700	293,830	307,722	1,602,252
CULTURAL PRACTICES:							
Water Use/Buffalograss	Univ. of Nevada/Bowman	15,000	15,750	16,538			47,288
Water Use/Bermuda	Univ. of GA/Carrow	12,273	12,359	13,488			38,120
Water Use/Zoysiagrass	Univ. of GA/Carrow	21,500					21500
Water Use/Bentgrass	Univ. of GA/Carrow	6,000					6000
Effluent Water	Univ. of Arizona/Mancino	25,000	26,250	27,563			78,813
Low Temperature	Clemson Univ./Barid	20,000	21,000	22,050			63,050
Drought Stress/Bentgrass	TAMU/White		22,453	23,576	24,754		70,783
Putting Green/Bermuda	Auburn Univ./Dickens			10,000	10,000	10,000	30,000
Mycorrhizae	Univ. of RI/Jackson	40,000					40,000
	Subtotal	139,773	97,812	113,214	34,754	10,000	395,553
ALTERNATIVE PEST MANAGEMENT:							
Mole Cricket	NC State Univ./Brandenburg		20,000	20,000	20,000		60,000
Black Turfgrass Ataenius	Univ. of California/Cowles		10,000	10,000	10,000		30,000
Black Turfgrass Ataenius	Cornell Univ./Villani		10,000	10,000	10,000		30,000
Sting Nematode Control	Univ. of Florida/Giblin-Davis		20,000	20,000	20,000		60,000
Allelopathy	Univ. of Arkansas/King		10,000	10,000	10,000		30,000
Dollar Spot	MI State Univ./Vargas		20,000	20,000	20,000		60,000
White Grubs	Univ. of Kentucky/Potter		20,000	20,000	20,000		60,000
Disease Suppression	Cornell Univ./Nelson		20,000	20,000	20,000		
Summer Patch	Rutgers/Kobayashi	20,000	21,000	22,050			63,050
Rhizoctonia solani	Mississippi State/Krans	25,000	26,250	27,563			78,813
Disease	Virginia PolyTech/Ha	25,000	26,250	27,563			78,813
Herbicides	Rutgers Univ./Day	45,000	47,250	49,613			141,863
	Subtotal	115,000	250,750	256,788	130,000	0	692,538
OTHER:							
International Turfgrass Conference	ITS/Watson	5,000	0	0	0	0	0
	Subtotal	5,000	0	0	0	0	0
	TOTAL	595,773	678,562	704,701	458,584	317,722	2,690,342
	BUDGET	650,000	682,500	716,625	752,456	790,079	3,591,660
	DIFFERENCE	54,227	3,938	11,924	293,872	472,358	901,319

Executive Summary

Overall Goals:

- Reduce turfgrass water requirements, pesticide use, and maintenance costs.
- Protect the environment while providing quality playing surfaces.
- Encourage young scientists to become leaders in turfgrass research.

The Turfgrass Research Program sponsored by the United States Golf Association, in cooperation with the Golf Course Superintendents Association of America, has three primary goals.

First, develop turfgrasses for golf courses which substantially reduce water use, pesticide use and maintenance costs.

Second, develop management practices for new and established turf which protect the environment while providing quality playing surfaces.

Third, encourage young scientists to become leaders in turfgrass research through direct involvement and financial support of higher education in the United States.

In January 1982, William H. Bengeyfield, then national director of the Green Section, led the newly formed USGA Turfgrass Research Committee to help direct a plan of action for the next ten years. The plan directed funds toward 1) the development of the Turfgrass Information File, 2) a better understanding of plant stress mechanisms, 3) evaluating cultural practices which improved the ability of golf course turf to tolerate stress, and 4) accelerating plant breeding efforts to develop turfgrasses with better resistance to climatic stress and pest problems.

In 1992, James T. Snow, national director of the Green Section, obtained approval for ongoing USGA funding of the Turfgrass Research Program. A five year plan was developed to direct funds toward 1) plant breeding efforts to develop turfgrasses with better resistance to stress and pest problems, 2) evaluating cultural practices which improve the ability of golf course turf to tolerate stress, and 3) evaluating valid alternative methods of pest control for use in integrated turf management systems.

Highlights for 1993

- CATO and CRENSHAW creeping bentgrass varieties were released and seed will be available for 1994.
- '315' and '378' buffalograss were released and sod will be increased and sold in 1994.
- Bermudagrass, alkaligrass, blue grama, and *Poa annua* seeded varieties are nearing release to commercial producers.
- USGA sponsored zoysiagrasses, bermudagrasses, and buffalograsses have performed well in the National Turfgrass Evaluation Program Trials.
- Cultural practice studies for buffalograss, bentgrass, zoysiagrass, and bermudagrass were initiated. Results for bentgrass and zoysiagrass comparisons with industry standards indicate improved performance under climates stress.
- Seven new alternative pest management projects were initiated to help reduce pesticide use on golf courses.

Turfgrass Breeding

Introduction

The quality and stress tolerance of a turf is the product of the environment, management practices and genetic potential of the grass plant. In many cases, the major limitations to quality turf is its inability to limit various stress effects, many of which can be modified or controlled through plant breeding.

Turfgrass breeding projects are directed toward reducing water use and pesticide use, and developing resistance to several stresses. The most desirable characteristics in potential new turfgrasses include:

- drought tolerance
- high and low temperature tolerance
- tolerance of non-potable water
- tolerance to acid, alkaline or saline soils
- reduced mowing and fertilization requirements
- traffic tolerance
- genetic stability of characters
- disease, insect and nematode resistance
- competitiveness against weeds
- tolerance to smog and other pollutants
- shade tolerance

The primary focus of USGA turfgrass breeding programs is the improvement of zoysiagrass, native grasses, *Poa annua*, bermudagrass and bentgrass. The turfgrasses resulting from the sponsored research must meet the needs of golf courses. In Table I, the breeding projects, species, and status of varieties are summarized.

Table I. Summary of USGA/GCSAA Turfgrass Breeding Projects.

Turfgrass	University	Status of Varieties
Creeping Bentgrass *Agrostis palustris*	Texas A&M University	CRENSHAW (Syn3-88) and CATO (Syn4-88) were released. Syn1-88, Syn92-1, Syn92-2, and Syn92-5 are under evaluation for release.
	University of Rhode Island	PROVIDENCE was released.
Colonial Bentgrass *Agrostis castellana*	DSIR-New Zealand and University of Rhode Island	A preliminary line, BR-1518, was entered in the NTEP trials. A new line will be tested at the University of Rhode Island in 1994.
Bermudagrass *Cynodon dactylon*	New Mexico State University	NuMex SAHARA, SONESTA, and several other seed propagated varieties were developed from this program.
	Oklahoma State University	Two seeded types, OKS91-11 and OKS91-1 were entered in the 1992 NTEP Trials.
C. transvaalensis	Oklahoma State University	Thirty experimental cultivars in initial turfgrass evaluations.
C. dactylon *X C. transvaalensis*	University of Georgia	TIFTON 10 was released, several MIDIRON and TIFWAY mutants are under evaluation and near release.
Buffalograss *Buchloe dactyloides*	University of Nebraska	Several are entered in the 1991 NTEP Trial. Vegetative: NE 84-315, NE 84-378, NE 84-436, NE 84-453, and NE 84-609. Seeded: NTDG-1, NTDG-2, NTDG-3, NTDG-4, and NTDG-5. Vegetative varieties 609, 315, and 378 were released.
Alkaligrass *Puccinellia* spp.	Colorado State University	Ten improved families are under evaluation and have been released.
Blue grama *Bouteloua gracilis*	Colorado State University	ELITE, NICE, PLUS and NARROW are under evaluation in anticipation of release.
Fairway Crested Wheatgrass *Agropyron cristatum*	Colorado State University	Narrow leaved and rhizomatous populations are entering preliminary turfgrass trials and a second cycle of selection.
Curly Mesquitegrass *Hilaria belangeri*	University of Arizona	Seed increases of 'fine' and 'roadside' populations are available for germplasm releases and further improvement.
Annual bluegrass *Poa annua* var *reptans*	University of Minnesota	Selections #42, #117, #184, #208, and #234 are under evaluation for seed production, naming and release.
Zoysiagrass *Zoysia japonica* and *Z. matrella*	Texas A&M University	Several vegetative selections are entered in 1991 NTEP Trial: DALZ8501, DALZ8502, DALZ8507, DALZ8508, DALZ85012, DALZ85014, DALZ85016, DALZ8701, and DALZ9006.
Seashore Paspalum *Paspalum vaginaturm*	University of Georgia	Germplasm assembled and under initial evaluation.

