EXECUTIVE SUMMARY
SEVENTH ANNUAL BENTGRASS REPORT 1991
BREEDING AND DEVELOPMENT OF BENTGRASS

Principle Investigator: M. C. Engelke
Research Assistant: Mr. Roland M. Murphy (Beginning July 1991)
Research Assistant: Ms. Mary Sue Wilson (Part-time)
Research Period of report: November 1990 to November 1991

The bentgrass breeding program has completed its seventh year of funding by the USGA/GCSAA - Bentgrass Research, Inc. In 1990, three bentgrasses identified as Syn1-88, Syn3-88 and Syn4-88 were submitted to the Texas A&M Plant Improvement Review Committee (PIRC) for release. Through due course of review, it was decided additional information was necessary to warrant release, and it was suggested additional locations be included in the evaluation and performance. Sufficient seed of Syn3-88 (approximately 4,000 pounds), and of Syn4-88 (approximately 2,000 pounds) was produced in 1991. Limited quantities of seed were made available for demonstration plantings, additional replicated trials and for nursery plantings on approximately 35 golf courses throughout the central and southern United States. In addition, two new golf courses have selected Syn4-88 (CATO) for use on all new greens. One course is located in Montgomery, Texas just north of Houston, and the second is just south of Dallas. A third course in Jonesboro, GA has selected Syn3-88 for use on nine newly constructed greens. Additional replicated plantings are being made at Las Colinas Sports Club, Dallas, Texas in cooperation with BRI and Mr. Tom Diamond, and in Jupiter FL at the Loxahachie Golf Club in cooperation with Mr. Phil Shumaker.

Syn4-88 once released will be named CATO creeping bentgrass in honor of the late Mr. Paul Cato, Colonial Country Club, Fort Worth and founding president of Bentgrass Research, Inc. Both Syn3-88 and Syn4-88 have performed well in trials conducted at several locations throughout the southern United States. Each will be resubmitted for release this fall. Syn1-88 continues to demonstrate considerable strength in root persistence and performance under adverse conditions. If released this fall, seed increase will be initiated in the Spring of 1992. Ample seed stocks exist of all three varieties to support additional field plantings.

Reselection, hybridization, and advanced screening programs resulted in the development of 7 new polycross populations in 1991. These in addition to the 14 populations generated during 1990 are being extensively evaluated for heat resistance, root growth characters, disease resistance and leaf hydration response. The disease resistance studies are continuing in cooperation with Dr. Phil Colbaugh with intentions of examining the heritability mechanisms of disease resistance as well as intensely reselecting for improved disease resistance. Two additional manuscripts have been prepared for publication selection techniques concerning leaf water hydration as it relates to heat tolerance in creeping bentgrass, and the second is in gross heat tolerance of the commercially available creeping bentgrass cultivars. Both manuscripts will be published in 1992.

Assessment of genotype performance continues in the greenhouse, field and laboratory, with screening of germplasm. Superior plants are being identified and recycled in the breeding program. Invaluable cooperation continues with Dr. Jerry Pepin and Mr. Doug King, of Pickseed West in Tangent OR, and with Dr. Virginia Lehman of Loft's Great Western in Lebanon, OR.

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SEVENTH ANNUAL REPORT NOVEMBER 1991

BREEDING AND DEVELOPMENT OF BENTGRASS

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BREEDING AND DEVELOPMENT OF BENTGRASS
M. C. ENGELKE, ROLAND M. MURPHY, AND M. SUE WILSON

I. INTRODUCTION

The bentgrass breeding program is a cooperative research project funded jointly by the Texas Agricultural Experiment Station (TAES), the United States Golf Association (USGA), and Bentgrass Research, Inc. (BRI). This project was initiated in Apr. 1985. Semiannual progress reports are submitted 1 May, and annual reports are submitted 1 Nov. each year. This report, with the May 1991 INTERIM REPORT, constitutes the 1991 Annual Progress Report for the Bentgrass Breeding Program.

II. PROFESSIONAL AND TECHNICAL SUPPORT

The Bentgrass Breeding Program has gone through considerable change during the past 15 months, with the departure of Dr. Virginia Lehman. Ms. Sue Wilson (DOH February 1990) remains on the project in a part-time capacity as a Research Assistant while she pursues her MBA. In July of 1991, we were fortunate to hire Mr. Roland M. Murphy, a spring graduate of Texas A&M. Mr. Murphy is employed full-time as Research Assistant on the program. Dr. Lehman continues to work with the program in assisting in seed production evaluation research in Oregon, in addition to the continued cooperation with Dr. Jerry Pepin, Pickseed West - Tangent Oregon.

III. STATUS OF BENTGRASS RELEASES

Since this is an annual report covering the period of time from November 1990 to November 1991, I must again draw attention to the disposition of the bentgrass releases which were denied by the Plant Improvement Review Committee. As stated in the **INTERIM REPORT** filed May 1, 1991 no action has been taken on request for assistance from the administrative offices of Texas A&M concerning the extensive cost associated with additional testing and evaluation as requested by the PIRC. At this time, cost of seed production of Syn3-88 and Syn4-88 alone approaches $30,000 for which the debt is due and payable to the seed producers in Oregon. As part of the program to extend testing and evaluation, I have been able to obtain limited grants-in-aid to defray a portion of these seed costs, through cooperative plantings with several golf courses as listed in Table 1. Close examination of the map (Figure 1) indicates that we have been successful to date in obtaining a rather broad area of evaluation under greens conditions. See **Appendix A.** SEED PRODUCTION AND DISTRIBUTION OF SYN3 AND SYN4 (CATO) CREEPING BENTGRASS. Testing and demonstration plantings extend from the States of Washington and Idaho to Michigan to Virginia, as well as through most of the southern states including Florida, Georgia, Mississippi and Louisiana. See also **Appendix B** SEED PRODUCTION STATUS, **Appendix C** CATO BENTGRASS, and **Appendix D** MISCELLANEOUS DATA TABLES for further details. Additional data has been assembled and will be included with the update to PETITIONS TO RELEASE as previously provided (Sixth Annual Report - 1990). The PETITIONS will be resubmitted to the Directors Office for release consideration within the next several weeks.

IV. NTEP TRIALS FOR BENTGRASS

The National Bentgrass greens and fairway trials have been a major disappointment concerning the TAES/USGA bentgrass lines. The only entry to be successfully entered in all the greens/fairway trials was Syn1-88 also identified as TAMU88-1 due to seed availability in the fall of

1989. Even though we contracted with additional locations to include Syn3-88 and Syn4-88 into field trials in the fall on 1990, only two locations were successful in establishment and providing significant data to date. As reported in the INTERIM REPORT, an additional planting was made in Austin Texas at the Crenshaw & Doguet Turfgrass, Inc. in April 1991 on the infamous GOLF HOLE. Unfortunately, due to a malfunctioning irrigation system, the entire green was lost in mid-summer and subsequently replanted to bermudagrass. As indicated in the previous section, approximately 30 sites have since been planted ranging from 18 holes to single plot nursery plantings. Included in several of these "demonstration" plantings are studies for interseed into existing bentgrass greens, i.e. Penncross, as well as looking as combinations or blends of both Syn3 and Syn4 which we affectionately dubbed Syn12.

V. NOTABLE PUBLICATIONS

Root Growth Characters

New techniques have been developed over the past 7 years to aid in selection for root growth characters with indications of high degree of heritability for root extension. A manuscript "Heritability estimates of creeping bentgrass root systems using flexible tubes", by Lehman, V. G. and M. C. Engelke will be published in the Nov-Dec 1991 issue of Crop Science. This manuscript was originally submitted 20 December 1989.

Leaf Water Content - Heat Tolerance

A second manuscript "Response and heritability of creeping bentgrass shoot water content under soil dehydration and temperature stress" , V. G. Lehman and M. C. Engelke. has been submitted to Crop Science and is presently in the review process. A draft copy was provided with the INTERIM REPORT.

Root Heat Resistance

A third manuscript "Root heat resistance of bentgrass cultivars" is in the TAES review process and will ultimately be submitted to Hort Science for publication. A draft copy of this manuscript is included as **APPENDIX E.** This manuscript presents the relative heat tolerance of commercial bentgrasses when grown under soil temperatures of 43°C (110 °F) at 10 cm (4 inch) soil depth for 10 weeks. The second cycle of heat stress evaluation of commercial and experimental varieties of creeping bentgrass was completed April 15, 1991 which included paired test plots of SYN1-88 and Seaside (its parental cultivar) to substantiate the value of using the hot-water heat bench as an effective evaluation and selection tool.

