1996
ANNUAL PROGRESS REPORT
BREEDING AND DEVELOPMENT
OF BENTGRASS

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1996 RESEARCH REPORT
BREEDING AND DEVELOPMENT OF BENTGRASS

EXECUTIVE SUMMARY

Principle Investigator:	Dr. M. C. Engelke
Co-Investigator:	Dr. I. Yamamoto
Technical Support:	Ms. J. M. Mills
Student Intern:	Ms. M. Doin
Research Period:	1 November 1995 through 1 November 1996.

The bentgrass project released 'Mariner' Creeping Bentgrass to the industry in 1996 with the variety being licensed to Pickseed West, Inc. which also handles CATO Creeping Bentgrass which was released in 1993. Mariner is a salt tolerant reselection from Seaside with improved turf quality. It is recognized as a specialized grass which will have considerable utility in areas where salinity is a problem.

Three additional grasses are being prepared for release in early 1997. E. F. Burlingham holds an option on 'Century' aka Syn92-1, and on 'Imperial' aka Syn92-5. TMI and SCOTTS hold an option on 'Backspin' aka Syn92-2. The initial seed harvest from the Syn96 series was made in 1996 (planted in the fall of 1995) with great production expectations. Three individual lines have been created which further combine added disease resistance including total resistance to Dollar Spot along with improved genetic color, texture and density of stand. Preliminary indications suggest these will provide a substantial incremental improvement for biological adaptability to natural environmental conditions.

The bentgrass breeding program has initiated a program for genetic improvement utilizing the concepts of biotechnology. Nodal explants have been generated of each of the parental lines of 'Crenshaw' all having excellent stability of phenotypes. In cooperation with Dr. Phil Colbaugh (Turfgrass Pathology) , the intent of the project will be to incorporate the gene(s) conditioning for Dollar Spot resistance directly into the parental clone(s) of 'Crenshaw' followed with minimal reselection to develop a Dollar Spot resistant variety with the excellent agronomic and biological characteristics of Crenshaw.

Research is also being conducted in cooperation with Dr. Richard White, Texas A&M College Station on methodology and success of interseeding of the new bentgrasses into existing bentgrass greens. Preliminary results are very encouraging based on electrophoresis analysis of Penncross greens which have been interseeded with Crenshaw utilizing various cultural procedures. Future efforts will also examine other methods of mechanical and chemical treatments and timing and rates of interseeding.

1996 RESEARCH REPORT
BREEDING AND DEVELOPMENT OF BENTGRASS

Dr. M. C. Engelke, Dr. I. Yamamoto, and Ms. J. M. Mills

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 April 1985. Semiannual progress reports are submitted 1 May, and annual reports are submitted 1 November each year. This report, with the May 1996 INTERIM REPORT, constitutes the 1996 Annual Progress Report for the Bentgrass Breeding Program.

II. PROFESSIONAL AND TECHNICAL SUPPORT

Ms. Jamie M. Mills holds the position of Research Assistant since June 1993 . She has a B.S. degree in Horticulture from Texas A&M University.

Ms. Marine Doin has worked on the project for 5 months as a foreign exchange student from Institut Superieur d;Agriculture - Membre de l'Universite Catholique de Lille, Lille Cedex, France. A part of her internship was supported by USGA. She worked closely with Dr. Yamamoto in tissue culture research and bentgrass breeding.

Dr. Ikuko Yamamoto (Assistant Research Scientist) joined the Turfgrass Breeding Program in February 1995. Dr. Yamamoto's responsibilities focus on breeding and development of bentgrasses by conventional methods and molecular genetic techniques. She works closely with Dr. Phillip Colbaugh for evaluation and screening of disease-resistant germplasm and attempts to introduce the resistant characteristics into susceptible cultivars. She also works to develop a reliable evaluation method of population shift in interseeded or blended greens. Approximately 40% of her time is devoted to the bentgrass project.

III. STATUS OF BENTGRASS RELEASES

THE 1988 SERIES OF CREEPING BENTGRASSES

In addition to **Cato** (Syn4-88) and **Crenshaw** (Syn3-88), both of which were released in 1993, **Mariner** (Syn1-88) was released in the spring 1996. Mariner is licensed to Pick Seed West, Tangent, OR. Seed production is estimated at approximately 80 acres. To date, approximately 20,000 pounds of seed were available from the 1995 crop. No information is available on 1996 production.

THE 1992 SERIES OF CREEPING BENTGRASSES

Three of Syn92 series (Syn92-1, Syn92-2, and Syn92-5) have been evaluated in regional tests and National Turfgrass Evaluation Program (NTEP) trials. Turf performance of the Syn92 series are evaluated excellent under the TAES and other national trials (see "1993 NTEP Trial" section). **Century** (Syn92-1) and **Imperial** (Syn92-5) have be optioned to E. F. Burlingham & Sons, Forest Grove, OR, and will be submitted for release in the fall 1996 for release in early 1997. **Backspin** (Syn92-2) has been optioned to Turf Merchants and Scott's for advanced testing and evaluation.

Century is a six clone synthetic cultivar of which parents were selected for uniformity in plant type and leaf color. Individual clones comprising this clone include: TAES2831; 3153; 3250; 3307; 3794; and 3799. Approximately 40 pounds of seed were harvested in 1994. More than 5 acres of additional seed production fields were initiated in 1994 and sufficient seed was provided in 1995 for further tests and evaluation. Century is classified into a late maturity group, and it is a reasonably good seed yielder.

Imperial is a seven clone synthetic cultivar, and it is one of the earliest in maturity and potentially, the highest seed yielding cultivars. Imperial possesses coarser textured leaves with intermediate to dark genetic color. Individual clones comprising this clone include: TAES2833; 2845; 2916; 2922; 3106; 3293; and 3307. Approximately 50 pounds of seed was harvested in 1994. The seed production field was increased in 1994 as the Century field, which provided sufficient seed for advanced tests and evaluation in 1995 and beyond.

Backspin (Syn92-2) is licenced to Turf Merchants (TMI) and Scott's for advanced testing and evaluation. **Backspin** is a four clone synthetic population of which parents were selected for *Rhizoctonia* and *Pythium* disease resistance. Individual clones comprising this clone include: TAES2859; 2916; 2922; and 3276. Backspin is classified into a medium-late maturity group with good seed production potential. Approximately 40 pounds of seed was harvested in 1994. Backspin possesses moderately coarse textured leaves with an intermediate leaf type.

Syn92-4 is a seven clone synthetic population and categorized in the latest maturity group. Individual clones comprising this clone include: TAES2852; 2915; 2916; 2922; 3153; 3225; and 3307. Sufficient amount of seed was produced in 1994 and 1995 for advanced testing and evaluations. No additional seed increase has been made. This cultivar is preforming very well in trials near Chicago and is available for release.

IV. OREGON BREEDER FIELDS

1996 Breeder performance nurseries were established in Oregon in November 1995. The nurseries include three individual polycross populations that were selected for multiple physiological characteristics: disease (dollar spot) resistance; fine texture; and dark color. The polycross population was identified as Syn96-1, Syn96-2, Syn96-3. Seed harvested in the fall 1996 will be provided for the future field testing and for entry in the 1997/98 NTEP bentgrass trials.

V. PARENT-PROGENY POLYCROSS POPULATION

A replicated parent-progeny nursery was established for most of the maternal clones in a modified soil based putting green in April 1993. The objective of this study is to evaluate the parental performance based on the progeny performance. Simultaneously, the method allows us to select superior progeny for further evaluation. The selected synthetic populations are our Syn96 series.

In addition, the maternal lines of the nursery are under examination for water stress studies, conducted by Mr. Gene Taylor. Mr. Taylor is a graduate student under the direction of Drs. Richard White (Texas A&M Univ., College Station, TX) and Engelke. The study will determine the genetic variability and possible heritability of water deficit tolerance among creeping bentgrasses.

VI. VEGETATIVE CREEPING BENTGRASS SELECTIONS

Assessment of genotype performance continues in the greenhouse, field and laboratory, with screening of germplasm. Originally, 73 superior clones were selected from the breeder fields of Syn92 series in Brooks and St. Paul, OR. The selections were evaluated for vegetative growth characteristics, genetic color, turf quality, heat and salinity tolerance, and root growth characteristics. Based on the results (a part of data is shown in Tables 1, 2, 3; also see 1995 Annual Report), selections were narrowed to 31 and now down to 13 clones. They include TAES 405;2, 4059, 4074, 4077, 4081, 4085, 4085, 4086. 4087, 4091, 4099, 4100, 4106 and 4111 and are redlined in the tables. These will receive intense study relative to production potential, recuperative rates and general turf performance along with intensive screening tests for disease and insect resistance will be conduct with Drs. Reinert and Colbaugh (Texas A&M Research Center, Dallas, TX).