Breeding and Evaluation of Kentucky Bluegrass, Tall Fescue, Fine Fescue, Perennial Ryegrass, and Bentgrass for Turf

Rutgers University

Dr. C. Reed Funk

Goals:

- Collect and evaluate interesting turfgrass germplasm.
- Collect and evaluate endophytes associated with cool-season turfgrass species.
- Continue the breeding and development of new cool-season turfgrasses.

Promising turfgrass germplasm and associated endophytes were collected from old turfs in New Jersey, Colorado, France and Spain. New sources of endophytes were found in *Poa* species native to Colorado and the mountains between France and Spain.

Severe turf loss was observed on all endophyte-free fine fescues in the 1989 National Fine Fescue Tests at both Adelphia and North Brunswick, NJ. Damage on endophyte-free fine fescues initially appeared as a summer patch disease with many root systems colonized by ectotrophic fungi. High populations of chinch bugs subsequently increased turf damage and slowed recovery. Studies are in progress to determine whether some endophytes in fine fescue might be associated with enhanced summer patch disease resistance.

Acremonium endophyte-enhanced resistance to dollar spot disease was again observed in field trials of fine fescue. Both mycelial growth and damage by the dollar spot fungus was greatly reduced on fine fescues containing an endophyte.

A few experimental selections of Kentucky bluegrass are performing well in low-maintenance turf trials receiving limited fertilizer, no irrigation, and no fungicides or insecticides. Most of the entries showing the best recovery from severe summer stress have been classified as mid-Atlantic ecotypes. They have deep extensive rhizomes, an ability to develop a deep root system during hot weather, medium broad leaves, and a growth habit intermediate between the tall narrow-leaved midwest common types and the lower-growing turf types. They are much more vigorous in spaced-plant nurseries than most turf-types. They generally show improved resistance to billbugs and better tolerance to some other insect pests.

The BVMG (i.e., BARON, VICTA, MERIT, GNOME) types of Kentucky bluegrass are showing increasing damage from stripe smut and other turfgrass maladies. The widespread use of these similar and probably closely related bluegrasses appears to promote an increasing abundance of pathogens adapted to these host genotypes.

Seed production was initiated on ELF and APM perennial ryegrasses. Germplasm developed at the New Jersey Agricultural Experiment Station was used in the breeding of these varieties.

Breeding and Development of Bentgrass

Dr. Milt Engelke

Texas A&M University

Goals:

- Develop stress tolerant bentgrass cultivars with specific emphasis on heat tolerance, root growth characters, turf quality, and resistance to natural disease and insect pests.
- Continue genetic studies involving heritability and stability of biological traits associated with stress tolerance.

CRENSHAW (Syn3-88) and CATO (Syn4-88) were released in April 1993. Considerable success has been realized in the performance and utility of both grasses, especially throughout the southern United States.

CATO has been licensed to Pickseed West, Tangent, Oregon and was placed into production in September 1993. Commercial seed stocks will be available in 1994.

CRENSHAW has been licensed to Lofts Seed, Inc., Bound Brook, NJ and was placed in production in September 1993. A limited quantity of seed was available for commercial distribution in 1993.

Syn1-88 seed was harvested from a 5 acre production field in August 1993. Seed production was approximately 550 pounds per acre and will be used in experimental plantings in cooperation with other universities and golf courses. Syn1-88 was evaluated extensively in California and West Texas for salinity tolerance under field conditions.

Five additional elite bentgrass breeding lines were increased in 1993. These new varieties were developed specifically for improvements in heat tolerance, root growth characters, disease resistance, turf quality, persistence and competitive ability. Syn92-1, Syn92-2 and Syn92-5 were included in the National Turfgrass Evaluation Trials (NTEP) trials along with Syn1-88. Both CATO and CRENSHAW were sponsored by their respective licensees.

Vegetative selections were identified in the Oregon seed production fields among the progeny of advanced lines. These selections will be evaluated for growth characters, turf quality, disease and insect resistance, traffic and salinity tolerance, heat tolerance, and root growth.

Breeding and Development of Zoysiagrass

Dr. Milt Engelke

Texas A&M University

Goals:

- Develop improved zoysiagrass cultivars with multiple character performance involving low water-use, persistence under drought and temperature stress, and tolerance to poor water quality.
- Develop seeded zoysiagrasses which are genetically stable with improved turf quality, persistence, and competitive ability.
- Continue genetic studies involving the heritability and stability of biological traits.

The National Turfgrass Evaluation Trials (NTEP) zoysiagrass trials included nine entries from the breeding program. DALZ8507, a fine-textured, cold hardy *Zoysia matrella* and DALZ8512 and DALZ8514 performed well during the year (See Table II).

A large breeder field (15,000 ft^2) of DALZ8502, DALZ8507, DALZ8512, and DALZ8514 were established in July 1992. All four fields were fully established by midsummer 1993. These fields will serve as: 1) planting stock for foundation production, once approved for release, and 2) source material for more extensive field evaluation studies. Release documents are being prepared for DALZ8507, DALZ 8512, and DALZ8514.

The DALZ8502 putting greens at TAES-Dallas continue to perform well. One is grown in sand and the other is on clay soil. In 1992, overseeding on part of the sand green and tee box revealed severe damage to this zoysiagrass and this practice will not be recommended in the future.

Under an agreement with Colonial Country Club, we have established a 4,500 ft^2 chipping green and a 1,500-ft^2 shaded tee box to continue field evaluation of DALZ8502. Rapid regrowth from the sod production area harvested for green and tee box evaluations demonstrates the extensive rhizome system of this fine-textured *Z. matrella* variety.

The Linear Gradient Irrigation System (LGIS) has been established with 12 experimental *Zoysias*, three bermudagrasses, a buffalograss, a St. Augustinegrass, and a Texas bluegrass to provide extensive inter- and intraspecies water-use and culture input comparisons. Of targeted interest is the influence of fertility levels across the moisture gradient on turfgrass performance.

Table II. 1993 Mean Turfgrass Quality Ratings of Zoysiagrass Cultivars For Each Month Grown At Twenty-Two Locations in the United States.