VI. NOTABLE COOPERATIVE RESEARCH ACTIVITIES

Several hundred progeny will be evaluated under greenhouse conditions for disease resistance response in cooperation with Dr. Phil Colbaugh. Crosses made during 1990 included four parental lines previously identified as resistant to Pythium, which were crossed with two highly susceptible parents. Such progeny are presently being established and will be inoculated under high soil temperatures to assess disease performance. Ideally, the design of the study will substantiate the presence of disease resistance, and also define the heritability of such resistance. If successful, this will lead to a publication, and further advancement in our attempts to develop disease resistance bentgrass cultivars. The initial inoculation occurred mid-June with assessment shortly thereafter. A second inoculation followed in a timely manner.

In cooperation with Dr. Colbaugh, the National Turf Trials at TAES-Dallas which included all three of our bentgrasses were inoculated with pythium in March. The preliminary assessment indicates SYN4-88 has excellent resistance to pythium cultures for which it was challenged, whereas SYN1-88 was considerably more susceptible and SYN3-88 was intermediate and only slightly better than Penncross. See **APPENDIX D.** Miscellaneous data tables. These data tables will not be discussed at this time, however, they will be included in the update to the PETITIONS TO RELEASE which were provided in the 1990 annual report. They are placed in this report as a fact of archival responsibility of the project leader to document continued investigations.

Assessment of genotype performance continues in the greenhouse, field and laboratory, with screening of germplasm. Superior plants are being identified and recycled in the breeding program. Fall seeding transplants made with Dr. Lehman suffered considerable winter heaving and subsequent loss in the spring of 1991. However, between the plant material with Lehman, and that remaining with Pickseed, we successfully developed an additional seven polycross populations involving 67 separate parental lines. Seed was harvested from each of the parental lines and will serve as the base for maternal line selection, and for establishing mini-plots on the research green at TAES-Dallas in the spring of 1992. See **APPENDIX B:** Seed Production Status Report which further elucidates the status of the three synthetics as well as the definition of the newly developed polycrosses.

In addition to the hybridization work in Oregon this summer, I spent considerable time in the breeder blocks SYN1-88, SYN3-88 and SYN4-88 and in the productions fields of SYN3-88 and SYN4-88.

VII. FUTURE WORK:

Major emphasis will continue on screening the hybrid populations and germplasm resources for heat tolerance, root growth characters and disease resistance. Many of the early field plots on the modified green site have been eliminated, having fulfilled their need. Additional field studies will be initiated this spring involving both transplanted and seed plot evaluation trials including many of the new polycrosses from 1990 and 1991. It appears that additional resources will have to be directed to seed production work in Oregon to enable us to obtain sufficient seed stock to provide more extensive testing and evaluation. To date, it has been possible to obtain only a few grams of seed of each of the populations or crosses. This year we established larger isolation blocks of many of the original cross made during 1990, and was able to obtain several hundred grams of seed - quantities sufficient to do earlier generation testing.

APPENDIX

APPENDIX A:

SEED PRODUCTION AND DISTRIBUTION OF SYN3 AND SYN4 (CATO) CREEPING BENTGRASSES

Seed production of Syn3-88 and Syn4-88 (Cato) was initiated in the fall of 1990 with the planting of 10 and 12 acres, respectively. Syn3-88 was established by broadcast seeding using approximately 3 pounds of seed per acre. Syn4-88 (Cato) was row planted at approximately the same seeding rate. Mr. Doug King of Pickseed West, Tangent, Oregon made all field arrangements and provided technical assistance throughout the production cycle.

Syn4-88 was severely infested with slugs (Scientific name ???) shortly after establishment. The fields were periodically treated, however the lateness of the season resulted in relatively poor plant development by early spring. I personally inspected this field in November 1990 (shortly after slug infestation) and again in April and in June. Plant development was severely stunted by the slugs. Additionally, a rather heavy infestation of Colonial and Highland bentgrass contaminants occurred. The combination of factors including heavy roguing to eliminate off-type plants resulted in relatively poor yields from this field. Consequently the field yielded approximately 2000 pounds of high quality (97.8% purity) of Syn4-88 seed. Due to the field contamination, I made the decision in June of 1991 to rogue the fields for off type plants and restrict the use of this seed stock for end-user and not allow this field to serve as a seed-stock field, i.e. foundation for subsequent increase. A total of 2000 pounds of seed (97.8% purity) was harvested. Approximately 500 pounds of the seed was early cleaned and distributed for demonstration testing (Figure 1 and Table 1). The remaining portion of the seed will be cleaned this fall and winter for additional plantings in the spring and next year. A new 5 acre seed-stock field was established using 1991 crop Breeder seed, with anticipated yields in excess of the 450 - 500 pounds per acre for 1992. Syn4-88 has been planted on nursery areas and practice putting greens of approximately 35 golf courses this fall. Most significantly, however 'Cato' Bentgrass has been planted to nine greens on each of two golf courses, one in Montgomery, Texas on the shores of Lake Conroe, and the second will be in Grandbury, Texas. Additional plantings include new seedings and overseedings on courses on Augusta National, August GA; Virginia Country Club, Richmond; Loxahachie Golf Club (Jack Nicklaus course) in Jupiter, Fl; Shady Oaks Golf Club in Fort Worth (3 greens) and numerous other locations (Figure 1, Table 1).

Syn3-88 production field was a total success with field (dirt) yields in excess of 750 pounds, yielding between 475-500 pounds per acre of clean seed. As with Syn4, approximately 500 pounds of seed was cleaned early and brought to Texas for plantings throughout the country. Figure 1 and Table 1 indicate the locations where plantings have been made. Lakes Spievy Golf Club in Jonesboro, GA chose to use SYN3 for the first 9 holes on a renovation project. Greens were established in mid-September with early positive reports. No additional fields will be established of Syn3-88 for seed stock. The remaining production (~4000 pounds remaining) will be fully cleaned and placed in cold storage for subsequent use as seed stocks when the variety is approved for release.

The cost of production, contracted at $4.50 per pound has generated considerable expenses, with estimated expenses for both Syn3 and Syn4 at $31,500. Added to this cost will be additional cleaning and shipping cost to make seed available for fall (1991) distribution for demonstration plantings as unanimously suggested by members of the Plant Improvement Review Committee. A small portion of the cost of production is being recovered through a cooperative testing and GRANT-IN-AIDE program by those Golf Courses using larger quantities of seed, however it is not expected to cover all costs. To date, approximately $2,950 has been pledged by participating courses.

STATUS OF SYN1-88 CREEPING BENTGRASSES SEED PRODUCTION AND DISTRIBUTION

Syn1-88 has not been entered into seed production primarily due to the difficulties associated with Syn3 and Syn4-88. Syn1-88 continues to perform exceptionally well, and appears to be improving with age. Syn1-88 is a direct selection from Seaside Creeping bentgrass and appears to possess many of the positive traits of this old land race cultivar. Only limited seed has been available of this variety, however it was the only entry from Texas A&M to be placed in the National Turf Evaluation Program in 1989. It is identified as TAMU88-1. Additional breeder seed was produced by Dr. Virginia Lehman of the Loft's corporation during 1990/91 in Lebanon, Oregon. Sufficient seed will be available to establish seed-stock fields as early as the spring 1992 if warranted. Syn1-88 has been recently sent to several golf courses in the Permian basin of West Texas where severe salinity problems occur. The cultivar of choice in this region is Seaside due to its exceptional salinity tolerance. Syn1-88 will be evaluated for performance under such conditions.

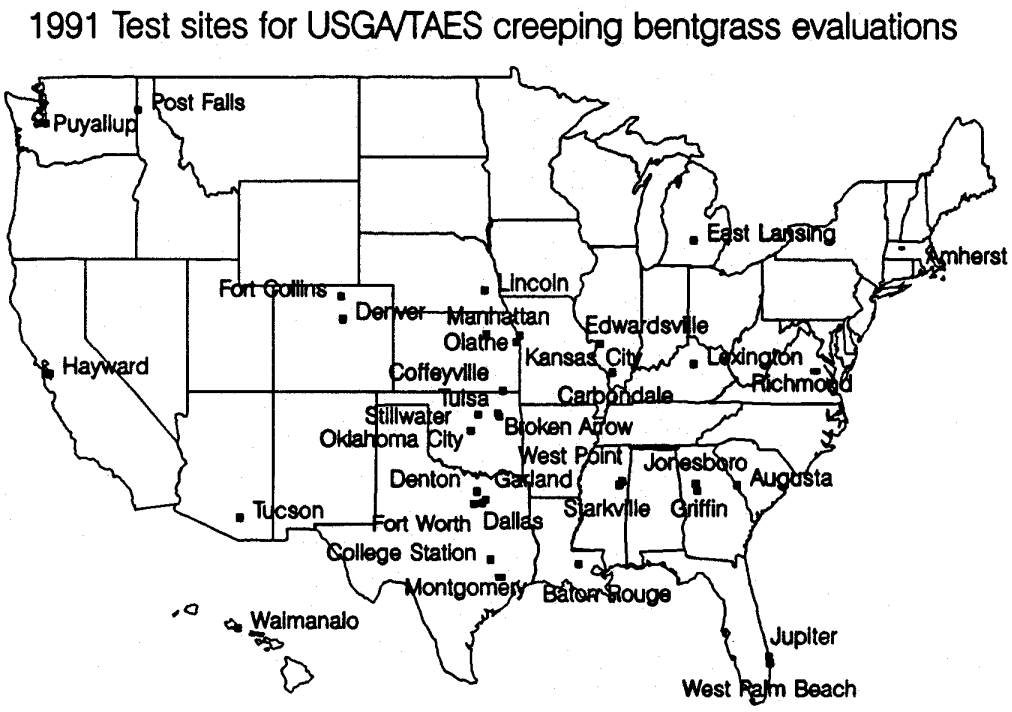

Figure 1. Miscellaneous evaluation and demonstration trials of Syn1, Syn3 and Syn4 Creeping Bentgrass. Not all entries are being evaluated at all locations.