VII. 1993 NTEP Sand-Modified Bentgrass Green Evaluations at TAES-Dallas

The NTEP sand-modified bentgrass green trial established in 1993 identifies cultivars with significant improvements in environmental adaptability (see 1995 USGA Annual Progress Report for establishment and management of the green). The trial contains 30 entries, 14 experimental and 16 commercial cultivars. In addition to visual evaluation of turfgrass quality, we have measured root length and tiller density. Turf quality, comprising density, uniformity, smoothness, color, and texture, was visually evaluated monthly. The number of tillers per sample plug (1.5-cm diam.) was counted twice in the growing season of 1996. The longest root length was measured twice in the summer of 1996 by taking sample plugs.

The experimental design was a randomized complete block design with three replications. The data was analyzed by analysis of variance (ANOVA) using SAS (SAS Institute, Inc., 1985). When the ANOVA *F*-statistic is significant ($\alpha = 0.05$), the means are separated by a Waller-Duncan *k*-ratio *t*-test. We summarize turfgrass performance using a turf performance index (TPI; Engelke, et. al., 1993). TPI is the number of times an entry is rated in the top statistical group. Although constrained by the assumptions of the underlying statistical

procedures, the TPI is a dimension less statistic. The TPI can be accumulated across trials, years and locations, and yield valuable information regarding the relative consistency of turfgrass performance of each of the entries.

Dollar Spot Resistance (Table 4): Significant differences in disease resistance to dollar spot was observed. Mariner (mean rating, 8.0), Pro/Cup (8.0), Southshore (8.0), and A-4 (7.8) were significantly more tolerant to the *Sclerotinia* than other entries in both March and April evaluations; while 18th Green (6.9) performed significantly better only in the March evaluation.

Root Depth (Table 5): There were no significant difference among entries in the 1996 observations. However, as in the previous years, Backspin and G-2 tended to produce deeper root systems.

*Tiller Number (*Table 6): No significant differences among entries were determined until May 1996. The number of tillers per plug increased for most of the entries from May to June. In June, 21 entries, especially G-6, Dominant, and A-1, possessed significantly more tillers than others.

Turf Quality (Table 7): All of the entries performed similar under the intensive management for golf-course putting greens. However, 9 out of 30 entries (18th green, C&C, Century, ISI-Ap-89150, Mariner, Regent, Southshore, Trueline, and VAR Ws 42102) were consistently rated in the top statistical group throughout the year (TPI=10). To examine specific characteristics (e.g., drought tolerance, mowing or traffic tolerance, nutrient requirement, and disease resistance), we may need to modify the cultural practices, so that we can determine phenotypic differences among entries.

Mowing Tolerance (Table 8): To examine the tolerance to low-mowing height, we compared turf quality under regular (5/32") and lower (7/64") mowing heights. All entries performed significantly better at the higher mowing height rather than the lower mowing height. However, within each mowing treatment, no statistical differences were observed among entries. Averaged over the season however, difference were noted among grasses. Fifteen of the 30 entries rated in the highest group when mowed at 5/32" whereas only four entries were significantly improved when mowed at 7/64", i.e, L-93 G-6, DG-P, L-93 and C&C. The differential mowing heights will continue to be applied throughout the next season to aid in further definition of the optimum management needed to maintain superior turf.

Leaf Texture (Table 9): The leaf texture for 22 entries were significantly finer than other entries. However, the difference may not be practical.

Color (Table 10): Although there were no significant differences in the genetic color rating, Century (8.0) possessed one of the darkest green colors, followed by A-4, C&C, Imperial, L-93, Pennlinks, Providence, Southshore, SR1020, and Trueline (7.7).

Drought Tolerance (Table 11): Turf performance under water stress conditions was examined in March 1996. During the study, irrigation practices were discontinued until the first water deficit symptoms appeared for Crenshaw, one of the drought tolerant cultivars. During the dry down periods, we examined turf performance three times, March 14, 21, and 28.

Water was applied through regular irrigation systems on March 13, 18, and 22 for 10 min. each.

On March 14, 1 day after regular irrigation, all entries maintained high turf quality. After a 7-day dry period, except a 10-min irrigation on March 18, 13 entries maintained significantly better turf quality than did other entries. Although, overall turf quality was gradually reduced, after 14-day dry period, except two 10-min irrigations on March 18 and 22, there were significant differences among entries in performance under water stress conditions. According to the TPI, Crenshaw, Imperial, Backspin, Cato, Century, Mariner, MSUEB, Regent, SR1020, Tendez, and L-93 can be considered relatively drought tolerant cultivars.

Summary of NTEP (Table 12): The results for the 1993 NTEP trial is summarized as a total of TPI values. Twenty-seven observations were made in 1996 evaluation; hence, the maximum possible TPI is 27. As shown in Table 12, Mariner and Southshore were ranked at the top with TPI = 26, followed by Providence and Regent (TPI = 25).

VIII. Introduction of Disease Resistance Cultivars

Development of screening methods: The essential element of success in the development of a synthetic cultivar is the ability of obtaining or identifying superior clones. In our 11-year project, we developed distinctive screening methods for heat tolerance using the greenhouse heat bench, drought and salt tolerance by the development of root-tube and saline-hydroponics. Presently and in cooperation with Dr. Phil Colbaugh, we are focusing on developing a reliable and quick screening methods for major turfgrass diseases, such as *Sclerotinia* dollar spot, *Rhizoctonia*, and *Pythium* blight diseases. An artificial inoculation technique has been established. The technique can be applied on plant materials in pots or directly on the field plots. In addition, we are developing a laboratory screening method, which allows instant multiple comparison among genotypes. The detail will be described when the method is completely established.

Introduction of disease resistance in susceptible cultivars: A disease susceptible cultivar can be improved by replacing its susceptible parental clones with morphologically and physiologically similar but resistant clones through intense backcross, top cross program.

In contrast, resistance gene(s) can be introduced through genetic engineering. To apply the biotechnology, the development of an efficient and repeatable tissue or cell culture system is important. Several studies have been conducted in this area; however, in most of the cases, embryos (seeds) of Penncross creeping bentgrass were used as explants. Since Penncross seeds are genetically heterogeneous, as in most of the cross-pollinated cultivars, plants regenerated from seed-derived callus are genetically different from each other, and the parental plant. In order to minimize the explant variation and to continue the lineage of good agronomic traits of the parental lines, we selected nodal segments harvested from superior clones as explants to develop an adequate tissue culture system. We believe that this could be the principal step in the practical application of advanced biotechnology in bentgrass breeding

programs. A part of this study was presented in a Turfgrass Biotechnology Workshop, East Lansing, MI, in August 1996 and will presented in the ASA annual meeting, Indianapolis, IN, in Nov. 1996.

IX. Electrophoretic Identification of Population Shift

Several new bentgrasses have been released for use on golf course putting greens in the last 3-5 years. Generally the introduction of these grasses to a golf course would require extensive greens renovation or new construction. There are in excess of 14,000 golf course in the United States alone. It is not conceivable that every golf course can afford the time nor financial resources to undergo renovation or major reconstruction just to change to a new grass. However, it should be possible that many of these courses could take advantage of these new grasses if their introduction and conversion did not require extensive renovation. When bentgrass putting greens are interseeded with new cultivars, it is desired to have a quick transition with minimal interruption of play. Studies of physical and chemical practices have been conducted for this purpose; however, there is no simple method to measure the population shifts. To facilitate the area of study as well as to provide the scientific evidence of cultivar transition, we propose the use of an electrophoretic technique. In this technique, isoenzyme banding patterns of bulk leaf samples from an interseeded green are compared with those of proportional blends of two cultivars (standard extract blends). The green's composition is estimated as a blend ratio of which isoenzyme phenotype is the most similar. In collaboration with Dr. Richard White (Texas A&M University, College Station, TX), we examined population shifts in Crenshaw-interseeded-Penncross greens at TAES-Dallas and Dallas Country Club (Appendix A). The percentage composition of Crenshaw interseeded in a Penncross green was detectable to as little as 5%. The electrophoretic technique could facilitate interseeding or competition studies by providing the scientific evidence of cultivar transition.

X. TABLES

Table 1. Scalp ratings[1] during 1996 for the bentgrass vegetative field trial at TAES-Dallas.