	Turfgrass Quality Ratings[1]											
Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DALZ 8507	4.8	5.3	5.5	5.9	5.0	6.5	6.6	6.7	6.7	7.0	5.4	6.3
EMERALD	4.7	4.9	5.8	6.2	5.6	6.6	6.4	6.4	6.4	6.6	5.3	5.9
CD 2013	4.0	4.2	5.1	5.3	5.4	6.2	6.2	6.3	6.5	6.3	5.7	5.4
DALZ 8508	4.3	4.8	5.6	5.4	5.1	6.1	6.3	6.5	6.5	6.3	5.1	5.8
TC 2033	4.3	4.9	5.4	5.4	5.3	6.1	6.3	6.4	6.3	6.6	5.5	5.8
DALZ 9006	4.6	4.9	5.5	5.9	4.9	6.2	6.3	6.4	6.5	6.7	5.7	6.3
QT 2004	4.0	4.2	4.9	5.5	5.4	6.2	6.1	6.3	6.2	6.0	4.9	5.3
SUNBURST	3.9	4.0	5.3	5.6	5.7	6.1	6.2	6.0	6.2	5.8	5.0	5.3
DALZ 8514	4.6	4.6	5.5	5.4	5.1	5.5	6.3	6.0	5.9	6.1	5.2	5.8
TC 5018	4.0	3.8	4.7	5.9	5.8	6.0	6.2	5.9	5.9	5.7	4.7	5.2
DALZ 8512	4.0	4.1	5.0	5.6	5.2	5.5	6.2	6.0	6.0	6.2	5.8	5.9
MEYER	4.2	4.4	4.7	5.3	5.3	6.1	5.9	5.8	5.9	5.6	4.4	4.5
EL TORO	4.3	4.4	5.5	5.4	5.3	5.4	6.0	5.8	5.8	6.0	5.4	6.0
BELAIR	3.9	3.6	4.3	5.3	5.2	5.8	5.8	5.9	5.8	5.1	4.0	3.6
CD 259-13	4.0	4.4	5.0	5.7	5.4	5.8	5.9	5.8	5.7	5.0	3.9	4.3
DALZ 8516	4.2	4.6	4.7	4.6	4.8	5.4	5.4	5.6	5.8	6.0	4.8	5.2
QT 2047	4.1	4.2	4.2	5.4	5.1	5.8	5.6	5.6	5.5	5.0	3.8	4.9
TGS-W10	3.7	3.7	4.3	5.5	5.2	5.5	5.6	5.6	5.6	5.2	4.4	4.4
TGS-B10	4.0	3.9	4.5	5.7	5.2	5.5	5.6	5.5	5.4	5.1	4.0	4.4
DALZ 8502	5.3	6.0	5.3	6.1	4.8	5.6	5.0	5.3	5.1	5.9	5.7	6.4
JZ-1	3.9	3.6	4.2	5.2	4.8	4.8	5.1	5.1	5.1	5.0	4.1	4.4
Korean Common	4.0	3.4	4.5	5.2	5.0	4.8	5.0	4.9	5.0	4.8	4.0	4.3
DALZ 8501	5.3	5.2	4.5	4.3	3.5	4.9	4.4	4.6	4.6	5.2	4.4	5.2
DALZ 8701	5.1	5.6	4.5	4.5	3.4	4.2	4.3	4.4	4.5	5.9	5.5	6.0
LSD Value[2]	0.6	1.1	0.9	1.2	0.7	0.7	0.6	0.5	0.6	0.6	0.9	1.0

1 Turfgrass Quality, where 1 = poor and 9 = ideal turf

2 To determine statistical differences among entries, subtract one entry's mean from another entry's mean. Statistical differences occur when this value is equal to or larger than the corresponding LSD Value (LSD 0.05).

Colonial Bentgrass (Agrostis tenuis Sibth.) Breeding and Cultivar Development

Dr. Bridget Ruemmele

University of Rhode Island

Goals:

- Develop resource efficient, improved colonial bentgrasses for use individually, in blends, or in mixtures with fine fescues.
- Improvements desired for colonial bentgrass include: brown patch resistance, increased cold hardinessd dark green color, close mowing tolerance, recuperative ability and wear tolerance, tolerance to reduced cultural inputs, retention of desired turf-type characters.

Primary emphases during the first year of the program included assessment of existing germplasm and acquisition of additional plants. Existing material came primarily from New England, and additional plants were obtained from the New Zealand collections of Dr. William Rumball, collection trips from Maine to Pennsylvania. A large area remains to be covered, including collections further south along the East Coast of the United States where higher humidity and heat conditions may be more favorable for obtaining brown patch (*Rhizoctonia* sp.) resistant colonial bentgrasses. The area of origin, Europe, needs to be explored as well.

Ms. Pei-Yu Zeng, an M.S. degree student, officially began working with this project last fall. Her thesis will concentrate on brown patch resistance screening in bentgrasses.

Cooperative collection efforts with private seed companies are forging associations which will enhance development of improved materials. This cooperative effort has already produced progeny from 69 collections which have been planted this fall for turf evaluation trials in Rhode Island.

Greenhouse facilities were greatly expanded with the addition of a 1,000 square foot polyhouse used almost exclusively for the turfgrass improvement program. This has facilitated the ability to increase plantings from seed or vegetative plant parts for field and greenhouse evaluations.

One of the most severe droughts in history for the Northeast region occurred last summer. Non-irrigated space plantings of the original bentgrass collection were examined for drought tolerance. Selections were grouped into one of three categories: low, medium, or high drought resistance. One group of each classification, containing three to five parents each, was established in a polycross nursery for seed production in spring of 1994. Progeny will be evaluated for brown patch resistance and its potential relationship with drought resistance.

Six isolates of *Rhizoctonia* sp. were increased for inoculating greenhouse materials in November and December, 1993.

Additional support was provided by the University of Rhode Island Faculty Development Program, the USDA, the New England Golf Course Superintendent's Association, private turf industries, plant royalties, the State of Rhode Island, and Federal Hatch funding.

Bermudagrass Breeding - Vegetative

Dr. Glenn Burton

USDA / University of Georgia

Goals:

- To develop improved, fine textured bermudagrass for golf course putting greens, tees and fairways.
- Develop and refine efficient screening techniques for cold-hardiness and energy reserves.

The 1992-1993 winter was too mild to separate bermudagrass genotypes in the field. The need for a laboratory method to consistently screen for cold tolerance in bermudagrass genotypes is apparent.

We have continued to try various freezing procedures. All involve a grow-out period of frozen plugs planted in sand on the greenhouse bench. Our freezing chamber is thermostatically controlled and can be adjusted to a stable freezing temperature that fluctuates no more than 3°F. An electric fan is placed in the bottom of the cabinet to circulate the air.

Our most recent approach consists of inverting plugs on one shelf in the freezer to try to simulate what happens when cold air hits the top of the dormant or green bermudagrass growing on the golf course. We have found that the soil from which the plugs are cut must have a uniform moisture content. Also, the genotypes must have had uniform management for more than one year.

Winter survival in plants has been associated with energy reserves stored in their roots and underground parts. In 1962 we described "A Method for Measuring Sod Reserves," *Agronomy Journal* 54:53-55. The method involved cutting 6 inch plugs of sod, putting them into large empty cans, letting them develop etiolated stems in the dark, and measuring the dry matter produced. We have modified this method, since used by others, by inverting another can over the one containing the plug. A small black opening is left on the north side for air exchange and water, and the cans are attached to each other with black plastic tape that excludes the light. We have then grown plants out in the greenhouse and separated the cans to measure the etiolated growth.

We also have modified the method by cutting both ends out of one can and attaching it to an inverted can, leaving an air opening by pushing the bottom can in about 3/8 inches. The two cans are taped together and forced into a cut in the soil made by the plug cutter. The cutter goes deep enough to insure that only rhizomes within the 6 inch plug contribute to the growth under the can. The cans are forced into the soil about 1.5 inches.

With this method we were able to observe significant reserve differences between 16 genotypes that involved the winter hardy Berlin bermuda as one parent. These had been mowed regularly and given low maintenance for 20 years. The number of cans needed to sample a plot will depend on the variation within the plot. We are currently using a total of 10 samples, counting plot replications in another test.

Development of Stress Tolerant Seashore Paspalum for Golf Course Usage

Dr. Ron Duncan

University of Georgia

Goals:

- Establish an extensive collection of genetic material.
- Improve the adaptibility of the species with special emphasis on: acid soil stress tolerance with deep rooting and root plasticity in high bulk density (compacted) soil, winterhardiness to expand its adaptation zone, and wear resistance that will meet or surpass golf course requirements.

Seashore paspalum, *Paspalum vaginatum* Swartz, is a low-input, environmentally compatible turfgrass with salt, drought, and waterlogging tolerance. It can withstand a pH range from 4.0 to 9.8. Additional common names include sand knotgrass, sheathed paspalum, siltgrass, salt jointgrass, seaside millet, saltwater couch, and biscuitgrass. Seashore paspalum is a perennial, warm-season, semi-aquatic diploid (2n=20) grass with an asexual mode of reproduction. It is native to tropical and subtropical areas, including North and South America, Africa, Australia, New Zealand, the Caribbean, and Central America. It is normally found along coastal regions.