Table 1. Seed distribution list of TAMU developed Creeping Bentgrass cultivars and qualtities of seed shipped during the fall of 1991. List is current as of October 18, 1991.

LOCATION ADDRESS	QUANTITY SYN4	QUANTITY SYN3	QUANTITY SYN1	DATE SHIPPED	Member BRI
Mr. Duke Ajemian Sunset Hills Country Club 2525 Hiway 157 South Edwardsville. Ill. 62025-3637 PHONE: 618 656 0640	10#	10#		9-13-91	No
Mr. Marsh Benson Superintendent 2604 Washington Road Augusta National Golf Club Augusta, GA 30904 P: 404 738 7761	10#	10#		9-13-91	No
Mr. Angus McMillan Bentwater Yacht and Country Club 800 Beltwater Drive Montgomery, Texas 77356 Phone: 409 597 4671	100#			9-25-91	Yes
Dr. Gil Landry Extension Specialist Georgia Station Griffin, GA 30223-1797 Phone: 404 228 7300	10# + trial	10# + trial	Trial	9-13-91	No
Mr. Pat Jones Shady Oaks Country Club Fort Worth, TX P: 817 732 3333	20#	20#		9-16-91	Yes (?)
Mr. Pat Rigsby Trosper Park G.C. 2301 S. E. 29th Street Oklahoma City, OK 73129	5#	#5	1#		No
Mr. Roland Harper Pecan Orchard Golf Course Grandbury, TX 817 927 4200 Leonard Bend Farm 120-122 Leonard Bend Grandbury, Tx 76048	100#				Yes (?)
Country Club of Virginia 709 S Gaskins Road ATTN: Mr. Alan Hess Golf Maintenance Richmond, VA 23233 P: 804 288 2891 x 264	30#	30#		9-13-91	No

LOCATION ADDRESS	QUANTITY SYN4	QUANTITY SYN3	QUANTITY SYN1	DATE SHIPPED	Member BRI
Mr. Tom Boyd 2117 Gebron Edmond, Ok 73034 Phone: 405 427 1454	10# SENT 9-13-91	10# SENT 9-13-91		9-13-91 UPS	No
Mr. Phil Shumaker Loxahachie Golf Club Jupiter, Fla p: 407 747 8893 Replicated Trial John Foy	Trial	Trial	Trial		No
Mr. Tom Diamond TPC, Los Colinas Sports Club	Trial	Trial	Trial	9-24-91	Yes
Burt Neddles Dallas Athletic Club, Dallas, Texas	5#	5#		9-16-91	Yes
Mike Allen Northwood Country Club, Dallas, Texas	5#	5#		9-16-91	?
Mike Plumber Lakewood Country Club, Dallas, Texas		5#		9-16-91	?
Alan Houdeck, Preston Trails C.C. Dallas, Texas	10#	10#		9-16-91	Yes
Wallace Menn, TAES College Station TAMU Turf Club 409-845-7110	1#	1#	1#	9-25-91	No
Bill Shrum, Brookhollow Country Club, Dallas Texas 938-1590	10# 5#	10# 5#		9-13-91 10-7-91	Yes (?)
Richard Youngscape 4120 Taliesin Lincoln, Nebraska 68520 H:402 489 4934 O:402 488 6467 Crenshaw-Coore Course	5#	5#	1#	9-13-91 9-20-91	No
Bill Coloredo Old Waverly Golf Club Old Waverly Road West Point, MISS 39773 601 494 6463	5#	5#		9-20-91	No
Mr. Fritz Law Denver Country Club East 1st Ave at Gilpin Denver, Colorado 80218 303 777 7648	Trial 1#	Trial 1#	Trial 100 gms	9-20-91	No

LOCATION ADDRESS	QUANTITY SYN4	QUANTITY SYN3	QUANTITY SYN1	DATE SHIPPED	Member BRI
Dr. Dave Kopeck University of Arizona Forbes Hall Plant Science Department Tucson, AZ 85721 602 621 5323	Trial 5#	Trial 5#	Trial 100 gms	9-20-91	No
Mr. Joe Hamilton Lakes Spievy Golf Club 8255 Clubhouse Way Jonesboro, Ga 30236		#100 sent from Oregon		9-27-91	No
Gary Schlinderle Oakmont CC 1212 State School Road Denton, Texas 76205 817 382 0887	5#	5#		10-2-91	No
Dave Fearis Blue Hills CC 777 W. Burning Tree Drive Kansas City, MO 64145 816 942 1167	5#	5#			No
Gary Hallett Meadowbrook C.C. 9300 E. 81st Tulsa, OK 74133 918 252 4116	5#	5#			No
Steve Lopeman Coffeyville C. C., R#4 Coffeyville, KS 67337 316 251 0086	5#	5#			No
Brad Davis Indian Springs C. C. 16006 E. 131st S. Broken Arrow, OK 74011 918 455 8645	5#	5#			No
Jim Golden Lindsay Municipal G. C. P.O. Box 708 Lindsay, OK 73052 405 756 3611	5#	5#			No
Mike Delaloye LaFortune Golf Course 5434 S. Hudson Tulsa, Ok 74134	5#	5#			No
Steve Gregory Shadow Glen G. C. 26577 W. 111th Street Olathe, Ks 66061 913 764 6531	5#	5#			No

LOCATION ADDRESS	QUANTITY SYN4	QUANTITY SYN3	QUANTITY SYN1	DATE SHIPPED	Member BRI
Bill Sherry Fire Wheel G. C. Garland, Texas 214 205 7878	5#	7#			No
Tom Staton Quality Turf 41-937 Waikupanaha Street Waimanalo, HI 96795 808 259 8191	5#	5#			No
Mr. John Foy USGA Green Section 8708 S. E.Colony St Hope Sound, FL 33455 407 546 2620	10#	10#			No
Brent Conrad Wichita Country Club	5#	5#			No (?)
Don Buckland West Texas Golf Course Snyder Texas	5#	5#		10-10-91	No
Mr. Bill Byrd 303 Country Club Road Ardmore, OK 73402 405 223 2104	10#	10#		10-14-91	No
David Stone The Honors Course 9601 Lee Hiway Ooltewah, TN 37363 615 238 4234	2#	2#		10-14-91	No
Mr Carl Suding Padre Isle Country Club 14353 Commodore Blvd Corpus Christi, TX 78418 512 949 8233	2#	2#	2#	10-18-91	No

APPENDIX B:

SEED PRODUCTION STATUS REPORT

SYN1-88: The parental lines of Syn1-88 were reestablished in Lebanon, Oregon in cooperation with Loft's Seed Company, working closely with Dr. Virginia Lehman. The previous breeder block was eliminated due to interference with farming practices of the contract grower, and sufficient seed was not available for subsequent increase. An approximately .20 acre breeder block was established with seed harvested in August 1991. The seed is now in Dallas, however it has not yet been cleaned. This seed will provided sufficient seed to establish seed stock fields as early as the spring of 1992. No increases will be initiated until the variety is officially released.

SYN3-88: The breeder field of Syn3-88 yielded considerable seed during 1990 and again in 1991. The breeder fields have been destroyed following 1991 seed harvest. The 1990 breeder seed was used in part to establish a 10 acre seed stock field near Scio, Oregon in October 1990. The 1991 breeder seed crop will be placed in cold storage in Oregon for future reference if needed. The Scio located Syn3-88 seed field yielded approximately 5000 pounds of clean (98% purity) seed in 1991. These yields are considered excellent for first year production. Part of the seed will be placed in cold storage and serve as future seed stock for planting registered, foundation and certified seed production. As described in another section, a portion of the seed was also used in establishing an extensive series of demonstration plantings on numerous golf courses across the United States.