Entry	06Feb	14Mar	Mean	TPI	Entry	06Feb	14Mar	Mean	TPI
4039	5.5	6.7	6.1	1	4078	6.3a	6.3	6.3	2
4040	8.5a	8.3	8.4a	2	4079	6.7a	7.3	7.0a	2
4041	6.8a	7.3	7.1a	2	4080	8.0a	8.3	8.2a	2
4042	9.0a	7.3	8.2a	2	4081	7.8a	8.3	8.1a	2
4043	8.3a	8.3	8.3a	2	4082	7.3a	7.7	7.5a	2
4044	7.2a	7.3	7.3a	2	4083	6.5a	8.0	7.3a	2
4045	8.5a	8.3	8.4a	2	4084	7.7a	5.7	6.7	2
4046	8.2a	6.7	7.4a	2	4085	6.7a	8.3	7.5a	2
4047	8.3a	8.3	8.3a	2	4086	8.5a	8.0	8.3a	2
4048	7.5a	7.7	7.6a	2	4087	8.3a	8.0	8.2a	2
4049	9.0a	8.0	8.5a	2	4088	7.3a	7.3	7.3a	2
4050	8.7a	7.7	8.2a	2	4089	8.5a	7.7	8.1a	2
4051	8.0a	7.3	7.7a	2	4090	9.0a	4.7	6.8	2
4052	8.2a	6.0	7.1a	2	4091	8.0a	7.7	7.8a	2
4053	8.5a	8.3	8.4a	2	4092	8.3a	8.3	8.3a	2
4054	6.3a	7.0	6.7	2	4093	9.0a	8.3	8.7a	2
4055	7.3a	7.3	7.3a	2	4094	9.0a	8.3	8.7a	2
4056	7.8a	7.7	7.8a	2	4095	8.0a	9.0	8.5a	2
4057	4.3	6.3	5.3	1	4096	9.0a	7.0	8.0a	2
4058	8.0a	8.3	8.2a	2	4097	8.2a	8.0	8.1a	2
4059	7.0a	7.0	7.0a	2	4098	8.5a	7.0	7.8a	2
4060	6.7a	6.0	6.3	2	4099	8.2a	8.0	8.1a	2
4061	8.2a	7.7	7.9a	2	4100	8.2a	8.3	8.3a	2
4062	9.0a	7.7	8.3a	2	4101	8.2a	8.0	8.1a	2
4063	9.0a	8.3	8.7a	2	4102	6.8a	7.0	6.9a	2
4064	9.0a	6.7	7.8a	2	4103	7.0a	7.7	7.3a	2
4065	7.8a	8.3	8.1a	2	4104	8.5a	8.7	8.6a	2
4066	5.0	6.0	5.5	1	4105	4.5	5.3	4.9	1
4067	6.8a	6.0	6.4	2	4106	6.7a	6.7	6.7	2
4068	8.0a	8.0	8.0a	2	4107	6.5a	7.3	6.9a	2
4069	9.0a	8.3	8.7a	2	4108	3.5	5.3	4.4	1
4070	6.0a	6.3	6.2	2	4109	9.0a	8.7	8.8a	2
4071	7.0a	7.0	7.0a	2	4110	7.8a	8.0	7.9a	2
4072	5.7a	5.3	5.5	2	4111	8.5a	7.3	7.9a	2
4073	8.3a	7.3	7.8a	2	Cato	7.5a	7.7	7.6a	2
4074	8.0a	7.0	7.5a	2	Crenshaw	9.0a	9.0	9.0a	2
4075	4.8	5.7	5.3	1	Penncross	9.0a	9.0	9.0a	2
4076	7.7a	7.3	7.5a	2	Seaside	7.5a	8.0	7.8a	2
4077	7.5a	8.0	7.8a	2	Mariner	9.0a	9.0	9.0a	2
MSD[3]	3.47	ns			MSD[3]	3.47	ns		

[1] Scalp ratings were based on 1-9 scale, where 9 is the best (no scalp damage) and 1 is the severest damage.

[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group 'a' indicates entry was in the highest statistical group. 'ns' indicates means were not significancy based on ANOVA *F*-test

[3] MSD is the minimum significant difference between means based on the Waller-Duncan *k*-ratio *t*-test(*k*-ratio=100). 'a' indicates entry was in the highest statistical group. 'ns' indicates means were not significancy based on ANOVA *F*-test.

Table 2. Turf quality ratings[1] during 1996 for the bentgrass vegetative field trial at TAES-Dallas.

Entry	24Jan	10Apr	15May	28May	28Jun	11Jul	15Aug	Mean	TPI	Entry	24Jan	10Apr	15May	28May	28Jun	11Jul	15Aug	Mean	TPI
4039	6.3a	5.0a	6.3	6.7	6.7	6.0a	6.0a	6.1	7	4078	5.7	5.8	7.2	6.7	6.7	7.0a	7.0a	6.6	6
4040	6.7a	6.2a	6.7	7.0	7.0	6.5a	6.8a	6.7	7	4079	6.0	5.7a	6.8	6.3	6.3	6.3a	6.7a	6.3	6
4041	7.0a	6.0a	6.8	6.2	6.2	6.8a	7.2a	6.6	7	4080	7.0a	7.0a	7.0	7.0	7.0	6.8a	6.8a	7.0a	7
4042	7.0a	7.3a	6.8	6.2	6.2	6.0a	6.3a	6.5	7	4081	7.0a	6.8a	7.5	5.5	5.5	6.5a	6.5a	6.5	7
4043	7.3a	7.0a	7.0	5.5	5.5	4.7	5.0a	6.0	6	4082	6.0	6.8a	7.0	7.0	7.0	7.2a	7.5a	6.9a	6
4044	6.7a	6.5a	7.5	5.0	5.0	4.5	4.8	5.7	6	4083	6.3a	6.7a	6.7	6.7	6.7	6.5a	6.7a	6.6	7
4045	7.0a	7.0a	7.2	7.0	7.0	6.0a	6.0a	6.7	6	4084	5.7	5.3a	6.5	5.7	5.7	6.2a	6.2a	5.9	6
4046	6.3a	7.0a	7.0	5.8	5.8	6.3a	6.3a	6.4	7	4085	5.7	5.2a	7.0	6.7	6.7	6.0a	6.0a	6.2	6
4047	6.0	7.5a	7.5	6.3	6.5	5.7a	5.8a	6.5	6	4086	6.3a	6.8a	7.0	6.8	6.8	7.2a	7.3a	6.9a	7
4048	6.0	6.2a	6.3	7.0	5.0	6.7a	6.5a	6.2	6	4087	7.3a	7.3a	7.3	6.2	6.2	7.2a	7.2a	7.0a	7
4049	7.3a	7.0a	7.3	5.7	5.7	6.8a	6.8a	6.7	7	4088	6.0	6.7a	6.3	6.8	6.8	7.3a	7.2a	6.7	6
4050	6.3a	6.2a	7.0	6.5	6.5	6.5a	6.7a	6.5	7	4089	7.0a	7.2a	6.5	5.8	5.8	6.7a	6.7a	6.5	7
4051	6.7a	6.7a	6.8	6.3	6.3	5.5a	5.5a	6.3	7	4090	6.7a	7.0a	7.2	6.2	6.2	6.2a	6.5a	6.5	7
4052	5.7	6.0a	7.0	5.8	5.8	5.5a	6.0a	6.0	6	4091	6.3a	7.3a	7.0	7.2	7.2	6.8a	7.2a	7.0a	7
4053	6.0	6.3a	6.7	5.8	5.8	7.3a	7.7a	6.5	7	4092	7.3a	7.2a	7.0	6.7	6.7	6.2a	6.2a	6.7	7
4054	6.0	6.2a	7.0	6.3	6.3	6.7a	7.0a	6.5	6	4093	6.7a	6.8a	7.2	6.7	6.7	6.8a	6.5a	6.8	7
4055	6.0	6.3a	6.7	6.3	6.3	6.3a	6.5a	6.4	6	4094	6.7a	7.8a	7.5	8.0	8.0	6.8a	7.3a	7.5a	7
4056	6.3a	6.5a	6.8	6.3	7.0	6.2a	6.2a	6.5	7	4095	6.0	7.0a	7.3	6.5	6.5	7.5a	7.2a	6.9a	6
4057	5.7	4.7a	7.3	4.8	4.8	6.5a	6.5a	5.8	6	4096	6.7a	7.2a	7.5	7.7	7.7	6.0a	6.2a	7.0a	7
4058	6.3a	7.5a	7.2	6.8	4.5	6.8a	6.3a	6.5	7	4097	6.0	6.8a	7.2	6.8	6.8	7.0a	6.7a	6.8	6
4059	6.3a	6.7a	6.5	5.5	5.5	6.3a	6.7a	6.2	7	4098	6.0	7.2a	7.3	6.7	6.7	6.2a	6.2a	6.6	6
4060	6.0	6.0a	6.2	5.7	5.7	6.5a	6.8a	6.1	6	4099	5.3	5.8a	6.3	6.5	6.5	7.0a	7.0a	6.4	6
4061	6.0	5.8a	6.2	6.3	6.3	6.0a	6.0a	6.1	6	4100	7.0a	7.0a	7.3	6.7	6.7	7.0a	7.2a	7.0a	7
4062	5.7	6.8a	7.2	7.2	7.2	6.7a	6.7a	6.8	6	4101	6.3a	6.8a	7.0	7.0	7.0	6.7a	6.7a	6.8	7
4063	5.7	6.5a	6.8	6.7	6.7	6.7a	6.7a	6.5	6	4102	6.3a	6.3a	5.3	7.0	7.0	7.2a	7.5a	6.7	7
4064	6.3a	6.8a	6.7	7.2	7.2	6.5a	6.5a	6.7	7	4103	6.0	7.3a	7.0	6.8	6.8	7.5a	7.5a	7.0a	6
4065	6.7a	7.2a	7.5	7.3	7.3	6.0a	6.0a	6.9a	7	4104	6.0	6.8a	6.8	5.8	5.8	6.2a	6.3a	6.3	6
4066	5.7	5.8a	6.2	5.5	5.5	6.3a	6.3a	5.9	6	4105	5.0	4.8a	6.2	6.3	6.3	7.0a	6.8a	6.1	6
4067	5.7	6.0a	6.7	6.5	6.5	6.7a	6.5a	6.4	6	4106	6.3a	5.7a	6.7	6.2	6.2	6.0a	6.3a	6.2	7
4068	6.3a	7.0a	7.2	6.2	6.2	6.3a	6.3a	6.5	7	4107	6.3a	6.0a	7.2	6.0	6.0	6.3a	6.3a	6.3	7
4069	7.7a	7.3a	7.3	6.0	6.0	6.3a	6.7a	6.8	7	4108	5.3	4.8a	5.5	5.8	5.8	6.0a	6.0a	5.6	6
4070	6.0	5.2a	6.0	5.8	5.8	6.3a	6.5a	6.0	6	4109	6.7a	7.2a	7.0	6.8	6.8	6.8a	7.0a	6.9a	7
4071	6.3a	6.3a	7.2	6.8	6.8	6.7a	6.7a	6.7	7	4110	6.3a	6.7a	6.8	7.2	7.2	6.8a	7.0a	6.9a	7
4072	6.0	5.3a	6.0	6.2	6.2	7.0a	6.7a	6.2	6	4111	6.0	7.2a	7.0	6.8	6.8	7.0a	7.0a	6.8a	6
4073	6.3a	6.8a	7.2	7.3	7.3	7.2a	7.2a	7.0a	7	Cato	6.7a	6.0a	5.8	6.8	6.8	6.7a	6.7a	6.5	7
4074	6.0	7.0a	6.7	6.7	7.0	6.8a	7.2a	6.8	6	Crenshaw	7.3a	7.7a	7.2	6.7	6.7	7.0a	7.0a	7.1a	7
4075	5.0	4.3	5.2	6.2	6.2	7.3a	7.5a	6.0	5	Penncross	6.7a	7.7a	6.7	6.5	6.5	6.8a	6.8a	6.8a	7
4076	6.0	6.0a	6.7	6.8	6.8	6.8a	6.8a	6.6	6	Seaside	6.7a	6.7a	6.8	4.8	4.8	7.2a	7.2a	6.3	7
4077	6.3a	6.8a	6.8	6.3	6.3	6.5a	6.5a	6.5	7	Mariner	7.0a	7.3a	7.3	6.3	6.3	5.7a	5.8a	6.5	7
MSD[3]	1.59	3.26	ns	ns	ns	2.22	2.74			MSD[3]	1.59	3.26	ns	ns	ns	2.22	2.74		