A total of 66 cultivars have been collected thus far: 4 from Africa, 7 from Argentina, 1 from Australia, 4 from the Caribbean, and 50 from the United States. Turf texture ranges from very fine to intermediate, to coarse, to very coarse ornamental types.

Various cultivars have been evaluated for adaptation to soil pH ranging from 3.9 to 6.5. Most genotypes have no trouble rooting in the high bulk density, low organic matter, acid red clay soils of Georgia.

Cold tolerance is the limiting characteristic for movement of the turf species inland. The documented low temperature tolerance is 17 to 18^0F. Field evaluation of 25 cultivars during the 1992-1993 winter at Griffin, GA produced two cold-shock recovery cycles of 16^0F at one site, and one 12^0F shock at another site. One cultivar was killed; two were damaged, but recovered; all others were not affected. Another field test has been planted at Blairsville in Northern Georgia

(Appalachian Mountains) at an elevation of 1,100 feet. Temperatures commonly reach 0°F during the winter at this location.

Management studies have been initiated for paspalum turf quality on putting greens and fairways. Herbicide evaluations on judiciously managed paspalum turf were established in 1993. Armyworm moth studies found significant differences among cultivars for either ovipositional (i.e., egg laying) preference or larval survivability. Tawny and southern mole crickets caused a significantly greater reduction in turf quality, compared to unifested controls, with some variation among the cultivars.

Tissue culture regeneration, RFLP and RAPD evaluations are underway to determine relatedness among the 66 paspalum ecotypes. Flow cytomerty analyses of the DNA content among *Paspalum* species and among seashore paspalum genotypes is providing information for future inter- and intraspecific breeding studies.

Some seashore paspalum cultivars require a temperature-induced trigger (cold shock $\leq$ 60°F) or a photoperiod-sensitivity trigger ($\leq$11 hours light or $\geq$16 hours light), or both, to initiate flowering. Other genotypes are photoperiod and temperature insensitive. Both traditional and biotechnological techniques are being used to improve winterhardiness and seed production capabilities of this species.

Breeding and Evaluation of Seeded Cold-Tolerant Bermudagrass Varieties

Dr. Charles Taliaferro

Oklahoma State University

Goals:

- Assemble, evaluate, and maintain *Cynodon* germplasm with potential for contributing to the genetic improvement of the species for turf.
- Improve bermudagrass germplasm populations for seed production potential, cold tolerance, and other traits conditioning turf performance.
- Develop, evaluate, and release superior seed-propagated, cold-tolerant, fine-textured, turf bermudagrass varieties for the U.S. transition zone and similar climates.
- Develop, evaluate, and release improved vegetatively-propagated bermudagrass varieties with specific adaptations and uses in the southern U.S., e.g. varieties for golf course putting greens in the deep south.

Two bermudagrass, *Cynodon dactylon*, broad-base genetic populations have been developed using phenotypic recurrent selection. One population, $C_{3fer\text{-}2tex}$, was developed from cold tolerant germplasm subjected to selection for increased fertility (seed set) and finer texture. The second population, C_{1ct}, was more recently developed from germplasm with high seed yield potential but moderate cold tolerance. Selection was practiced within the population for increased cold tolerance and fine texture.

Synthetic varieties derived from selected parental plants of $C_{3fer\text{-}2tex}$ have demonstrated good cold tolerance and turf quality in comparison to control varieties.

Evaluation of more than 3,000 African bermudagrass, *C. transvaalensis*, progeny plants has demonstrated extensive variability for many characteristics. Wide variation exists for important turf performance traits such as response to high or low temperatures, low mowing tolerance, texture, color and sod density. The wide phenotypic variability indicates substantial genetic diversity within the species.

Hybrid populations have been developed to study the magnitudes of genetic variances and heritabilities of selected traits. African selections had finer texture, greater sod density, and greater cold tolerance than TIFGREEN or TIFDWARF. The African bermudagrasses tend to have lighter green color, more thatch, and greater susceptibility to scalping than conventional varieties.

Morphologically or cytologically variant TIFDWARF plants were found among progeny regenerated from tissue culture. Morphological variants are either more or less dwarfed than TIFDWARF. Cytological variants have higher chromosome numbers (2n=45 or 2n=54) than the expected chromosome number of 2n=27.

Alterations in protein synthesis associated with cold acclimation was studied in MIDIRON and TIFGREEN bermudagrasses. Both varieties synthesized cold-regulated (COR) proteins of several size ranges, in association with cold acclimation. MIDIRON crowns synthesized COR proteins in greater numbers and amounts than TIFGREEN crowns.

Table III. 1993 Mean Turfgrass Quality Ratings of Seeded Bermudagrass Cultivars For Each Month Grown At Twenty-One Locations in the United States.

	Turfgrass Quality Ratings[1]											
Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
OKS 91-11	3.8	4.3	5.0	4.9	5.7	5.8	6.0	5.9	5.9	5.7	4.3	4.5
JACKPOT (J-912)	4.3	5.1	4.9	4.1	5.4	5.7	5.9	5.8	5.7	5.8	4.6	5.0
SULTAN (FMC 6-91)	4.4	4.9	4.8	4.3	5.4	5.6	5.8	5.7	5.8	5.7	4.9	5.0
J-27	4.0	4.7	5.0	4.6	5.8	5.8	6.0	5.8	5.7	5.4	4.3	4.9
MIRAGE (90173)	4.3	4.9	5.0	4.3	5.7	5.8	5.8	5.7	5.7	5.6	4.3	5.0
FMC 5-91	4.4	5.2	4.6	4.1	5.4	5.2	5.7	5.6	5.6	5.6	4.6	4.9
FMC 2-90	3.9	4.8	4.7	3.9	5.3	5.4	5.4	5.4	5.4	5.4	4.3	4.7
GUYMON	4.1	4.4	4.8	4.7	5.9	5.5	5.7	5.3	5.5	5.2	4.1	4.5
OKS 91-1	4.3	4.8	4.3	3.7	5.4	5.3	5.5	5.3	5.5	5.2	4.1	4.5
FMC 3-91	4.3	4.7	4.7	4.1	5.2	5.1	5.3	5.4	5.4	5.4	4.4	4.8
NuMex SAHARA	4.3	4.8	4.6	4.4	5.4	5.3	5.3	5.4	5.4	5.3	4.0	4.5
SUNDEVIL	4.4	4.6	4.4	4.1	5.1	5.2	5.3	5.2	5.5	5.5	4.2	4.4
SONESTA	4.3	4.7	4.7	4.0	4.9	5.2	5.3	5.2	5.4	5.3	4.1	4.6
PRIMAVERA (FMC 1-90)	4.2	4.7	4.2	3.7	4.8	4.9	5.1	5.3	5.2	5.0	4.1	4.5
CHEYENNE	4.1	4.3	4.3	3.9	4.7	4.7	5.0	5.2	5.2	5.2	4.1	4.2
Arizona Common	4.2	4.3	4.2	3.8	4.6	4.7	4.9	5.1	5.2	5.0	3.9	4.2
LSD Value[2]	0.6	0.9	0.9	1.4	0.7	0.7	0.5	0.5	0.4	0.4	0.9	0.9

[1] Turfgrass Quality, where 1 = poor and 9 = ideal turf.

[2] To determine statistical differences among entries, subtract one entry's mean from another entry's mean. Statistical differences occur when this value is equal to or larger than the corresponding LSD Value (LSD 0.05).