Syn4-88: See **APPENDIX C:** Cato Bentgrass. The breeder field of Syn4-88 has yield considerable seed in both 1990 and 1991. The breeder fields have been destroyed following the 1991 seed harvest. A 12 acre seed increase field was established in October 1990 near Tangent, Oregon, however, considerable degree of off-type contaminants were observed in the field prior to pollination. Heavy roguing of these off types resulted in elimination of many plants, therefore seed yield was adversely affected. Approximatley 2000 pounds of clean seed was harvested and will be used exclusively for demonstration plantings. Breeder seed from 1991 was used to establish a 5 acre seed increase field near Hubbard, Oregon. Sufficient seed stock should be available from this field in 1992 to insure adequate seed for entering the market in 1992-1993. See note on **CATO CREEPING BENTGRASS.**

The 1991 Hybridization Program: Most of the crosses (Table 1b) were accomplished by isolating culms in water bottles and through physically digging and moving plants. These culm crosses are highly effective in making crosses and obtaining limited qualtities of seed. In addition to the populations generated through these culm crosses in 1991, the parental clones selected during 1990 were placed in isolation with 3 replicates of each parent, with additional quantities of seed harvested in 1991. Seed will be cleaned with progeny plots established at TAES-Dallas in the spring of 1992.

Table 1b. A listing of 1991 Polycross populations of Creeping Bentgrass developed in Lebanon Oregon, in June 1991. Each population will be referenced as a synthetic (Synx-91), where x = A thru F. A brief description of each polycross population is included.

SynA-91: A 10 clone polycross population which was selected for early maturity, with each of the parental clones demonstrating good vegetative spreading ability, medium to strong genetic color, and comparable leaf growth characters, with green panicle. Most of the parental clones are good seed producers. Includes accession #'s as follows: TAES 2764, 2783, 2867, 2899, 3158, 3213, 3259, 3269, and 3273.

SynB-91: A nine (9) clone polycross population which was selected for early maturity, curly leaf type, and curly stolons, small red glumed panicle and compact growth habit. All clones may be closely related but all exhibit strong genetic color and fine leaf texture. Clone 2743 is in common with Syn3-88. Includes accession #'s as follows: TAES 2743, 3719, 3720, 3721, 3723, 3724, 3726, 3727 and 3732.

SynC-91: This a 19 clone synthetic with early maturity, and dark genetic color. Most clones appear to be good in spread habit, with a relatively open crown and red glumes in the seed head. The parental clones have relatively good seed production characters. Includes accession #'s TAES 1886, 2557, 2742, 2842, 2843, 2857, 2879, 2895, 3157, 3175, 3254, 3264, 3266, 3276, 3279, 3283, 3284, 3290, 3293.

SynD-91: A nine (9) clone polycross population which was selected for late maturity curly leaf type, and fine texture. Includes accession #'s as follows: TAES 2792, 2793, 2839, 3303, 3308, 3309, 3315, and 3334.

SynE-91: An eight (8) clone polycross population which is medium-late in maturity, with dark green curly leaves, straight stolon growth and with a compact growth habit. Includes accession #'s TAES 2559, 2743, 2745, 2797, 2853, 2927, 3231 and 3246.

SynF-91: A 12 clone polycross population which is very late in maturity, with dark green genetic color in leaves. Many of these clones may not have produced seed or flowered. Fine textured, straight leaves with compact tight growth. Includes accession #'s TAES 2893, 2937, 3140, 3149, 3185, 3193, 3198, 3200, 3201, 3202, 3204 and 3214.

APPENDIX C

CATO BENTGRASS

Paul Cato passed away in August 1991. In his departure he left many friends and associates who shared his vision and goals for promotion and improvement of the game of golf. Paul Cato was past President, Greens Chairman, and Tournament chairman of Colonial Country Club. Paul was the founding father of Bentgrass Research, Inc., and was instrumental in developing the vision and goals of developing bentgrasses which would significantly improve the game of golf for Texas and the Southern United States.

As a tribute to the late Paul Cato, Texas A&M Research and Extension Center - Dallas, and Bentgrass Research Inc (BRI), will name one of the new bentgrasses developed by Texas A&M, the United States Golf Association and BRI for his efforts, and leadership in in establishing Bentgrass Research Inc. and for his devotion to the game of golf.

CATO bentgrass has improved heat tolerance, disease resistance, persistence and turf quality for putting greens. Its improved root system adds to its persistence under the harsh environmental conditions of Texas. CATO has excellent turf color and density of stand. Cato was developed using several plants selected from Texas golf courses.

BRI has established the Paul Cato Memorial Fund for those interested in contributing to his memory. All contributions will be directed to further improvement of bentgrasses of Texas and the southern United States.

APPENDIX D

Table D1. National Turf Evaluation Program (NTEP) Bentgrass variety trials conducted at Mississippi State University under contract with Dr. Jeff Krans. Trials established in the Fall of 1989. Data presented is quality notes recorded as 1-9, where 9 = best.

Cultivar	AUG90	SEP90	OCT90	NOV90	DEC90	JAN91	FEB91	MAR91	AP91	PS
88CBE	3.7ns[1]	5.0ns	5.3ns	5.0ab	5.0a-d	5.7a-d	6.0ns	5.7a-d	6.7ab	9
88CBL	4.0	4.7	6.0	6.7a	6.3a	6.3ab	6.7	6.0abc	7.0a	9
ALLURE	3.3	3.7	4.3	4.0ab	4.0 d	4.7 de	5.3	4.7 de	6.3abc	6
BARDOT	3.3	4.0	5.3	6.0ab	5.3a-d	5.3bcd	6.7	5.7a-d	6.3abc	8
BR1518	3.0	3.3	4.0	5.0ab	4.7bcd	5.0cde	5.3	5.0cde	6.0bcd	5
CARMEN	4.0	4.3	5.3	5.3ab	5.3a-d	5.3bcd	5.7	5.0cde	6.3abc	7
COBRA	4.3	5.3	5.3	6.0ab	5.3a-d	6.0abc	6.3	6.0abc	6.7ab	9
EGMONT	3.0	4.0	5.0	5.3ab	5.0a-d	4.7 de	5.7	5.3b-e	6.0bcd	6
EMERALD	3.0	3.7	4.3	4.7ab	4.3 cd	4.0 e	5.3	4.3 e	5.3 d	5
FORBES89	3.7	4.3	5.7	6.0ab	6.3a	6.0abc	6.7	6.0abc	7.0a	9
MSCB6	4.3	6.0	6.7	6.0ab	6.0ab	6.0abc	5.7	6.3ab	7.0a	8
MSCB8	4.3	5.7	5.7	5.7ab	6.0ab	6.3ab	6.0	6.0abc	7.0a	9
NATIONAL	3.0	3.7	5.0	5.3ab	5.0a-d	5.3bcd	5.3	4.7 de	6.0bcd	6
NORMARC1	4.7	6.0	6.0	6.7a	6.0ab	6.0abc	6.0	6.3ab	7.0a	9
PENNCROS	3.7	5.0	5.7	6.0ab	5.0a-d	5.7a-d	5.3	6.0abc	6.7ab	9
PENNLINK	4.3	5.3	6.0	6.3ab	5.7abc	6.0abc	6.3	6.0abc	7.0a	9
PROVIDEN	5.0	5.3	6.3	6.0ab	5.7abc	6.0abc	6.0	5.7a-d	6.7ab	9
PUTTER	4.0	5.0	5.7	5.3ab	5.7abc	6.0abc	5.3	5.3b-3	6.7ab	8
SR1020	4.7	5.3	6.0	6.3ab	6.0ab	6.0abc	6.7	6.0abc	7.0a	9
SYN3-88	4.7	4.7	6.0	6.0ab	6.0ab	6.7a	6.3	6.7a	7.0a	9
Syn1-88	3.3	4.3	6.0	5.7ab	5.3a-d	5.7a-d	6.0	5.3b-e	6.7ab	8
TRACENTA	3.3	3.7	5.0	4.7ab	4.7bcd	4.7 de	5.0	5.0cde	5.7cd	5
UM8401	3.0	4.0	4.7	5.7ab	5.3a-d	5.0cde	5.3	5.0cde	6.3abc	7
WVPB89D1	4.0	5.0	5.7	6.0ab	5.7abc	6.0abc	5.0	6.0abc	7.0a	9

[1]Means within a column followed by the same letter are not significantly different using the Waller-Duncan k-ratio t test, where k=100.
[2]PS=Phenotypic Stability = number of occurrences a genotype was in top statistical group for each date.

Table D2. Quality evaluations on the Bentgrass Variety trials at TAES-Dallas by multiple evaluators. Quality is visually assessed using a scale of 1 - 9, where 9 = best.