[1] Turf quality ratings were based on 1-9 scale, where 9 is the best and 5 is the minimum acceptable turf quality.

[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group.

'a' indicates entry was in the highest statistical group. 'ns' indicates means were not significancy based on ANOVA *F*-test.

[3] MSD is the minimum significant difference between means based on the Waller-Duncan *k*-ratio *t*-test(*k*-ratio=100).

Table 3. Turf performance index (TPI)[2] summary for the bentgrass vegetative field trial at TAES-Dallas.

Entry	Tb.1	Tb.2	TPI	%[3]	Entry	Tb.1	Tb.2	TPI	%[3]
4039	1	7	8	88.9	4078	2	6	8	88.9
4040	2	7	9	100.0	4079	2	6	8	88.9
4041	2	7	9	100.0	4080	2	7	9	100.0
4042	2	7	9	100.0	4081	2	7	9	100.0
4043	2	6	8	88.9	4082	2	6	8	88.9
4044	2	6	8	88.9	4083	2	7	9	100.0
4045	2	6	8	88.9	4084	2	6	8	88.9
4046	2	7	9	100.0	4085	2	6	8	88.9
4047	2	6	8	88.9	4086	2	7	9	100.0
4048	2	6	8	88.9	4087	2	7	9	100.0
4049	2	7	9	100.0	4088	2	6	8	88.9
4050	2	7	9	100.0	4089	2	7	9	100.0
4051	2	7	9	100.0	4090	2	7	9	100.0
4052	2	6	8	88.9	4091	2	7	9	100.0
4053	2	7	9	100.0	4092	2	7	9	100.0
4054	2	6	8	88.9	4093	2	7	9	100.0
4055	2	6	8	88.9	4094	2	7	9	100.0
4056	2	7	9	100.0	4095	2	6	8	88.9
4057	1	6	9	100.0	4096	2	7	9	100.0
4058	2	7	9	100.0	4097	2	6	8	88.9
4059	2	7	9	100.0	4098	2	6	8	88.9
4060	2	6	8	88.9	4099	2	6	8	88.9
4061	2	6	8	88.9	4100	2	7	9	100.0
4062	2	6	8	88.9	4101	2	7	9	100.0
4063	2	6	8	88.9	4102	2	7	9	100.0
4064	2	7	9	100.0	4103	2	6	8	88.9
4065	2	7	9	100.0	4104	2	6	8	88.9
4066	1	6	7	77.8	4105	1	6	7	77.8
4067	2	6	8	88.9	4106	2	7	9	100.0
4068	2	7	9	100.0	4107	2	7	9	100.0
4069	2	7	9	100.0	4108	1	6	7	77.8
4070	2	6	8	88.9	4109	2	7	9	100.0
4071	2	7	9	100.0	4110	2	7	9	100.0
4072	2	6	8	88.9	4111	2	6	8	88.9
4073	2	7	9	100.0	Cato	2	7	9	100.0
4074	2	6	8	88.9	Crenshaw	2	7	9	100.0
4075	1	5	6	66.7	Penncross	2	7	9	100.0
4076	2	6	8	88.9	Seaside	2	7	9	100.0
4077	2	7	9	100.0	Mariner	2	7	9	100.0
#Obs.	2	7	9		#Obs.	2	7	9	

[1] A maximum of 9 observations per entry are reported in tables 1 and 2.

[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group (does not include overall mean).

[3]% = the frequency for which the entry was in the highest statistical group across all tests and based on the number of trials for which the entry was included in this document.

Table 4. Dollar spot ratings[1] during 1996 for the 1993 NTEP sand-modified bentgrass trial at TAES-Dallas.

Entry	18Mar	17Apr	Mean	TPI[2]
18th Green	7.0a	6.8	6.9	1
A-1	6.3	6.3	6.3	0
A-4	7.8a	7.8a	7.8	2
Backspin	6.3	6.5	6.4	0
BAR As 493	6.3	6.5	6.4	0
C&C	6.5	6.3	6.4	0
Cato	5.0	5.2	5.1	0
Century	5.3	5.5	5.4	0
Crenshaw	6.0	5.8	5.9	0
DG-P	6.3	6.5	6.4	0
Dominant	5.3	5.7	5.5	0
G-2	5.7	6.0	5.8	0
G-6	6.0	6.2	6.1	0
Imperial	5.3	5.5	5.4	0
ISI-Ap-89150	5.5	5.5	5.5	0
L-93	4.8	5.0	4.9	0
Lopez	5.0	5.0	5.0	0
Mariner	8.0a	8.0a	8.0	2
MSUEB	5.8	5.8	5.8	0
Penncross	6.0	6.0	6.0	0
Pennlinks	4.7	4.7	4.7	0
Pro/Cup	8.0a	8.0a	8.0	2
Providence	7.5a	7.5a	7.5	2
Regent	5.7	5.7	5.7	0
Seaside	6.0	6.0	6.0	0
Southshore	8.0a	8.0a	8.0	2
SR1020	6.7	6.7	6.7	0
Tendez	4.7	4.7	4.7	0
Trueline	5.7	5.8	5.8	0
VAR Ws 42102	6.7	6.7	6.7	0
MSD[3]	1.1	1.0		

[1] Dollar spot ratings were based on a 1-9 scale, where 9 is undamaged and 1 is 100% damaged.