Breeding, Evaluation and Culture of Buffalograss for Golf Course Turf

Dr. Terrance Riordan

University of Nebraska

Goals:

- Develop vegetative and seeded turf-type buffalograsses which conserve energy and water.
- Develop buffalograss establishment protocols and management systems to provide acceptable golf course rough and fairway turf at significantly reduced levels of energy input.
- Determine range of adaptation of turf-type buffalograsses.
- Evaluate potential insect and disease pests of buffalograss.
- Evaluate physiological and biochemical principles of environmental stress and nutrient utilization in buffalograss.

The sales of '609' buffalograss are expected to meet the projections of Crenshaw & Doguet Turfgrass. This has been accomplished by selling almost all of the 104 acres at Bastrop, TX.

Both '315' and '378' cultivars were officially released by UNL, and plant patents are nearly complete. Approximately 15 acres of '315' have been planted at Nickerson, Nebraska, and 20 acres of '378' have been planted at Mead, Nebraska. Sod and plugs will be available in 1994.

Cold, wet weather in 1993 has negatively affected buffalograss seed production and has set back the release of new seeded cultivars. However, both cooperating groups, Native Turfgrass Group (NTG) and Sharps Bros, continue to make progress toward developing seeded turf-type buffalograsses.

During 1992 and 1993, '315', '378', AZ143, NE 84-436, and NTDG-2 were the top performers at the Mead, NE. The National Turfgrass Evaluation Program (NTEP) reported that '609', '315', '378', and BUFFALAWN were the top vegetative selections, and the NTDG (now NTG) series are among the top seeded buffalograsses.

The phytotoxicity of several herbicides, including MON 12051, Barricade®, pendimethalin, and Dimension®, was evaluated to determine their potential for use on buffalograss. No phytotoxicity was observed, indicating that with proper label clearance their use would be acceptable.

Observations of a planting date study initiated in 1992 indicate that cultivars differ in their optimum planting date. For example, '315' plots planted in September survived the winter. A buffalograss traffic tolerance study was initiated with two mowing heights, three fertility levels, and two traffic levels. Preliminary observations indicate excellent tolerance and recovery from wear.

Table IV. 1993 Mean Turfgrass Quality Ratings of Buffalograss Cultivars For Each Month Grown At Nineteen Locations in the United States.

	Turfgrass Quality Ratings[1]											
Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
609 (NE 84-609)	4.0	4.7	4.7	5.4	5.5	5.7	6.2	6.1	6.4	6.2	5.8	5.0
315 (NE 84-315)	4.0	3.5	4.8	5.9	6.2	6.4	5.9	5.7	6.2	4.8	4.0	4.2
378 (NE 85-378)	4.0	3.5	4.4	5.9	6.0	6.3	5.9	5.9	6.0	4.7	4.6	4.4
BUFFALAWN	4.3	5.0	5.2	6.5	5.3	6.0	6.4	5.7	5.8	6.2	5.1	5.3
NTDG-5	4.0	3.7	4.8	5.8	5.6	6.0	5.8	5.9	6.0	4.9	4.4	4.4
NTDG-4	4.0	4.0	4.7	5.8	5.8	6.1	6.0	5.6	6.0	5.0	4.0	3.8
NE 84-436	4.0	3.8	4.9	5.9	5.8	6.1	5.7	5.9	6.0	4.9	4.8	4.6
NTDG-2	4.0	3.7	4.7	5.5	5.4	5.8	5.8	5.6	6.2	5.0	4.0	4.3
NTDG-1	4.0	3.7	4.6	5.7	5.4	6.1	6.0	5.6	5.9	4.9	4.3	4.3
PRAIRIE	4.0	4.8	4.9	5.5	5.3	5.6	6.2	5.9	6.0	5.8	5.2	4.9
AZ 143	4.0	4.5	4.9	6.1	5.5	5.8	5.7	5.7	6.0	4.8	4.0	4.6
NTDG-3	4.0	3.8	4.2	5.8	5.5	6.1	5.9	5.8	5.8	4.7	4.2	4.3
RUTGERS	4.0	5.0	5.1	6.1	5.0	5.5	6.1	5.4	5.6	5.9	5.1	4.9
TOP GUN (BAM 101)	4.0	3.7	4.4	5.7	5.3	5.8	5.7	5.5	5.6	5.0	4.3	4.3
TEXOKA	4.0	3.2	4.3	5.5	4.9	5.4	5.8	5.5	5.5	5.2	4.4	4.6
HIGHLIGHT 4	4.0	5.0	4.8	5.5	5.1	5.3	6.0	5.7	5.6	5.8	5.3	5.2
HIGHLIGHT 25	4.3	4.8	5.2	6.1	5.4	5.5	5.8	5.3	5.5	5.8	5.2	5.1
SHARPS IMPROVED	4.0	3.7	4.7	5.7	5.4	5.7	5.7	5.4	5.6	4.8	4.2	3.7
HIGHLIGHT 15	4.0	5.0	5.2	5.9	5.1	5.4	5.9	5.4	5.4	5.7	4.8	4.6
PLAINS (BAM 202)	4.0	3.7	4.6	5.3	5.0	5.4	5.5	5.4	5.3	4.9	4.1	4.0
BISON	4.0	3.5	4.7	5.3	4.9	5.3	5.3	5.3	5.4	4.8	3.9	4.0
NE 84-45-3	3.7	3.5	4.4	5.0	5.1	5.5	5.7	5.2	5.1	4.3	3.7	3.6
LSD Vaule[2]	0.3	0.5	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.7	1.5	1.6

1 Turfgrass Quality, where 1 = poor and 9 = ideal turf.

2 To determine statistical differences among entries, subtract one entry's mean from another entry's mean. Statistical differences occur when this value is equal to or larger than the corresponding LSD Value (LSD 0.05).

Improvement of *Poa annua* for Golf Turf

Dr. Donald White

University of Minnesota

Goals:

- Expand the evaluation and development of the advanced selections for turf quality, seed production, and seeding recommendations.
- Continue and expand seed production evaluations in Oregon.
- Continue and expand the development of a "breeder's" seed supply.
- Expand seeded evaluation plantings at selected golf course and university locations.

Field evaluations of the five prime selections continued at the San Diego CC, Chula Vista, CA; The Country Club, Brookline, MA; Oswego CC, Oswego, OR; and were expanded at the University of Minnesota. Mowing heights varied form 1/8 to 1/2 inches. Evaluations at all locations indicate that all selections continue to produce excellent turf. All selections overwintered well at all locations and experimentals 42, 184, and 208 received the highest ratings at all locations.

Approximately 250 new accessions were added to the program. Twenty-two of these are diploid (2n=14 chromosomes) while the rest were normal tetraploid (2n=28) types. Some of the diploids produced flowers; however, to date all are sterile. Purported *Poa infirma* seed was acquired for crossing with *P. supina* and *P. annua*. Subsequent growth and DNA analysis indicate that the material is probably an annual type of *P. annua*. Crosses were completed to several selections and selfed seed was also collected for further evaluation.

A total of 2,250 accessions were evaluated in a field space planting. Twenty-five new crosses were executed for combining desirable characteristics. New materials with promise include one *P. supina* (PS56-S3) which produces uniform, fine textured and dark green progeny. Interspecific crosses of *P. supina* X *P. annua* produced dark green, vigorous, rugged progeny. Flow cytometry has enabled us to conduct a large number of chromosome evaluations and identify the 14 chromosome types.

The 14 chromosome *P. annua* plants are all fine textured, dense, and dark green. Investigations at several golf courses reveal that up to 24 percent of the *P. annua* samples collected from greens were diploid (2n=14) chromosome types. These 14 chromosome plants were not found in fairways or roughs. Low height of cut and other putting green management practices apparently selected for the diploid types.

Observations continue to support findings that seeded plantings are superior to sodded plantings. Variation in seed dormancy was observed. Experiments showed that seed selections of 184, 493, and 117 require a pre-plant, moist, cold treatment of 7 to 14 days to overcome dormancy. Otherwise, 7 to 8 months in seed storage is required.