	Quality												
	Evaluators - June 5, 1990												
Cultivar	bar	eng	gas	jar	kae	mor	motn	plc	ptr	rhw	snw	mek	Avg	PS[1]
Syn4-88	7.0a	6.8a	6.0a	8.3ns	7.3ns	5.8a	7.5ns	7.0a	6.5a	6.5a	7.8a	7.8a	7.0a	12
Syn3-88	6.8a	7.0a	6.0a	7.0	6.8	6.0a	7.0	5.3a	6.8a	7.0a	7.5a	6.5a	6.6	12
Syn1-88	6.5a	6.5a	5.0a	7.5	6.0	5.5	7.3	5.0a	6.3a	4.5	6.8a	6.0a	6.1	10
SR1020	7.3a	7.3a	5.3a	7.4	7.3	6.5a	7.8	7.0a	7.3a	7.5a	8.0a	7.0a	7.1a	12
SR1019	6.8a	7.3a	6.3a	7.0	5.8	6.0a	6.5	6.0a	5.8a	6.5a	7.5a	6.8a	6.5	12
Southshore	5.5a	5.8	5.0a	7.0	5.7	5.0	6.3	5.0a	6.0a	4.5	6.0	6.2a	5.7	9
Seaside	4.5	6.2a	4.5	6.8	5.8	5.5	6.5	3.7	5.5	4.5	5.7	4.8	5.3	4
Putter	7.0a	6.5a	5.5a	8.4	6.3	6.3a	7.3	6.8a	6.5a	6.8a	7.0a	7.0a	6.8	12
PSU126	6.0a	6.3a	5.0a	6.8	5.5	5.8a	7.3	4.5	6.0a	6.3a	7.0a	5.5	6.0	10
Penncross	6.5a	6.3a	5.0a	7.8	6.0	5.0	6.5	5.3a	6.5a	4.8	6.3	5.5	5.9	8
National	5.0	5.3	5.2a	6.5	6.2	5.2	6.8	4.3	5.3	4.0	5.7	5.5	5.4	4
Cobra	6.5a	6.3a	5.0a	7.0	6.5	5.5	6.8	6.3a	6.3a	5.3	7.3a	6.0a	6.2	9

	Quality								
	Evaluators - September 26, 1990								
Cultivar	bar	oli	crd	crn	jaa	ots	tmb	avg	PS
Syn4-88	4.8a	4.8a	5.0a	6.5a	5.0a	3.5	4.0a	4.8	6
Syn3-88	6.0a	6.0a	7.3a	7.3a	6.0a	5.3a	5.3a	6.1a	7
Syn1-88	5.5a	5.0a	5.3a	7.0a	4.8a	4.0a	4.5a	5.1	7
SR1020	3.5	4.3a	4.5	6.0	3.3	3.5	3.0a	4.0	2
SR1019	4.8a	5.3a	5.0a	6.3	5.0a	3.8a	4.0a	4.9	6
Southshore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Seaside	4.0a	5.0a	5.5a	6.5a	4.2a	3.8a	5.3a	4.9	7
Putter	3.8	4.3a	5.0a	6.3	3.8a	3.8a	4.5a	4.5	5
PSU126	4.8a	4.8a	4.5	6.8a	4.3a	3.5	4.3a	4.7	5
Penncross	4.3a	3.8	4.5	5.8	4.2a	3.8a	4.2a	4.3	4
National	4.3a	4.5a	6.0a	6.0	2.8	4.3a	4.3a	4.6	5
Cobra	5.3a	5.3a	6.0a	6.8a	5.3a	4.0a	4.5a	5.3	7

	Quality								
	Evaluators - November 16, 1990								
Cultivar	bar	eng	gbm	jar	stp	wer	avg	PS	Total PS
Syn4-88	3.5a	6.3a	4.8a	5.9a	4.3a	5.8a	5.1	6	24
Syn3-88	4.3a	6.8a	5.3a	7.0a	6.0a	5.8a	5.8a	6	25
Syn1-88	2.8a	5.0a	3.8a	5.8a	5.0a	6.0a	4.7	6	23
SR1020	3.0a	5.5a	3.5a	5.4a	4.3a	5.3a	4.5	6	20
SR1019	3.3a	5.0a	3.5a	5.8a	3.5a	5.5a	4.4	6	24
Southshore	0.0	0.0	0.0	0.0	0.0	0.0	0.0		9*
Seaside	3.3a	5.5a	4.2a	6.4a	4.7a	5.3a	4.9	6	17
Putter	2.8a	4.8a	3.5a	4.5a	4.0a	5.0a	4.1	6	23
PSU126	2.5a	5.3a	3.8a	5.0a	4.0a	4.8a	4.2	6	21
Penncross	3.0a	5.0a	3.8a	5.9a	5.0a	5.5a	4.7	6	18
National	4.0a	6.2a	4.0a	6.3a	5.3a	5.3a	5.2	6	15
Cobra	3.5a	5.5a	4.8a	6.5a	5.3a	6.0a	5.2	6	22

*Reestablished Fall 1990 [1]PS = Phenotypic stability= best statistical grouping.

Table D3. Quality ratings of the National Turf Evaluation Program (NTEP) entries cultivars of creeping bentgrass at TAES-Dallas during 1991 as rated by TAES researchers.

	Date - 1990									1991	
Variety	2Jan	15Jan	22Jan	9Feb	16Mar	4Apr	1May	11Jul	16Jul	29Jan	PS[1]
88.cbe	2.3a[2]	2.3	2.0ns	4.0a	3.5a	2.7a	3.7ns	3.3a	5.7a	2.3ns	9
88.cbl	1.7a	2.0	2.0	3.3	3.0	3.7a	3.3	4.3a	5.3a	1.7	6
BR1518	1.7a	2.3	1.7	3.3	2.8	2.7a	2.3	3.2a	5.0a	2.7	7
Carmen	1.3	1.3	1.7	2.7	3.3a	3.5a	3.0	4.0a	5.3a	2.3	7
Cobra	2.0a	2.7a	2.0	4.3a	4.0a	4.0a	4.7	5.7a	6.0a	2.0	10
Forbes89	2.7a	2.3	2.3	4.0a	3.7a	3.7a	3.7	4.0a	5.3a	3.0	9
MSCB-6	1.3	2.3	2.0	3.3	3.7a	3.8a	3.0	4.3a	5.7a	2.7	9
MSCB-8	2.3a	2.7a	2.3	4.3a	3.8a	4.2a	3.5	4.7a	5.7a	3.3	10
National	1.7a	2.0	1.7	3.3	2.8	3.7a	3.7	3.7a	5.3a	2.7	7
Normarc1	4.7a	3.3a	3.0	4.7a	4.2a	4.0a	4.3	4.7a	5.3a	2.3	10
Penncross	4.3a	3.0a	2.3	4.0a	3.7a	4.2a	3.3	3.7a	5.7a	3.3	10
Pennlinks	3.0a	3.0a	2.0	3.7	3.5a	3.7a	3.7	5.0a	6.3a	3.7	9
Providenc	1.7a	2.7a	1.7	3.3	3.2a	4.0a	2.8	4.3a	6.3a	2.7	9
Putter	2.3a	3.0a	2.7	5.0a	4.7a	4.7a	4.0	5.3a	5.7a	2.7	10
SR1020	2.3a	2.3	2.3	4.0a	4.0a	4.5a	3.7	5.7a	6.3a	3.3	9
Syn1-88	2.3a	2.7a	2.7	4.7a	4.2a	4.2a	3.7	3.8a	6.3a	4.3	10
Syn3-88	.	.	.	.	0.0	2.3a	2.5	1.3	3.3	2.3	3[3]
Syn4-88	.	.	.	.	0.0	2.0	1.7	2.2	3.0	3.0	2[3]
UM84-01	3.0a	3.0a	2.0	3.3	3.7a	3.7a	3.7	4.7a	5.0a	3.3	9
WVPB89-d-	5.3a	2.7a	2.0	4.0a	3.7a	3.3a	4.0	3.8a	5.7a	2.0	10

[1]Phenotypic stability = number of occurrences a genotype was in the highest statistical group.
[2]Means within a column followed by the same letters are not significantly different using the Waller-Duncan k-ratio t test, where k = 100. Quality rated 1-9, with 9=best.
[3]Reestablished Feb 1991.

Table D4. Quality ratings of three experimental varieties and seven commercial cultivars of creeping bentgrass at TAES-Dallas during 1991 as rated by TAES researchers.

Cultivar	Quality - 1991									PS[1]
	9apr	11May	13Jul	25Jul	29Jul	4Sep	26Sep	26Sep	18Oct	
Cobra	6.2a[2]	6.2	6.0a	6.2a	6.5ns	6.0ns	4.5ns	5.5ns	5.7ns	8
National	5.8	6.5a	6.0a	5.7	6.0	6.7	4.5	5.7	5.7	7
PSU126	6.2a	6.5a	4.5	6.2a	4.2	5.7	4.5	4.2	5.0	7
Penncross	5.8	6.7a	2.7	5.7	5.2	6.0	3.5	6.2	5.7	5
Putter	5.5	7.2a	6.7a	5.5	6.2	5.7	5.0	6.5	6.2	7
SR1019	6.5a	7.0a	6.2a	6.5a	5.2	5.5	5.7	6.2	5.7	9
SR1020	6.5	6.7a	6.0a	6.5a	5.5	6.0	4.7	6.5	5.7	8
Seaside	6.2	5.7	3.5	6.2a	5.5	5.7	4.7	5.5	5.2	6
Southshore	2.0	4.5	4.0	2.0	5.2	6.2	4.5	4.5	4.7	5
Syn1-88	5.8	6.5a	6.5a	5.7	7.2	5.3	4.7	4.2	6.5	7
Syn3-88	6.8a	7.2a	8.3a	6.7a	5.7	6.0	5.7	5.5	6.0	9
Syn4-88	7.2a	7.5a	6.5a	7.2a	6.0	6.5	6.2	6.7	5.7	9

[1]Phenotypic stability = number of occurrences a genotype was in the highest statistical group.
[2]Means within a column followed by the same letters are not significantly different using the Waller-Duncan k-ratio t test, where k = 100. Quality rated 1-9, with 9=best.