[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group.

[3] MSD is the minimum significant difference between means basedon the Waller-Duncan *k*-ratio *t*-test (k=100).

'a' indicates entry was in the highest statistical group. 'ns' indicates means were not significancy based on ANOVA *F*-test.

Table 5. Root depth ratings[1] during 1996 for the 1993 NTEP sand-modified bentgrass trial at TAES-Dallas.

Entry	19Mar	20Jun	Mean	TPI[2]
18th Green	17.7	17.5	17.6	2
A-1	18.6	18.4	18.5	2
A-4	18.8	19.1	18.9	2
Backspin	23.4	21.6	22.5	2
BAR As 493	18.7	18.1	18.4	2
C&C	19.9	20.1	20.0	2
Cato	20.7	20.7	20.7	2
Century	19.4	19.7	19.5	2
Crenshaw	21.5	21.1	21.3	2
DG-P	20.3	20.3	20.3	2
Dominant	18.6	18.6	18.6	2
G-2	22.1	21.5	21.8	2
G-6	17.4	17.5	17.5	2
Imperial	17.4	17.2	17.3	2
ISI-Ap-89150	17.7	17.7	17.7	2
L-93	18.5	18.5	18.5	2
Lopez	20.3	20.3	20.3	2
Mariner	18.0	17.6	17.8	2
MSUEB	19.9	19.5	19.7	2
Penncross	19.5	18.6	19.1	2
Pennlinks	21.1	21.1	21.1	2
Pro/Cup	17.5	17.0	17.3	2
Providence	21.6	20.9	21.3	2
Regent	18.7	18.0	18.3	2
Seaside	19.8	18.7	19.3	2
Southshore	17.9	17.7	17.8	2
SR1020	21.6	20.9	21.2	2
Tendez	21.2	13.4	17.3	2
Trueline	17.6	18.3	18.0	2
VAR Ws 42102	15.6	15.3	15.4	2
MSD[3]	ns	ns		

[1] Root depth ratings were based on the longest root (mm) measured in a sample plug.

[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group.

[3] MSD is the minimum significant difference between means basedon the Waller-Duncan *k*-ratio *t*-test (k=100).

'a' indicates entry was in the highest statistical group. 'ns' indicates means were not significancy based on ANOVA *F*-test.

Table 6. Tiller count ratings[1] during 1996 for the 1993 NTEP sand-modified bentgrass trial at TAES-Dallas.

Entry	19Mar	20Jun	Mean	TPI [2]
18th Green	46.3	48.0a	47.2	2
A-1	66.3	64.3a	65.3	2
A-4	49.0	46.0a	47.5	2
Backspin	41.7	36.7	39.2	1
BAR As 493	45.7	45.7a	45.7	2
C & C	44.3	42.7	43.5	1
Cato	45.3	45.3a	45.3	2
Century	39.7	38.0	38.8	1
Crenshaw	41.3	39.0	40.2	1
DG-P	46.3	46.3a	46.3	2
Dominant	65.7	66.0a	65.8	2
G-2	46.7	46.3a	46.5	2
G-6	67.3	67.0a	67.2	2
Imperial	44.7	45.7a	45.2	2
L-93	44.0	44.0a	44.0	2
Lopez	42.0	42.3	42.2	1
Mariner	41.0	39.0	40.0	1
MSUEB	40.7	40.0	40.3	1
Penncross	42.7	38.3	40.5	1
Pennlinks	52.0	50.0a	51.0	2
Pro/Cup	46.3	44.0a	45.2	2
Providence	60.0	59.3a	59.7	2
Regent	44.0	44.0a	44.0	2
Seaside	51.7	48.7a	50.2	2
Southshore	61.0	58.7a	59.8	2
SR1020	47.7	46.0a	46.8	2
Tendez	61.7	59.7a	60.7	2
Trueline	49.7	46.0a	47.8	2
VAR Ws 42102	52.0	52.0a	52.0	2
MSD[3]	ns	1.6		

[1] Tiller count ratings were based on the number of tillers in a 1.5 cm diameter sample plug.

[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group (does not include overall mean).

[3] MSD is the minimum significant difference between means basedon the Waller-Duncan *k*-ratio *t*-test (*k*=100).

'a'indicates entry was in the highest statistical group. 'ns' indicates means were not significancy based on ANOVA *F*-test.

Table 7. Turf quality[1] ratings during 1996 for the 1993 NTEP sand-modified bentgrass trial at TAES-Dallas.

Entry	24Jan	20Feb	30Mar	25Apr	28May	24Jun	11Jul	15Aug	19Sep	10Oct	Mean	TPI[2]
18th Green	6.7	7.2a	7.0	6.8	6.3	7.0	6.7	6.7	6.7	7.3	6.8a	10
A-1	6.7	6.3	6.8	7.7	6.5	7.2	7.0	6.7	7.2	7.2	6.9a	9
A-4	6.7	6.7	7.0	7.3	6.3	7.3	6.5	6.8	7.0	7.0	6.9a	9
Backspin	6.3	6.3	6.7	6.8	5.2	7.3	6.8	6.8	7.3	7.3	6.7a	9
BAR As 493	6.3	6.3	6.8	6.8	6.0	6.5	6.7	7.0	6.8	7.0	6.6a	9
C&C	6.0	7.5a	6.7	6.7	6.5	7.3	6.7	6.3	7.2	7.5	6.8a	10
Cato	6.3	6.2	6.7	7.2	6.2	7.2	6.7	6.7	7.0	7.0	6.7a	9
Century	6.0	6.8a	6.5	6.8	6.3	7.2	6.8	6.8	7.0	7.0	6.7a	10
Crenshaw	6.7	5.3	7.2	7.8	6.3	7.7	6.2	6.2	7.0	7.0	6.7a	9
DG-P	6.7	6.5	6.8	7.0	5.7	7.5	7.0	7.0	7.3	7.3	6.9a	9
Dominant	6.0	5.8	7.7	7.3	5.8	7.3	6.3	6.3	7.2	7.0	6.7a	9
G-2	6.0	6.0	6.8	6.3	5.8	6.7	6.3	6.3	6.8	6.8	6.4	9
G-6	6.3	6.5	7.3	6.7	6.3	7.0	6.8	6.8	7.2	7.5	6.8a	9
Imperial	6.7	6.0	7.0	7.0	6.0	7.2	6.7	6.7	7.2	7.0	6.7a	9
ISI-Ap-89150	6.7	7.2a	7.0	7.2	5.8	7.2	7.0	7.0	7.2	7.3	7.0a	10
L-93	7.0	6.5	6.7	6.7	5.7	6.7	6.2	6.2	7.3	7.5	6.6a	9
Lopez	7.3	6.5	7.2	6.0	5.7	7.0	6.5	6.5	7.0	7.0	6.7a	9
Mariner	6.7	7.2a	6.8	7.3	6.3	7.3	6.5	6.5	6.8	7.2	6.9a	10
MSUEB	6.3	6.3	6.0	6.8	5.2	6.7	6.3	6.3	7.0	7.2	6.4	9
Penncross	6.3	5.8	5.8	6.0	5.5	6.5	6.5	6.5	7.2	7.2	6.3	9
Pennlinks	6.0	6.0	7.2	7.0	5.5	6.8	6.5	6.3	7.3	7.2	6.6a	9
Pro/Cup	6.7	6.7	7.0	7.5	5.3	7.0	6.7	6.8	7.2	7.2	6.8a	9
Providence	7.0	6.2	7.0	7.7	6.8	6.8	7.0	6.8	7.2	7.2	7.0a	9
Regent	6.7	7.2a	6.5	7.2	7.2	7.5	6.8	6.8	7.3	7.2	7.0a	10
Seaside	6.7	6.2	6.8	6.3	6.0	6.7	6.0	5.8	6.7	6.7	6.4	9
Southshore	6.3	7.0a	7.2	7.3	6.5	6.7	7.3	7.3	7.2	7.2	7.0a	10
SR1020	6.3	6.7	7.0	7.5	7.0	7.5	7.2	7.0	7.2	7.3	7.1a	9
Tendenz	6.7	6.2	7.2	7.0	5.2	7.3	6.3	6.3	7.3	7.3	6.7a	9
Trueline	6.7	6.8a	6.7	7.2	5.7	7.2	6.3	6.3	7.2	7.2	6.7a	10
VAR Ws 42102	6.0	7.0a	7.3	7.0	5.8	7.0	6.3	6.8	7.3	7.3	6.8a	10
MSD[3]	ns	0.68	ns	ns	ns	ns	ns	ns	ns	ns	0.52	

[1] Turf quality ratings were based on 1-9 scale, where 9 is the best and 5 is the minimum acceptable turf quality.