Preliminary research indicated that inheritance of flowering habit was controlled by one gene; however, recent research results indicates that a more complicated model exists. Some *P. annua* types exhibit no requirements for flowering to occur, and contrary to the literature, some respond to photoperiod alone, cold induction alone, or to both photoperiod and cold.

Experiments with gibberelic acid (GA) show that it increases internode length. Preliminary work revealed that a timely GA treatment can enable removal of all flower heads with one mowing. This could change the way we manage *P. annua* on existing greens.

We now have enough seed to expand the field evaluation operations with larger plots and more sites. There is enough seed to produce breeder's seed which would be sufficient for planting foundation seed in 1994. Negotiations are still underway to make final arrangements for this planting. Negotiations also continue toward releasing the best materials to a commercial seed company for marketing the first seeded variety by 1996.

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Cultural Practices

Introduction

A series of research projects with the aim of substantial reduction in water use, pesticide use and maintenance costs are conducted on a regional basis. This is necessary because of regional differences in climatic, soil and stress conditions. The objectives of these studies has focused on the following:

- Range of adaptation and stress tolerance of new grasses resulting from the breeding projects
- Evaluation of direct and interacting effects of two or more cultural practices
- Management of native and low maintenance grasses
- Development of cultural programs which substantially reduce weedy species in golf turf
- Development of cultural practices which allow efficient turf management under conditions of poor quality soils or severe air pollution, or which permit the use of effluent or other marginal quality waters
- New research techniques that reduce pesticide and other chemical usage

The results of these studies have led to the development of maintenance programs that conserve substantial quantities of water, reduce fertilizer needs and decrease mowing frequency; all without impairment of functional quality or aesthetic appeal.

Characterization of Water Use Requirement and Gas Exchange of Buffalograss Turf

Dr. Daniel Bowman

University of Nevada

Goals:

- To determine water use requirements of buffalograss.
- To examine genotypic variation in water use.
- To determine the effect of nitrogen fertilization on water use.
- To determine the relationship between photosynthesis and growth of buffalograss under drought stress.

Since irrigation accounts for nearly half of urban water use, considerable savings could be realized by planting turfgrasses with low water use requirements. Buffalograss may be the ideal species for both water savings and aesthetics, but water use data are scarce and one can only speculate on water requirements. This study will generate irrigation crop coefficients for buffalograss and identify intraspecific water use differences, if any, among a diverse selection of genotypes.

A field project was established at the University of Nevada, Reno (UNR) Valley Road Field Station to determine water use requirements of seventeen buffalograss genotypes representing a diverse genetic background. This project utilizes a line source water gradient designed to provide a continuum of irrigation volumes ranging from a value slightly exceeding potential evapotranspiration (ET) to essentially zero. By planting the buffalograss varieties in strips perpendicular to the irrigation line, turf performance can be measured at any given irrigation amount. Further, minimum irrigation requirements are indicated by that point in the gradient beyond which the turf cannot survive.

Plots were planted and established during the summer of 1992. The total experimental plot area measures 153 by 88 feet, and is surrounded by a 43 ft border planted to 'Vegas' tall fescue. Plugs of 17 buffalograss selections, representing three ploidy levels, were planted on 15 inch centers in individual plots measuring 4.5 by 44 ft. The experimental design was a randomized complete block design with four replicates.

Four mini-lysimeters (6 inches in diameter, 12 inches deep and each with a drain hole and removable plug to stop drainage) were established in the greenhouse for each genotype. Cores for the lysimeters were drilled in each plot 6.5 ft. from the main irrigation line. These will be used to determine ET gravimetrically under non-limiting conditions.

By October, 1993, all genotypes, except the three planted late, were fully established. Both the diploid and tetraploid genotypes were maintaining good color as late as October 12, while the hexaploids were well into dormancy.

It is planned to establish the line source gradient beginning July 1, 1994. Both outside lines will be adjusted to water only the tall fescue border. Irrigation will be scheduled based on ET (Penman) as determined with an on-site weather station. Performance, actual ET, and plant water status data will be collected during the 1994 and 1995 growing seasons.

Fertility Effects on Creeping Bentgrass, Pest, Water, and Root Relationships

Dr. Robert Carrow

University of Georgia

Goals:

- Compare new USGA sponsored bentgrasses with two industry standards for:
    - shoot growth.
    - root growth.
    - water use.
    - disease and insect tolerance.

Creeping bentgrass (*Agrostis palustris* Huds.) is the preferred species for golf greens in the upper South. The hot, humid environment of the Southeast, however, results in substantial high temperature and disease stress on this cool-season species.

The objectives of this project were to compare three experimentals from Texas A&M University with two industry standards for 1) root growth and water extraction patterns in the summer months, 2) shoot growth, and 3) disease and insect tolerances. The five bentgrasses included PENNCROSS, PENNLINKS, Syn1-88, CRENSHAW (Syn3-88), and CATO (Syn4-88).

On a 5-year old USGA specification putting green, two nitrogen fertility programs and two fungicide programs were included for each variety. The annual fertility programs were 3.5 lb N and 7.0 lb N per 1000 ft^2, while the two fungicide programs were preventative and curative. For the curative program, substantial disease development was allowed before curative rates of a fungicide were applied. This allowed disease infection and recovery from disease to be monitored. The mowing height was 5/32 inches with clippings removed.

A summary of the conclusions to date are:

1. CRENSHAW and CATO exhibited significantly better visual quality and shoot density than PENNCROSS. As the summer progressed, both cultivars maintained better density and quality.

2. CATO was the only cultivar that did not exhibit

a greater deterioration in quality and shoot density in late summer at high N versus low N. This indicates that CATO could withstand higher N when needed without adversely affecting late summer performance.

3. Relative to PENNCROSS: Syn1-88 was much more susceptible to brown patch; CRENSHAW was very susceptible to dollar spot; all cultivars were more susceptible to the *Curvularia* yellow spot.

4. At the higher N regime, CRENSHAW and CATO tended to exhibit less root decline (based on percent changes in root length density) than PENNCROSS within the top 4 to 8 inches of soil. This was a trend and not a strong treatment effect.

5. CATO often extracted more soil moisture than PENNCROSS during the summer months, which would lessen the effects of indirect high temperature stress over the summer.

6. All bentgrasses were found to be equally susceptible to black cutworm induced feeding injury. All grasses were equally suitable for larval survival and growth as measured in these short-term, no-choice field studies.

Data still under analysis includes brown patch and dollar spot evaluation, thatch buildup over 3 years, and rooting. These results may alter the above conclusions to some extent.

Zoysiagrass Performance, Water Use, and Rooting as Affected by Traffic and Nitrogen

Dr. Robert Carrow

University of Georgia

Goals:

- Evaluate nine new experimental zoysiagrasses for:
  - water use.
  - drought tolerance.
  - cultural requirements.
  - stability under environmental stress and pest pressure.

Zoysiagrass (*Zoysia japonica*) is a deep-rooted, drought resistant species in many areas of the United States, especially in the transition zone. Due to considerable genetic diversity among ecotypes, zoysiagrass has been targeted by the USGA as a species that could be developed through breeding to exhibit low water use, high drought avoidance and high drought tolerance.

Objectives of the current study were to evaluate nine experimental zoysiagrasses from Texas A&M University versus three commercial cultivars under three nitrogen levels and three traffic programs for:

a) evapotranspiration (ET), spatial rooting/water extraction patterns, and drought avoidance/tolerance responses
b) basic cultural requirements (fertility, disease, insect, traffic tolerance)
c) determination of the stability of these grasses to environment, disease, and insect pressures.

A summary of the observations to date are:

1. The entries which were most rapid to cover during plugging were 8514, EL TORO, and 8512, while the least were 8516 and 8502.

2. Cultivars exhibiting substantial cold induced winter injury at this location are 8501, 8502, and 8701.

3. Consistently high visual quality has been expressed by 8507, EMERALD, and 8512 at 1.25 and 2.50 lb N/1000 ft^2/yr and by 8501 at

3.75 lb N. The lowest visual quality has been 8501 across all N levels.