Table D5. Mean quality ratings of Syn4-88 and seven cultivars of creeping bentgrass, Augusta, GA, 1989 and 1990.[1] Notes taken by Dr. Gil Landry.

Cultivar	DATE-1989				Phenotypic Stability[3]
	5 July	30 Aug	27 Sep	16 Nov	
					--#(4 Max)--
	------ Quality (1-9, 9=best) -------				
Syn1-88	5.0[2]	5.0	4.8	5.7	0
Syn3-88	7.0a	7.0a	6.0a	8.0a	4
Syn4-88	6.7a	5.2	4.7	6.3	1
Penncross	5.0	4.8	4.7	5.7	0
SR1019	6.3	5.5	5.0	5.7	0
SR1020	7.5a	5.7	5.5a	7.7a	3
Pennlinks	4.8	4.7	4.7	6.0	0
Cobra	4.8	4.8	4.3	5.7	0
Seaside	5.0	4.3	3.8	5.0	0
Putter	5.8	4.3	4.5	7.7a	1

[1]Partial data set; complete data set includes two additional experimentals.
[2]Means followed by the same letter in the same column are not significantly different using the Waller-Duncan k-ratio t test, where k = 100. ns=nonsignificant.
[3]Phenotypic Stability

Table D6. Mean quality ratings of Syn4-88 and seven cultivars of creeping bentgrass, Augusta, GA, 1989 and 1990.[1] Notes taken by Dr. Gil Landry.

Cultivar	DATE-1990							Phenotypic Stability[3]
	22 Jan	27 Feb	23 Mar	17 Jul	9 Aug	16 Nov	18 Dec	
								--#(7 Max)--
	---------- Quality (1-9, 9=best) ----------							
Syn1-88	5.0ns	5.7	6.5	5.7a	5.0ns	6.5	6.8ns	4
Syn3-88	7.3	7.3a	8.2a	6.5a	5.3	6.7a	7.0	7
Syn4-88	7.3	6.0	7.0a	6.2a	5.3	6.7a	6.8	6
Penncross	7.0	4.0	6.0	5.2	4.3	5.5	6.7	3
SR1019	7.3	7.3a	7.5a	5.8a	5.0	6.7a	7.0	7
SR1020	7.7	7.7a	7.2a	6.2a	5.0	8.0a	7.5	7
Pennlinks	7.5	5.3	6.7	6.0a	5.0	6.3	6.5	4
Cobra	7.0	4.3	6.2	5.7a	4.2	6.3	7.7	4
Seaside	7.0	4.0	6.7	5.8a	4.3	6.3	6.8	4
Putter	7.2	5.3	7.7a	5.7a	4.5	7.2a	7.2	6

[1]Partial data set; complete data set includes two additional experimentals.
[2]Means followed by the same letter in the same column are not significantly different using the Waller-Duncan k-ratio t test, where k = 100. ns=nonsignificant.
[3]Phenotypic Stability

Table D7. Mean quality ratings of Syn4-88 and seven cultivars of creeping bentgrass, Augusta, GA, 1989 and 1990.[1] Notes taken by Dr. Gil Landry.

Cultivar	DATE-1991							Phenotypic Stability[3]
	10 Jan	14 Mar	14 Apr	15 May	5 Jun	17 Jul	14 Aug	--#(7 Max)--
	---------- Quality (1-9, 9=best) ----------							
Syn1-88	6.8ns	6.3a	6.2ns	5.5	5.8	5.7ns	5.5a	5
Syn3-88	5.8	5.5	6.7	6.8a	7.5a	6.3	6.3a	6
Syn4-88	6.7	5.5	6.0	5.5	6.1	5.8	6.2a	4
Penncross	6.3	6.2a	5.8	5.7	5.4	5.8	5.0	4
SR1019	6.5	6.5a	6.7	7.2a	6.9a	6.2	5.8a	7
SR1020	7.0	6.0a	6.3	6.0a	6.2	5.8	5.7a	6
Pennlinks	6.3	6.0a	5.8	6.0a	5.3	5.5	5.2	5
Cobra	6.8	5.8a	6.0	5.2	5.7	5.5	5.2	4
Seaside	6.5	5.3	6.3	5.3	6.5	6.0	6.0a	4
Putter	6.0	5.8a	6.5	6.2a	6.1	6.5	6.2a	6

[1]Partial data set; complete data set includes two additional experimentals.
[2]Means followed by the same letter in the same column are not significantly different using the Waller-Duncan k-ratio t test, where k = 100. ns=nonsignificant.
[3]Phenotypic Stability

Table D8. Density of stand and Grain at Augusta National Golf Course of three experimental and seven commercial cultivars of creeping bentgrass. Density is measured on 1-9 scale, where 9 = dense. Notes recorded by Dr. Gil Landry.

Cultivar	Density of Stand[1]		Grain[2]			PS[3]
	9/89	6/91	11/89	3/91	5/91	
Syn1-88	4.7[4]	6.8ns	6.0	7.0a	6.2a	3
Syn3-88	6.7a	8.2	8.0a	6.7a	7.3a	5
Syn4-88	4.2	6.8	6.7	6.2	5.7	1
Putter	4.2	6.8	5.7	6.8a	5.8	2
SR1019	4.8	6.8	6.3	7.5a	7.3a	3
SR1020	5.7	6.2	7.3a	7.5a	7.3a	4
Seaside	3.7	6.7	4.3	6.0	6.5a	2
Pennlinks	4.8	6.8	5.0	6.3	6.0	1
Penncross	4.2	6.0	3.7	6.7	5.3	1
Cobra	4.2	5.7	4.0	6.0	5.0	1

[1]Density of stand measure 1 - 9, where 9 = high density.
[2]Grain measured 1 -9, where 9 = no noticable grain.
[3]PS = Phenotypic Stability.
[4]Means followed by the same letter in the ame column are not significantly different using the Waller-Duncan k-ratio t test. ns = non-significant.

Table D9. Thatch Accumulation and rooting depth of three experimental and seven commercial creeping bentgrass cultivars at Augusta National Golf Course Nursery. No traffic is imposed on the test site. Plots were established in Nov 1988. Notes taken by Dr. Gil Landry.

	Depth of Thatch[1]	Root depth[2]		PS[3]	
Cultivar	11/89	7/91	11/89	3/91	
Syn1-88	0.47ns[4]	1.1ns	3.5a	5.8ns	4
Syn3-88	0.63	1.0	3.1a	5.1	4
Syn4-88	0.42	1.2	3.1a	6.8	4
Putter	0.37	1.0	2.7a	6.1	4
SR1019	0.47	1.0	2.9a	4.8	4
SR1020	0.50	1.1	3.0a	5.5	4
Seaside	0.45	1.2	2.2	7.2	3
Pennlinks	0.43	1.2	2.6a	5.5	4
Penncross	0.43	1.2	2.9a	6.0	4
Cobra	0.47	1.1	3.3a	5.7	4

[1]Thatch depth in cm.
[2]Root depth in cm.
[3]PS = Phenotypic Stability.
[4]Means followed by the same letter in the ame column are not significantly different using the Waller-Duncan k-ratio t test. ns = non-significant.

Table D10. Field observations of Pythium occurrence on three experimental and seven commercial creeping bentgrass cultivars at Augusta National Golf Course Nursery. No traffic is imposed on the test site. Plots were established in Nov 1988.

	Dallas Field Notes	Augusta Field Notes
Cultivar	% Infection	
Syn1-88	12.5a[1]	18.3a
Syn3-88	13.8a	21.7a
Syn4-88	49.8	30.0
Putter	25.0a	0.0a
SR1019	27.5a	16.7a
SR1020	25.0a	37.7
Seaside	12.5a	13.3
Pennlinks	28.8a	45.0
Penncross	22.5a	25.0
Cobra	11.3a	16.7a

[1]Means followed by the same letter in the ame column are not significantly different using the Waller-Duncan k-ration t test. ns = non-significant.

Table D11. Bentgrass tiller counts on greens maintained as putting surface comparing commercial and experimental bentgrass varities at TAES-Dallas 1991.