[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group (does not include overall mean).

[3] MSD is the minimum significant difference between means based on the Waller-Duncan *k*-ratio *t*-test (*k*-ratio=100). 'a' indicates entry was in the highest statistical group. 'ns' indicates means were not significancy based on ANOVA *F*-test.

Table 8. Turf quality ratings[1] under different mowing heights (5/32" & 7/64") 1996 for the 1993 NTEP sand-modified bentgrass trial at TAES-Dallas.

Entry	27Sep		03Oct		10Oct		Mean		TPI[2]
	5/32"	7/64"	5/32"	7/64"	5/32"	7/64"	5/32"	7/64"	
18th Green	7.2	6.2	7.3	6.3	7.3	6.3	7.3a	6.3	6
Regent	7.0	5.7	7.0	5.8	7.2	5.8	7.1	5.8	6
Bar As 493	7.0	5.7	7.0	5.8	7.0	5.8	7.0	5.8	6
Var Ws 42102	7.2	6.0	7.3	6.2	7.3	6.2	7.3a	6.1	6
Trueline	7.2	6.2	7.2	6.2	7.2	6.0	7.2a	6.1	6
Seaside	6.7	6.0	6.7	6.0	6.7	6.0	6.7	6.0	6
Cato	6.7	5.7	7.0	5.5	7.0	5.5	6.9	5.6	6
Pro/Cup	7.2	6.2	7.2	6.2	7.2	6.2	7.2a	6.2	6
Crenshaw	6.8	5.8	7.0	6.2	7.0	6.2	6.9	6.1	6
Southshore	7.3	5.8	7.3	5.8	7.2	5.8	7.3a	5.8	6
Providence	7.2	6.2	7.3	6.3	7.2	6.3	7.2a	6.3	6
SR1020	7.5	6.0	7.3	6.2	7.3	6.0	7.4a	6.1	6
Century	7.0	6.0	7.0	6.3	7.0	6.3	7.0	6.2	6
Backspin	7.3	6.0	7.3	5.8	7.3	5.8	7.3a	5.9	6
Imperial	6.7	5.7	6.7	5.8	7.0	5.8	6.8	5.8	6
Penncross	6.8	5.7	7.0	5.7	7.2	5.7	7.0	5.7	6
A-1	6.8	5.7	7.2	5.7	7.2	5.7	7.1	5.7	6
A-4	7.2	6.0	7.2	6.0	7.0	6.2	7.1	6.1	6
G-2	6.7	5.5	6.8	5.7	6.8	5.7	6.8	5.6	6
G-6	7.5	6.7	7.5	6.7	7.5	6.7	7.5a	6.7a	6
Pennlinks	6.8	5.8	7.2	6.2	7.2	6.2	7.1	6.1	6
DG-P	7.2	6.3	7.2	6.7	7.3	6.5	7.2a	6.5a	6
Msueb	7.0	6.2	7.2	6.2	7.2	6.2	7.1	6.2	6
L-93	7.3	6.8	7.5	6.8	7.5	6.8	7.4a	6.8a	6
Lopez	7.0	6.2	7.0	6.2	7.0	6.2	7.0	6.2	6
Tendez	7.3	6.0	7.3	6.0	7.3	6.0	7.3a	6.0	6
ISI-Ap-89150	7.3	6.0	7.3	6.3	7.3	6.3	7.3a	6.2	6
Mariner	7.2	6.0	7.2	6.3	7.2	6.3	7.2a	6.2	6
C&C	7.5	6.5	7.5	6.5	7.5	6.3	7.5a	6.4a	6
Dominant	7.0	6.2	7.0	6.2	7.0	6.2	7.0	6.2	6
MSD[3]	ns	ns	ns	ns	ns	ns	0.38	0.46	

[1] Turf quality ratings were based on 1-9 scale, where 9 is the best and 5 is the minimum acceptable quality.

[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group (does not include overall mean).

[3] MSD is the minimum significant difference between means based on the Waller-Duncan *k*-ratio *t*-test(*k*-ratio=100). 'a' indicates entry was in the highest statistical group. 'ns' indicates means were not significancy based on ANOVA *F*-test.

Table 9. Leaf texture rating[1] during 1996 for the 1993 NTEP sand-modified bentgrass trial at TAES-Dallas.

Entry	15May	Mean	TPI[2]	Entry	15May	Mean	TPI[2]
18th Green	7.3	7.3	0	L-93	8.8a	8.8	1
A-1	8.5a	8.5	1	Lopez	7.5	7.5	0
A-4	8.7a	8.7	1	Mariner	8.2a	8.2	1
Backspin	8.3a	8.3	1	MSUEB	7.5	7.5	0
BAR As 493	7.7a	7.7	1	Penncross	8.3a	8.3	1
C&C	8.7a	8.7	1	Pennlinks	8.3a	8.3	1
Cato	8.5a	8.5	1	Pro/Cup	7.5	7.5	0
Century	8.7a	8.7	1	Providence	8.2a	8.2	1
Crenshaw	8.7a	8.7	1	Regent	8.2a	8.2	1
DG-P	8.3a	8.3	1	Seaside	8.5a	8.5	1
Dominant	8.0a	8.0	1	Southshore	8.8a	8.8	1
G-2	8.7a	8.7	1	SR1020	8.0a	8.0	1
G-6	8.7a	8.7	1	Tendez	8.3a	8.3	1
Imperial	7.2	7.2	0	Trueline	7.8a	7.8	1
ISI-Ap-89150	7.2	7.2	0	VAR Ws 42102	8.7a	8.7	1
MSD[3]	1.3			MSD[3]	1.3		

[1] Texture rating was based on 1-9 scale, where 9 is the finest and 1 is the coarsest.
[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group (does not include overall mean).
[3] MSD is the minimum significant difference between means based on the Waller-Duncan *k*-ratio *t*-test (*k*-ratio=100). 'a' indicates entry was in the highest statistical group. 'ns' indicates means were not significancy based on ANOVA *F*-test.

Table 10. Color rating[1] during 1996 for the 1993 NTEP sand-modified bentgrass trial at TAES-Dallas.

Entry	14May	Mean	TPI[2]	Entry	14May	Mean	TPI[2]
18th Green	7.3	7.3	1	L-93	7.7	7.7	1
A-1	7.3	7.3	1	Lopez	7.3	7.3	1
A-4	7.7	7.7	1	Mariner	7.0	7.0	1
Backspin	7.0	7.0	1	MSUEB	7.3	7.3	1
BAR As 493	7.2	7.2	1	Penncross	7.3	7.3	1
C&C	7.7	7.7	1	Pennlinks	7.7	7.7	1
Cato	7.5	7.5	1	Pro/Cup	6.5	6.5	1
Century	8.0	8.0	1	Providence	7.7	7.7	1
Crenshaw	7.3	7.3	1	Regent	7.0	7.0	1
DG-P	7.5	7.5	1	Seaside	7.8	7.8	1
Dominant	7.5	7.5	1	Southshore	7.7	7.7	1
G-2	7.0	7.0	1	SR1020	7.7	7.7	1
G-6	7.3	7.3	1	Tendez	7.0	7.0	1
Imperial	7.7	7.7	1	Trueline	7.7	7.7	1
ISI-Ap-89150	7.5	7.5	1	Var Ws 42102	7.2	7.2	1
MSD[3]	ns			MSD[3]	ns		

[1] Color rating was based on 1-9 scale, where 9 is the darkest green plot and 5 is the minimum acceptable turf color.
[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group (does not include overall mean).
[3] MSD is the minimum significant difference between means based on the Waller-Duncan *k*-ratio *t*-test (*k*-ratio=100). 'a' indicates entry was in the highest statistical group. 'ns' indicates means were not significancy based on ANOVA *F*-test.

Table 11. Stress ratings[1] during 1996 for the 1993 NTEP sand-modified bentgrass trial at TAES-Dallas.