4. All cultivars substantially improved in quality from 1.25 to 2.50 lb N with some improvement from 2.50 to 3.75, but of lesser magnitude.

5. Differential cultivar responses are starting to develop under the three traffic treatments.

6. Evapotranspiration (ET) rates over all dates ranged from 3.93 for MEYER to 2.77 mm d^{-2} for 8507. Cultivars exhibiting lowest ET and very little wilt during a moderately severe dry-down were 8501, 8512, EL TORO, and 8502.

7. Cultivars demonstrating moderately severe wilt in late summer dry-down were 8516, 8507, 8508, and 9006.

8. Rooting data under cultivar and traffic regimes are currently being processed.

9. Tawny mole cricket injury and suitability for oviposition was lowest for 8502 and 8514, while 8516 exhibited greatest damage.

Seeded Bermudagrass Performance, Water Use, and Rooting as Affected by Traffic and Nitrogen

Dr. Robert Carrow

University of Georgia

Goals:

- ET, drought resistance, rooting/water extraction patterns and shoot responses will be determined under field conditions.
- Basic cultural programs (fertility, disease/insect, traffic tolerance) will be defined.
- Determine environmental stability of these grasses with respect to environment, disease, and insect pressures.

The turfgrass breeding programs are developing grasses with high drought resistance, including low evaportranspiration (ET). The development of basic cultural programs and adaptation data on new turfgrasses is needed before they are released. This would insure rapid acceptance of these grasses by golf course superintendents and other growers.

In this project, a soil is used that imposes two of the major soil stresses (i.e., high soil strength and aluminum toxicity) that may produce differential rooting responses from the bermudagrasses. ET, drought resistance, rooting/water extraction patterns and shoot responses of newly seeded bermudagrasses are determined under field conditions. Any bermudagrass cultivar able to develop a deep and extensive root system, will have a major drought avoidance advantage.

The new seeded bermudagrasses are grown under fairway management. Data obtained in Georgia is compared to similar data from Oklahoma to determine the stability of these grasses with respect to environment, disease, and insect pressures.

Nine experimental seeded bermudagrasses from the USGA supported breeding program at Oklahoma State University and two commercial seeded bermudagrass cultivars (Arizona Common and PRIMAVERA) were seeded at 1.25 lb PLS/1000ft^2 on June 8, 1993. The experimental cultivars were: 91-1, 91-2, 91-3, 91-4, 91-10, 91-12, 91-14, and 91-15. By mid-fall 1993, more than 90 percent coverage was observed for 91-2, PRIMAVERA, and 91-1. Traffic and N-program treatments will be initiated in April 1994.

Turfgrass Irrigation with Municipal Effluent: Nitrogen Fate, Turf Kc Values and Water Requirements

Dr. Charles Mancino

University of Arizona

Goals:

- Determine the potential movement of organic contaminants and nitrogen contained in municipal secondarily treated wastewater used to irrigate turf.
- Develop information pertaining to this movement; how these contaminants can be managed to reduce the risk of groundwater pollution.
- Determine how effluent irrigation influences the water and nitrogen requirements of turf.
- Evaluate the evapotranspiration equations currently in use in the southwestern US.

Two weighing lysimeters have been installed at the University of Arizona Karsten Turfgrass Research Center for researching the consumptive water use of turf, nitrogen fertilizer loss through leaching, and solute transport through a fine sand soil profile.

Each tank is 13 feet deep and 8 feet in diameter, and has a soil-filled weight of approximately 99,120 lbs. Each tank has sampling ports in groups of five which are spaced at 120^0 intervals around the tank. These ports begin at the 3.3 foot depth (level) and are then positioned every 1.6 feet down to a depth of 11.5 feet. Tensiometers with pressure transducers, Time Domain Reflectometry (TDR) probes, and ceramic and stainless steel solution samplers have been installed, three at each level.

A single neutron probe access tube was installed in the center of each lysimeter. These devices are used for sampling soil water and monitoring soil moisture content. A Cardinal scale with an electronic loadcell measures changes in tank weight to ± 0.44 lbs (0.002" water loss or gain).

Land preparation and irrigation system installation was completed on the site. A dual irrigation system was used so that each lysimeter can receive wastewater or potable water. A wind speed shut-off switch and zero trajectory heads were installed to prevent drift. The lysimeter computer will also be able to shut the irrigation system off when a predetermined amount of water has been applied.

Low Temperature and Drought Regulated Gene Expression in Bermudagrass

Dr. William Baird

Clemson University

Goals:

- Isolate cDNA clones of genes preferentially transcribed under conditions of low temperature or related water stress.
- Characterize their stress-specific expression.
- Determine the primary molecular structure of these clones.
- Isolate the corresponding genomic clones that contain the inducible response element(s).

Nuclear DNA samples have been isolated from three cultivars of bermudagrass (MIDIRON, TIFWAY, and TIFGREEN). 'U-3' also will be included in these studies. The DNA preparations are of sufficient quality (high molecular weight, and free of contaminating proteins and polysaccharides) and quantity that restriction endonuclease digestion can readily be performed. The digested DNA was used in differential hybridization analysis (Southern blots) of the bermudagrass nuclear genome.

Heterologous gene probes for nuclear sequences correlated with induction at low-temperatures or by exposure to conditions of water deficit, originally isolated from dicotyledonous species, will be used to screen these membrane blots. Initial surveys by dot and slot-blot analysis, using undigested genomic DNA and entire plasmid clones as gene probes, indicate that many of these genes will likely detect related sequences in these cultivars, and these may prove to be evolutionarily conserved in bermudagrass.

Institutional support for the purchase of additional growth chambers has been acquired. These chambers will be utilized in establishing standard conditions of temperature, light and humidity to reproduce the environmental parameters necessary for low-temperature acclimation. Characterizing the expression of sequences related to the heterologous gene probes under these standardized environmental conditions is the next objective of this project.

Use of VA Mycorrhizae in Establishment and Maintenance of Greens Turf

Dr. Noel Jackson

University of Rhode Island

Goals:

- Identify species of mycorrhizal fungi associated with bentgrass and *Poa annua*.
- Develop techniques to culture fungi.
- Use fungi to promote turfgrass establishment, minimize phosphorous applications, and increase disease tolerance.

This report describes research carried out from November 1992 through November 1993. The original project consisted of several interdependent studies: identifying the species of mycorrhizal fungi that are associated with velvet and creeping bentgrass and *Poa annua*, culturing these fungi, and testing the fungi to promote establishment of greens turf, minimize applications of phosphorous fertilizers, offer protection against root pathogens, enhance resistance of greens to invasion by *Poa annua*, and increase drought tolerance.

Major accomplishments during the period covered by this report include:

1. Field and greenhouse studies with mycorrhizal fungi conferred markedly enhanced drought tolerance in creeping bentgrass.

2. Mycorrhizal turf contains significantly more proline, an amino acid implicated in drought tolerance and disease resistance.

3. Three fungal isolates significantly stimulate growth and early establishment of turf.

4. Fertilization of mycorrhizal turf with low levels of phosphorus results in plant growth that is equal or superior to that resulting from higher phosphorus levels.

5. Mycorrhizal PENNCROSS turf is greener than nonmycorrhizal turf, possessing nearly 60 percent more chlorophyll.

6. Benefits of mycorrhizae could be consistently

maintained by frequent applications of a complete fertilizer solution containing low concentrations of phosphorus. Established mycorrhizal turf that no longer showed benefits (because of excessive application of phosphorus or fungicides) could be easily restored.

7. A commercial source of mycorrhizal inoculum has been found. In addition to providing their own fungal isolate, they are willing to produce inoculum of our sand dune isolates that have shown promise in the sand green medium.