Variety	May 17	Jun 24	Aug 9	Sep 5	Oct 10	Avg	PS[1]
Syn3-88	83.0a	52.0a	53.0	65.8	80.0	66.8a	5
SR1020	75.8a	44.8a	65.2	66.8	66.5	63.8a	5
Syn4-88	75.5a	50.2a	49.0	66.8	74.0	63.1a	5
Pennlinks	68.8a	34.0	69.8	64.2	65.2	60.4a	4
Putter	74.5a	35.0a	58.2	58.0	58.5	56.8	5
Penncross	62.0a	39.5a	53.0	61.2	47.5	52.6	5
Seaside	64.8a	46.2	44.8	58.5	67.8	55.4	4
Syn1-88	68.2a	34.8	58.5	53.0	68.8	56.6	4
National	74.5a	30.0	52.8	56.5	58.8	54.5	4
SR1019	54.8	34.2	55.8	61.5	70.2	55.3	3
Cobra	62.8a	34.5	51.0	55.2	61.5	53.0	4
Southshore	13.5*	31.8	58.8	57.0	56.0	43.4	3
	64.8	38.9	55.8	60.4	64.1	56.8	
m.s.d.	28.1	17.0	n.s.	n.s.	n.s.	9.0	

*Established spring 1991.
[1]P.S. = Phenotypic stability = number of occurrences a genotype was in top statistical group.

Table D12. Bentgrass tiller counts comparing the cultivars in the NTEP trials at TAES-Dallas on greens maintained as putting surface in 1991.

Variety	May 23	Jun 24	Aug 8	Sep 10	Oct 10	Avg	PS[1]
Syn3-88	0.0*	32.7	31.7	37.3	27.7	25.9	4
Syn4-88	0.0*	18.3	32.7	27.7	27.3	21.2	4
SR1020	57.7a	27.3	38.3	33.3	31.0	37.5a	5
Pennlinks	48.3a	23.7	39.0	33.7	19.3	32.8a	5
Putter	52.0a	30.0	41.7	41.0	26.7	38.3a	5
Penncross	40.7a	27.7	38.0	30.3	25.0	32.3a	5
Syn1-88	46.0a	22.7	34.7	34.3	26.0	32.7a	5
National	44.0a	22.0	28.7	30.3	25.3	30.1	5
SR1019	48.7a	26.0	35.0	35.3	26.7	34.3a	5
Cobra	57.7a	26.7	36.0	33.7	29.3	36.7a	5
WVPB-D-15	35.3	30.3	39.3	25.7	20.7	30.3	4
88-CBE	44.7a	23.7	48.3	32.3	21.3	34.1a	5
Forbes89-12	55.7a	15.7	37.0	41.3	19.0	33.7a	5
Carmen	45.7a	28.7	36.7	32.3	30.0	34.7a	5
88-CBL	56.3a	28.3	40.0	22.7	22.0	33.9a	5
Normarc101	43.3a	28.3	36.0	29.0	20.3	31.4	5
MSCB-6	47.0a	25.3	33.0	35.3	21.3	32.4a	5
MSCB-8	41.0a	19.7	44.3	41.7	23.0	33.9a	5
UM8401	52.0a	23.3	27.3	34.0	33.3	34.0a	5
BR1518	47.3a	20.0	31.0	32.7	29.7	32.1a	5
avg	43.2	25	36.4	33.2	25.2	32.6	
m.s.d.	17.8	n.s.	n.s.	n.s.	n.s.	6.4	

*Established spring 1991.
[1]P.S. = Phenotypic stability = number of occurrences a genotype was in top statistical group.

Table D13. Bentgrass root growth characters greens maintained as putting surface comparing commercial and experimental bentgrass varities at TAES-Dallas 1991.

Variety	May 17	Jun 24	Aug 9	Sep 5	Oct 10	Avg	PS[1]
Syn3-88	11.5	9.4	8.6	5.1	7.0	8.3	4
SR1020	13.0a	11.7	7.0	5.7	6.2	8.7	5
Syn4-88	13.0a	9.8	8.9	7.7	8.2	9.5	5
Pennlinks	13.3a	11.7	8.0	6.4	8.1	9.5	5
Putter	12.5a	10.6	7.4	7.6	7.7	9.1	5
Penncross	12.2a	10.5	7.6	7.2	7.7	9.0	5
Seaside	12.1a	9.4	8.0	6.4	6.8	8.5	5
Syn1-88	12.8a	10.6	8.5	5.9	7.8	9.1	5
National	12.2a	8.0	8.2	6.4	8.0	8.5	5
SR1019	12.4a	10.5	8.0	7.1	7.3	9.0	5
Cobra	13.8a	11.2	8.3	6.6	7.7	9.5	5
Southshore	0.0*	14.2	8.1	7.3	8.1	7.5	4
	11.6	10.6	8.0	6.6	7.6	8.9	
m.s.d.	2.1	n.s.	n.s.	3.4	n.s.	2.2	

*Established spring 1991.
[1]P.S. = Phenotypic stability = number of occurrences a genotype was in top statistical group.

Table D14. Bentgrass root growth comparing the cultivars in the NTEP trials at TAES-Dallas on greens maintained as putting surface in 1991.

Variety	May 23	Jun 24	Aug 8	Sep 10	Oct 10	Avg	PS[1]
88-CBE	13.9	13.0	7.6	7.3	8.7	10.1a	5
88-CBL	13.8	14.0	6.4	8.5	8.3	10.2a	5
BR1518	14.4	13.6	8.9	8.1	7.0	10.4a	5
Carmen	13.9	12.9	9.7	7.2	6.8	10.1a	5
Cobra	13.7	10.1	7.7	7.3	7.3	9.2a	5
Forbes89-12	13.1	11.3	7.5	7.2	8.6	9.6a	5
MSCB-8	13.4	9.1	7.5	9.0	9.5	9.7a	5
MSCB-6	13.6	10.0	8.7	7.3	7.5	9.4a	5
National	14.0	11.7	9.3	8.4	8.0	10.3a	5
Normarc101	13.9	12.0	9.1	7.7	8.5	10.3a	5
Penncross	14.0	11.3	8.6	8.7	7.6	10.0a	5
Pennlinks	13.5	11.2	7.5	7.8	6.5	9.3a	5
Putter	13.9	11.3	8.2	9.8	7.6	10.2a	5
SR1019	13.5	9.5	8.9	7.6	8.5	9.6a	5
SR1020	12.6	10.9	7.2	7.6	7.6	9.2	5
Syn1-88	13.9	11.6	9.2	8.9	9.3	10.6a	5
Syn3-88	0.0*	9.4	7.4	6.5	8.6	6.4	5
Syn4-88	0.0*	9.6	7.3	6.6	8.5	6.4	5
UM8401	13.6	10.1	7.6	7.8	6.8	9.2a	5
WVPB-D-15	13.2	12.8	9.5	8.8	8.1	10.5a	5
avg	12.3	11.3	8.2	7.9	8.0	9.5	
m.s.d.	0.97	n.s.	n.s.	n.s.	n.s.	1.5	

*Established spring 1991.
[1]P.S. = Phenotypic stability = number of occurrences a genotype was in top statistical group.

APPENDIX E

Root Heat Resistance of Bentgrass Cultivars

M.C. Engelke and V.G. Lehman[1]

Additional index words. Agrostis stolonifera var. palustris (Huds.), Agrostis tenuis (Sibth.),

Abstract. The objectives of this study were to develop a screening technique to evaluate effect of elevated soil temperatures over an extended time period, and utilize the technique to distinguish cultivar performance of bentgrasses. Soil temperatures were elevated to 40C, and maintained there for 21 days. Percent leaf firing was evaluated at 7 day intervals. 'Duchess', an Agrostis tenuis Sibth. cultivar, exhibited the greatest decline in plant performance as indicated by green shoot tissue at 40C soil temperatures. When evaluated as percent plants surviving from the original stand over 35 days of elevated soil temperatures, the commercially available cultivar 'Seaside', Agrostis stolonifera var. palustris, which consists of a highly variable, heterogenous population, had the largest number of surviving plants.

Creeping and colonial bentgrasses provide the highest quality putting surfaces in the Northern U.S. Demand is increasing for use of bentgrass in the Southern U.S., distant in climatic and temperature conditions from the areas where bentgrass is thought to have originated in Germany and Eurasia and is adapted (Ward, 1969). Wallner et al. (1982) utilized measurement of electrolyte leakage from leaf tissue into solution to characterize in vitro heat tolerance of creeping bentgrass (Agrostis stolonifera var. palustris Huds.) that had been heat-hardened by exposure to elevated temperatures for 10 days. Blum (1988) referred to testing for short duration at near-lethal temperatures as a "crisis" situation for the plant. Of more relevance to the geneticist is a technique to evaluate plant performance over a time x temperature interaction similar to what most plants would incur in the field environment. The objectives of this study were to develop a greenhouse rapid screening technique to determine the effect of elevated root heat temperatures on whole plant performance and survival for a several week time period, and utilize the technique to distinguish among bentgrass cultivars.