Entry	14Mar	21Mar	28Mar	Mean	TPI
18th Green	6.3	5.7	5.3a	5.8	2
A-1	6.3	5.7	5.0	5.7	1
A-4	5.7	5.7	5.0	5.4	1
Backspin	7.0	7.3a	6.3a	6.9a	3
BAR As 493	6.3	5.7	5.3a	5.8	2
C&C	6.3	6.7a	6.0a	6.3	3
Cato	7.0	7.3a	6.0a	6.8a	3
Century	7.3	6.7a	6.3a	6.8a	3
Crenshaw	7.7	7.7a	7.0a	7.4a	3
DG-P	6.7	6.7a	6.0a	6.4	3
Dominant	5.7	5.7	5.0	5.4	1
G-2	6.0	6.0	4.7	5.6	1
G-6	6.7	6.3	5.7a	6.2	2
Imperial	7.0	7.3a	6.7a	7.0a	3
ISI-Ap-89150	6.0	6.0	5.3a	5.8	2
L-93	6.3	6.7a	5.7a	6.2	3
Lopez	6.3	6.3	5.3a	6.0	2
Mariner	6.7	6.7a	6.3a	6.6	3
MSUEB	7.0	7.0a	5.7a	6.6	3
Penncross	6.3	6.3	5.7a	6.1	2
Pennlinks	6.3	6.0	5.0	5.8	1
Pro/Cup	6.3	6.0	5.0	5.8	1
Providence	6.3	6.3	6.0a	6.2	2
Regent	7.0	7.0a	5.7a	6.6	3
Seaside	6.3	5.7	4.7	5.6	1
Southshore	6.7	6.3	6.0a	6.3	2
SR1020	7.0	6.7a	6.0a	6.6	3
Tendez	7.3	6.7a	5.7a	6.6	3
Trueline	6.0	5.7	5.3a	5.7	2
VAR Ws 42102	6.7	6.3	5.3a	6.1	2
MSD[3]	ns	1.3	1.9	0.8	

[1] Color rating was based on 1-9 scale, where 9 is the darkest green and 5 is the minimum acceptable turf color.

[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group (does not include overall mean).

[3] MSD is the minimum significant difference between means based on the Waller-Duncan *k*-ratio *t*-test (*k*-ratio=100). 'a' indicates entry was in the highest statistical group. 'ns' indicates means were not significancy based on ANOVA *F*-test.

Table 12. Turf performance index (TPI) summary for the 1993 NTEP sand-modified bentgrass trial at TAES-Dallas.1996.

Entry	Table 1	Table 2	Table 3	Table 4	Table 5	Table 6	Table 7	Table 8	Total	%[3]
Mariner	2	2	1	10	6	1	1	3	26	96.3
Southshore	2	2	2	10	6	1	1	2	26	96.3
Providence	2	2	2	9	6	1	1	2	25	92.6
Regent	0	2	2	10	6	1	1	3	25	92.6
18th Green	1	2	2	10	6	0	1	2	24	88.9
A-4	2	2	2	9	6	1	1	1	24	88.9
C & C	0	2	1	10	6	1	1	3	24	88.9
Cato	0	2	2	9	6	1	1	3	24	88.9
Century	0	2	1	10	6	1	1	3	24	88.9
DG-P	0	2	2	9	6	1	1	3	24	88.9
L-93	0	2	2	9	6	1	1	3	24	88.9
SR1020	0	2	2	9	6	1	1	3	24	88.9
Tendez	0	2	2	9	6	1	1	3	24	88.9
Trueline	0	2	2	10	6	1	1	2	24	89.9
VAR Ws 42102	0	2	2	10	6	1	1	2	24	88.9
Backspin	0	2	1	9	6	1	1	3	23	85.2
BAR As 493	0	2	2	9	6	1	1	2	23	85.2
Crenshaw	0	2	1	9	6	1	1	3	23	85.2
G-6	0	2	2	9	6	1	1	2	23	85.2
Imperial	0	2	2	9	6	0	1	3	23	85.2
ISI-Ap-89150	0	2	2	10	6	0	1	2	23	85.2
Pro/Cup	2	2	2	9	6	0	1	1	23	85.2
A-1	0	2	2	9	6	1	1	1	22	81.5
Dominant	0	2	2	9	6	1	1	1	22	81.5
G-2	0	2	2	9	6	1	1	1	22	81.5
MSUEB	0	2	1	9	6	0	1	3	22	81.5
Penncross	0	2	1	9	6	1	1	2	22	81.5
Pennlinks	0	2	2	9	6	1	1	1	22	81.5
Seaside	0	2	2	9	6	1	1	1	22	81.5
Lopez	0	2	1	9	6	0	1	2	21	77.8
# Observations	2	2	2	10	6	1	1	3	27	

[1] A maximum of 27 observations per entry are reported in tables 4 through 11.

[2] TPI is the turf performance index which is the number of times an entry was rated in the top statistical group (does not include overall mean).

[3]% = the frequency for which the entry was in the highest statistical group across all tests and based on the number of trials for which the entry was included in this document.

Appendix A

Measuring Population Changes in Interseeded Bentgrass Putting Greens by Electrophoresis

I. Yamamoto, R. H. White, and M. C. Engelke

ABSTRACT

A quick transition with minimal interruption of play is desirable when bentgrass putting greens are interseeded with new cultivars. Studies of physical and chemical practices have been conducted for this purpose; however, there is no simple method to measure the population shifts. To facilitate the area of study as well as to provide the scientific evidence of cultivar transition, we propose the use of an electrophoretic technique. Isoenzyme banding patterns of bulk leaf samples from an interseeded green were compared with those of proportional blends of two cultivars. The green's composition was estimated as a blend ratio of which isoenzyme phenotype was the most similar. Electrophoresis can be used as a simple technique for measuring population shifts of interseeded or initially blended greens.

INTRODUCTION

The high demand for bentgrasses for establishing putting greens and fairways, has resulted in the development of a large number of cultivars within the past 10 years. Some of these new cultivars were specifically developed for certain characteristics, such as disease resistance or drought/heat tolerance, and perform better than older cultivars under such conditions (Burton, 1992). In certain areas where existing putting greens have specific problems, renovation of the greens with newly improved cultivars is desirable. In the southern U.S., where 'Penncross' creeping bentgrass (*Agrostis palustris* Huds.) is used as the primary putting-green cultivar, for example, the introduction of a new creeping bentgrass cultivar which possesses heat and/or drought tolerance will enhance the turf performance and reduce the intensity of cultural practices.

The introduction of new cultivars to a golf course may require an extensive green renovation or new construction, the least preference for most of the 14,000 golf courses in the United States. Many of them could take advantage of the new cultivars if the introduction or conversion were achieved with minimal interruption of play. Interseeding of new cultivars onto the preexisting putting greens would make it possible. Unlike the establishment of new greens, interseeding is more complicated. Timing and rate of seeding, physical cultivations, chemical applications at the seeding, and managemental practices during the transition are some of the important areas of study to enhance the efficiency and success in the interseeding. To date, however, there is no simple method to measure the population shifts of an interseeded green. To facilitate this area of study and to provide the scientific evidence of cultivar transition, establishment of a quick, reliable, and economical method for monitoring population dynamics is necessary. The objective of this study was to identify population dynamics using the isoenzyme banding patterns obtained by the starch gel electrophoresis.

MATERIALS AND METHODS

'Crenshaw' creeping bentgrass, possessing a persistent root system and tolerates heat and drought (Engelke, et al., 1993), was used as an interseeding cultivar. The interseeding was conducted on an experimental Penncross putting green at Texas A&M Research Center, Dallas, TX (Site 1) in April 1995 and on a Penncross nursery at Dallas Country Club, Dallas, TX (Site 2) in Oct. 1995. The experimental design was a randomized complete block with split-block arrangement with three replications at each location. Factors in strips were chemical suppression treatments and mechanical disruption treatments. Plot size was 0.9 by 1.8 m. Three chemical treatments applied 72 h prior to seeding were: i) none; ii) cimectacarb (growth regulator), trinexapac-ethyl; and iii) glyphosate (herbicide), N-(phosphonomethyl)glycine. Mechanical treatments applied were: i) none; ii) vertical mowing; iii) Star-tines aerification[1]; and iv) core-tines aerification. Seed were mixed with a 24.5-Kg N ha^{-1} organic fertilizer (N-P-K = 6-0.9-0) and seeded by a drop-type spreader at 49 Kg ha^{-1}. The area was uniformly topdressed and regular mowing (at 5-mm height) was continued immediately after seeding. The area was maintained under putting green conditions: mowed five times per week; fertilized 33 Kg N ha^{-1} per month at Site 1 and 24.5 Kg N ha^{-1} per month at Site 2; irrigated and applied pesticides as needed. The experimental plots at Site 1 were not fertilized for 30 d after seeding.