Alternative Pest Management

Introduction

The purpose of these research studies is to evaluate valid alternative methods of pest control for use in integrated turf management systems. Projects investigate alternative pest control methods that include:

- Biological control
- Nonchemical control including cultural and mechanical practices
- Allelopathy
- Selection and breeding for pest resistance
- Ecological balance of turfgrass species
- Application of integrated turf management practices utilizing IPM and low cultural inputs.

Development of Improved Turfgrass with Herbicide Resistance and Enhanced Disease Resistance through Transformation

Dr. Peter Day

Rutgers University

Goals:

- Establish a transformation system for creeping bentgrass.
- Improve the utility of creeping bentgrass by incorporating genes to confer herbicide resistance or enhanced resistance to fungal pathogens.

This program aims to establish a transformation system for creeping bentgrass (*Agrostis palustris*) which will enable us to improve the utility of this important recreational turfgrass by incorporating genes to confer herbicide resistance or enhanced resistance to fungal pathogens. While still providing high quality playing surfaces for golf, these improvements will help conserve natural resources by reducing chemical treatments against major fungal pests and remove weeds using available broad-spectrum and environmentally friendly herbicides.

Two milestones for successful turfgrass transformation are: 1) establishment of a plant regeneration system to produce regenerants at high efficiency, and 2) development of a high frequency transformation system to obtain large numbers of transgenic plants.

Using surface sterilized seed as explant material for callus initiation, we developed a turfgrass tissue culture and regeneration system. Embryogenic callus lines with high regeneration potential were established from eight commercially important creeping bentgrass varieties. Suspension cultures were initiated from embryogenic callus lines. Both embryogenic callus cultures and suspension cells were used as targets for stable transformation using a gene gun.

The *E. coli* ß-glucuronidase (GUS) gene was used as a scorable marker and the *bar* gene, which confers resistance to the herbicide bialaphos (*Basta*™), was used as a selectable marker. We optimized various parameters to improve transient expression of GUS in cultured bentgrass to high levels, and we have developed a turfgrass transformation system with particle bombardment. Transformations were obtained from EMERALD, PUTTER, and SOUTHSHORE creeping bentgrass. Experiments incorporating several herbicide resistance genes in other cultivars are in various stages of completion.

Both plate and liquid selection were successful in obtaining herbicide resistant bentgrass. Transgenics have been confirmed by herbicide tests, polymerase chain reaction (PCR) assay and southern blot hybridization to show the presence of the transgenes.

We are also developing a protoplast transformation system. Regenerants were obtained from protoplasts through direct DNA uptake with polyethylene glycol (PEG) or electroporation. These plants will be tested for herbicide sensitivity by spraying in the greenhouse.

Recovery of *Rhizoctonia solani* Resistant Creeping Bentgrass Germplasm Using the Host-Pathogen Interaction System

Dr. Jeffrey Krans

Mississippi State University

Goals:

- Recover *R. solani* selected variants of creeping bentgrass using the Host-Pathogen Interaction System (HPIS).
- Screen and grade recovered *R. solani* selected creeping bentgrass variants using an *in vitro* whole plant disease screening system.
- Establish a clonal repository of *in vitro* screened *R. solani* resistant creeping bentgrass variants.
- Verify whole plant resistance of *in vitro* screened variants using greenhouse studies for determining *R. solani* resistance.
- Evaluate progeny for resistance to *R. solani*.
- Select parents that exhibit resistance to *R. solani* in conjunction with other desirable turf characteristics.

Considerable progress has been made toward recovering brown patch (*Rhizoctonia solani*) resistant creeping bentgrass germplasm. In the laboratory, 203 plant variants were recovered from bentgrass callus that was co-cultured with *R. solani* via the Host-Pathogen Interaction System (HPIS). Due to the success in recovering germplasm in the HPIS, we are able to select large numbers of variants, while maintaining a predictable production schedule of germplasm that will be subjected to additional screening in the laboratory, greenhouse, and field evaluations.

Laboratory studies addressing *in vitro* plantlet screening against *R. solani* is progressing favorably. Plantlets recovered from HPIS screening were inoculated by placing 1 mm plugs of *R. solani* mycelium on the leaves. Preliminary results indicate segregation of resistance among the variants. A comprehensive study has been initiated based on these findings. If this procedure proves reliable, another level of screening will be incorporated into an already intense screening procedure. Bentgrass germplasm will undergo cellular, plantlet, and whole plant screening prior to field evaluation.

The variants we are working with at the whole plant level are being maintained in our newly acquired environmental control greenhouse (ECG). The ECG is equipped with a 3 ton heatpump air conditioner that allows us to provide an optimum, stress-free environment for growing creeping bentgrass on a year round basis. Thus we can provide adequate light, optimum temperatures, humidity, and so forth while isolating the variants from various greenhouse contaminants.

A fritted clay growth medium is used to propagate the variants and prepare them for the next level of *R. solani* screening experiments. These screenings are scheduled to begin in November 1993. The variants will be rated on their response to *R. solani* and recovery rate from infection. Those displaying enhanced resistance will be maintained in a clonal repository for preservation, field evaluation, and seed production.

Our objective is to take superior lines to the field and evaluate them for enhanced resistance to *R. solani*. Ultimately we hope to isolate and provide *R. solani* resistant genetic material to the available germplasm collection for the purpose of developing superior creeping bentgrass varieties.

Development of Genetically Engineered Creeping Bentgrass Resistant to Fungal Disease

Dr. Sam Ha

Virginia Polytechnic Institute and State University

Goals:

- Improve disease resistance of creeping bentgrass using a new genetic engineering approach.
- Introduce the bean chitinase gene into creeping bentgrass to develop varieties resistant to fungal diseases.

This project is designed to improve disease resistance of creeping bentgrass using genetic engineering. The objectives are 1) to develop efficient gene transfer systems in creeping bentgrass and 2) to develop genetically engineered creeping bentgrass with high expression of chitinase genes. Chitinase is one of the defense-response proteins induced in plants upon fungal infections. It is a lytic enzyme that catalyzes the hydrolysis of chitin, a cell wall component of many fungal pathogens. It was shown that constitutively high expression of this protein in genetically engineered tobacco resulted in enhanced resistance to fungal diseases.

For the first year of this project we focused our research efforts on developing a reliable genetic transformation system for creeping bentgrass and isolating chitinase genes from Kentucky bluegrass.

To develop gene delivery systems in creeping bentgrass, we have tried two methods: particle bombardment using a gene gun, and direct gene transfer into protoplasts (plants cells without cell walls) by electric discharges. Parameters affecting efficiencies of gene delivery for both methods have been optimized and transformed cells are now being selected. We have also identified strong regulatory sequences required for a high level of foreign gene expression in creeping bentgrass. Based on these results, transformation vectors that are more suitable for creeping bentgrass are being constructed.

A partial fragment of chitinase genes has been isolated from Kentucky bluegrass and we are currently working on isolation of complete chitinase genes.

New Alternative Pest Management Projects

University Principal Investigator	Title
North Carolina State Univ. Rick L. Brandenburg	Behavioral Studies of the Southern and Twany Mole Cricket
University of California Richard Cowles	Biological Control and Management of Black Turfgrass Ataenius
University of Florida Robin M. Giblin-Davis	*Pasteuria* sp. for Biological Control of the Sting Nematode, *Belonolaimus Longicaudatus* in Turfgrass
University of Arkansas John W. King	Allelopathy vs. *Acremonium* Endophytes vs. Competition Affects on Crabgrass Supression by 12 Perennial Ryegrass
Michigan State University Joseph Vargas	Control of Bentgrass Pathogenc Fungi Dollar Spot, Brown Patch, and Pythium Blight Using Chitinase
University of Kentucky Daniel A. Potter	Cultural Control, Risk Assessment and Environmentally Responsible Management of White Grubs and Cutworms on Golf Courses
Cornell University Eric B. Nelson	Genetic Basis of Biological Control in a Bacterium Antagonistic to Turfgrass Pathogens
Rutgers University Donald Kobayashi	Identification of Parasitic Bacteria as Biological Control Agents Against Summer Patch Disease