Elevated soil temperatures were achieved by circulating hot water through 1.3 cm diameter copper pipe embedded in a greenhouse bench at a depth of 16 cm. The bench, 1.2 x 2.4 x 0.6 m, contained fine, washed noncalcarious sand (97% which passed U.S. sieve size no. 30). On 15 July 1988, 14 x 14 x 6.4 cm trays, filled with the same sand, were planted with bentgrass seed at a rate of 0.49 kg ha^{-1}. The plants were clipped twice weekly to 1.3 cm, and fertilized with 49, 9.6, and 28 kg ha^{-1} of N, P, and K, respectively, each growing month using 28-8-18 soluble fertilizer. After 6 weeks of growth, the plants and soil were removed intact from the trays, and transplanted to the modified greenhouse bench. On 3 Oct. 1988, the soil temperature was elevated to 32C, with elevation to 40C on 10 Oct., and maintained at 40C for 21 days. Ambient greenhouse temperatures did not exceed 18 or 29C during the study. The soil was subirrigated when moisture was depleted at 7.6 cm depth, as monitored by gypsum blocks attached to mercury columns, approximately every five days. The experimental design was a randomized complete block with seven replications. The data compiled consisted of percent leaf firing of individual plants, as indicated by browning and drying of tissue, at 7 day intervals for 21 days. Data for firing, determined as percent values, were transformed using the angular transformation (Steel and Torrie, 1980).

A duplicate study was transplanted into the greenhouse bench after the plants were 6 weeks of age on 4 April 1989. Soil temperature was initially elevated to 32C, and gradually elevated over 4 weeks time period to 40C. The plants were clipped, watered, and fertilized as in the Oct. study. Ambient air temperatures did not exceed 18 or 31C during the study. Spearman's rank correlation (Steel and Torrie, 1980) procedure was used to correlate cultivar performance between the first and second studies.

On 7 Sept. 1990, a third study was initiated using five commercially available and three experimental lines of creeping bentgrass. The plants were established as in the above studies on 7 Sept. 1990, and transplanted into the heated greenhouse bench on 1 Dec. Soil temperatures were elevated from 28C on 31 Jan. 1991 to 40C on 18 Feb., and maintained at that temperature until study conclusion. Ambient air temperatures did not exceed 19 or 32C during the study. Fertilization and clipping were as in the above studies. The plants were sub-irrigated to soil saturation approximately every 3 days. On 25 Feb., the plants were sprayed with metalaxyl fungicide at a rate of 30 ml per 4.5 liters of water as a preventive measure for Pythium spp. Counts of live plants, as indicated by at least 10% green shoot tissue, were made on 31 Jan. and approximately every 4 days thereafter until study conclusion. This study was conducted as a randomized complete block design with seven replications. Data for surviving plants, determined as percent values, were transformed using the angular transformation (Steel and Torrie, 1980).

'Duchess', an A. tenuis Sibth. species, exhibited a more rapid rate of leaf firing than the creeping bentgrass cultivars in the first two studies (Tables 1-2). The rankings of percent leaf firing of the cultivars after 21 days of elevated soil temperatures were similar between the first two studies (r_s=0.79, $p>0.05$).

When elevated soil temperatures were continued for 35 days (Table 3), the cultivar 'Seaside', A. stolonifera var. palustris, consisting of a highly heterogeneous population of plants, had the greatest percent survival of plants of the commercially available cultivars. 'Syn4-88', 'Syn1-88', and 'Seaside' retained more plants across time than the other cultivars tested (Figure 1). The cultivar 'SR1020', a newly released creeping bentgrass cultivar originating from the University of Arizona, had the lowest percentage of surviving plants. 'SR1020' ranked second in overall mean quality in the 1989 National Bentgrass Test on modified soils under greens test conditions (Morris, 1990). The heat resistance rankings must be recognized as only one component of overall plant performance. Other factors that contribute to field performance such as disease and moisture stress resistance must be considered in final plant selection for use in a given environment.

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The greenhouse screening technique was consistent between two separate studies in rank performance of leaf firing of bentgrass cultivars, indicating stability of the technique in defining root heat stress resistance. When number of plants were counted as survivors of root heat stress, the highly heterogeneous plant population 'Seaside' had the greatest number of survivors. This suggests the technique would be applicable in breeding efforts to select persistent type plants with genetic heat stress resistance.

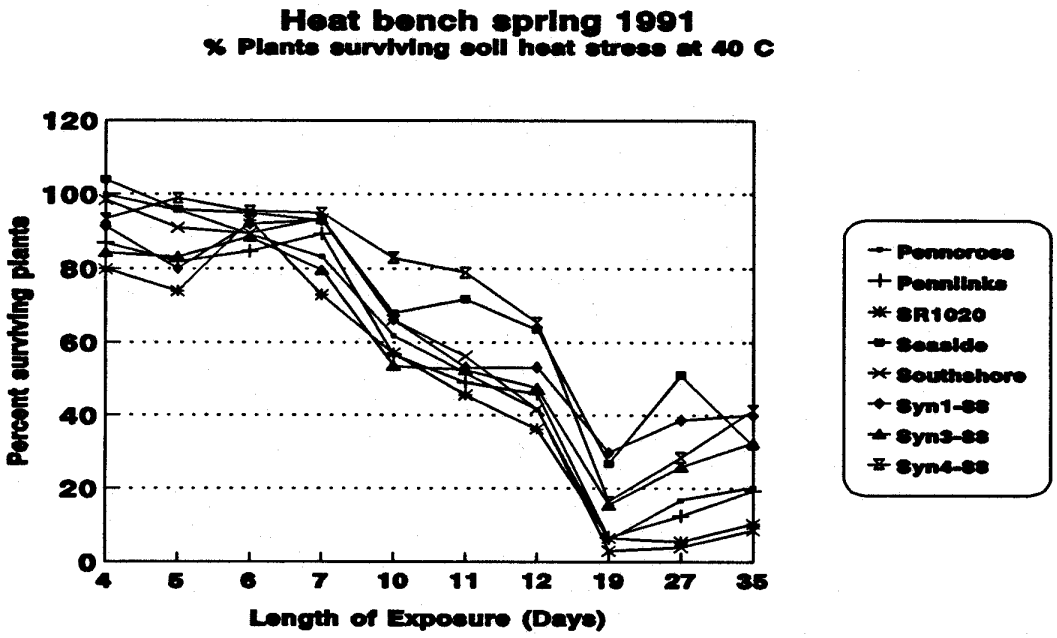

Figure 2. Daily response of selected bentgrass cultivars to prolonged elevated soil temperatures.

Table 1. Percent firing of eight bentgrass cultivars exposed to high soil temperatures in a greenhouse bench, Oct. 1988.

	Number of days of elevated soil temperatures				
	7	14	21		
Cultivar	Fired tissue (%)		Duchess	44.2a*	87.3a
	92.7a				
National	13.3 b		31.7 b	55.0b	
Emerald	10.0 bc		10.3 c	55.8b	
Prominent	7.5 bc		10.8 c	21.7c	
Pennlinks	5.8 bc		9.5 c	22.5c	
Penncross	4.2 bc		16.2 c	22.5c	
Cobra	1.7 c		9.3 c	26.7c	
Penneagle	1.7 c		8.3 c	21.7c	

*Means within a column followed by the same letter are not significantly different using the Waller/Duncan multiple comparison procedure (k ratio=100).

Table 2. Percent firing of eight bentgrass cultivars exposed to high soil temperatures in a greenhouse bench, April 1989.

	Number of days of elevated soil temperatures		
	7	14	21
Cultivar	Fired tissue (%)		
Duchess	17.8ab*	52.1+ns	99.0a
National	25.2a	53.8	96.5ab
Emerald	4.7c	20.2	90.2ab
Prominent	21.0a	42.1	83.7a
Pennlinks	11.8abc	37.9	97.7a
Penncross	6.3bc	20.9	84.0b
Cobra	6.3bc	37.1	89.7ab
Penneagle	3.3c	23.4	81.3b

*Means within a column followed by the same letter are not significantly different using the Waller/Duncan multiple comparison procedure (k ratio=100).
+ns=non-significant.

Table 3. Percent surviving plants of 8 varieties of creeping bentgrass after 35 days of elevated soil temperatures, Feb. 1991.

Cultivar	Surviving plants (%)
Syn4-88	69.7a*
Seaside	70.1a
Syn1-88	63.8ab
Penncross	56.7 bc
Syn3-88	56.3 c
Southshore	55.2 c
Pennlinks	53.4 cd
SR1020	48.2 d

*Data analyzed with arcsin square root transformation with means within a column followed by the same letter not significantly different using the Waller/Duncan multiple comparison procedure (k ratio=100). Data presented as percent means.

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