Populations were examined 6 and 12 month after interseeding for Site 1 and 6 month after for Site 2. Direct sampling was conducted for Site 1 six month after interseeding and indirect method was used for other cases. In the direct method, leaf samples were directly clipped from each treatment plot with a pet trimmer and the clips were simultaneously collected by a handy vacuum cleaner. In the indirect method, a core sample (10-cm diam.) was taken from each of experimental plots, planted in a pot, and grown under greenhouse conditions for 3 to 4 weeks. Then plants were uniformly trimmed at 2.0 to 2.5-cm height, and 0.5 to 1-cm length leaves were clipped from the uniform canopy. The leaf samples were mixed well, and a 0.165 g of healthy leaf tissue (consisting of more than 500 leaves) was used for extraction in direct method. In indirect method, 0.33 g tissue was extracted to minimize any variation due to sampling vias by increasing the number of leaves. For standards, bulk leaf extracts from 100% Crenshaw and 100% Penncross were proportionally mixed at volume ratios of 0:100 to 100:0 at 5% increments in a laboratory. Leaf extracts were examined by horizontal starch gel electrophoresis described in Yamamoto and Duich (1994). The gel and electrode buffers were tris-citrate (pH 8.4) and lithium hydroxide-borate (pH 8.1). The gel was horizontally sliced into four slices, and the third slice was stained for phosphoglucose isomerase (PGI), of which effectiveness for bentgrass identification is reported (Yamamoto and Duich, 1994).

[1] A spike type light aerification.

RESULTS AND DISCUSSION

Standard Blends

Theoretically, the banding pattern obtained from a bulk sample represents the proportional blend of individual plant phenotypes (banding patterns) in the population. A difference in the frequency of each isoenzyme in the population, therefore, appears as a difference in the intensity of each band. Accordingly, when two cultivars are blended, the intensity differences in bands are proportional to the ratios of two cultivars.

Isoenzyme banding patterns of the standard blends showed gradual morphological changes along the ratios of two cultivars (Fig. 1). Penncross has five isoenzyme bands at PGI-2 region, and Crenshaw has 10, minimum. Only the bands at PGI-2 region, cytosolic bands, were examined since plastid bands at region-1 were more variable and probably affected by gel and electrophoretic conditions, age of sample materials, and possibly other environmental conditions such as fertilization (Yamamoto, 1990). When as small as a 5%-Crenshaw extract was mixed with Penncross, although it was very light intensity, band-1 of Crenshaw was detectable. On the other hand, discrimination of a 5%-Penncross mix from 100% Crenshaw was difficult since PGI-2 bands of Penncross were completely overlapped with those of Crenshaw. The slowest migrating band of Crenshaw, band-10, could be an effective indicator for determining whether Crenshaw contributed more than 25% to the population.

Population Shift in the Interseeded Green

Samples taken from Site 1, 6 and 12 month after interseeding were compared with 11 standard blends, consisting of 0 to 100% Crenshaw at 10% increments. A part of the results is shown in Fig. 2. The population changes in the interseeded plots were estimated based on the presence of Crenshaw specific isoenzyme bands and the intensity differences of the bands. At the first glance, we could estimate that Samples 3, 6, and 10 in Fig. 2 comprised more than 50% Crenshaw. Close examination and repeated tests using 50 to 100% standard blends revealed that the samples consisted approximately 80% Crenshaw. The proportion of Crenshaw in Samples 1, 2, 4, 5, 7, 8, 9, and 11 were determined as close to 20% but not exceed it since band-7, which was easily detectable in the standard blends of 20% or more Crenshaw, were not visible. The Crenshaw's bands completely masked the Penncross bands; therefore, determination of small proportion of Penncross in Crenshaw is more difficult than vice versa.

The results 12 months after interseeding were similar to those of 6 months, suggesting that the success of interseeding might be determined in the early stage of establishment. The percentage of seedling emergence and survival rate of young seedlings could be the essential factors for success in the interseeding. The composition of a population, however, will change after years depending on the environmental stresses, cultural practices, and genetic ability for the competition.

Samples taken from Site 2 six month after interseeding were compared with 11 standard blends, consisting of 100 to 0% Penncross at 10% increments (Fig. 3). A slight but detectable band-1 in all samples suggested that samples were not 100% Penncross. On the other hand, band-7, which was detectable in the standard blends of 10% or more Crenshaw, did not appear in any samples. Accordingly, we could conclude that Samples 1 through 12 had a similar composition of two cultivars, 90 to 95% Penncross and 10 to 5% Crenshaw. Regardless of either chemical or mechanical treatments, Crenshaw interseeding into Penncross putting green at Site 2 was not successful. Site 2 was a nursery green of a golf course, and the green was not intensively

managed like the experimental green at Site 1. Management program of the greens after interseeding might be another essential factor for the success in the interseeding.

CONCLUSIONS

By comparing the isoenzyme banding patterns obtained from interseeded greens with the standard extract blends, the population shifts between Penncross and Crenshaw were successfully determined. The electrophoretic technique could facilitate interseeding or competition studies by providing the scientific evidence of cultivar transition. The technique could be limited when isoenzyme phenotypes of two cultivars are the same or very similar. Banding patterns at PGI-2 were, however, reported as highly polymorphological in creeping bentgrasses (Yamamoto and Duich, 1994).

REFERENCES

Burton, G. W. 1992. Breeding improved turfgrasses. p. 759-76. *In* D. V. Waddington et al. (ed.) Turfgrass. Agronomy Monograph no. 32. ASA-CSSA-SSSA, Madison, WI.

Engelke, M. C., V. G. Lehman, W. R. Kneebone, P. F. Colbaugh, J. A. Reinert, and W. E. Knoop. 1993. 'Crenshaw' creeping bentgrass release documentation. *In* 1993 Annual research report: Concerning breeding and development of bentgrass. Texas A&M Res. Ctr. Dallas, TX.

Yamamoto, I. 1990. *Agrostis* cultivar identification and Penncross characterization by electrophoresis. M. S. thesis, Penn State Univ. University Park, PA.

Yamamoto, I., and J. M. Duich. 1994. Electrophoretic identification of cross-pollinated bentgrass species and cultivars. Crop Sci. 34: 792-98.

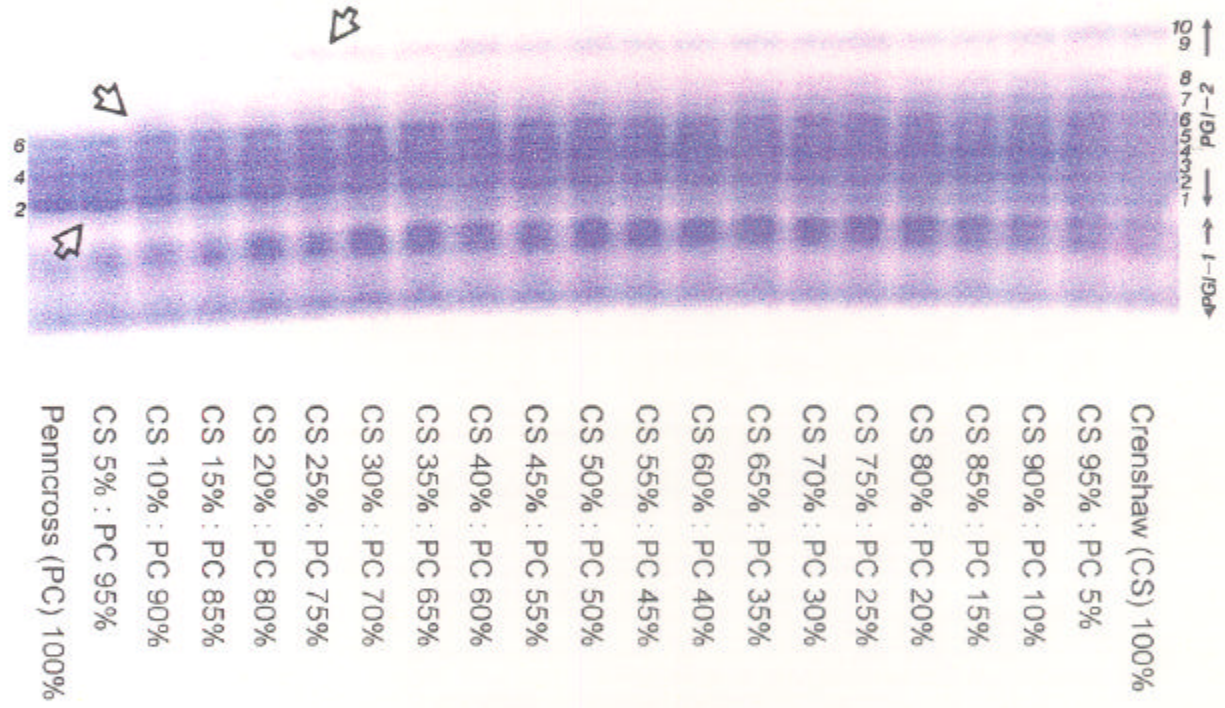

Fig. 1. PGI isoenzyme banding patterns: proportional extract mixes of Crenshaw and Penncross.

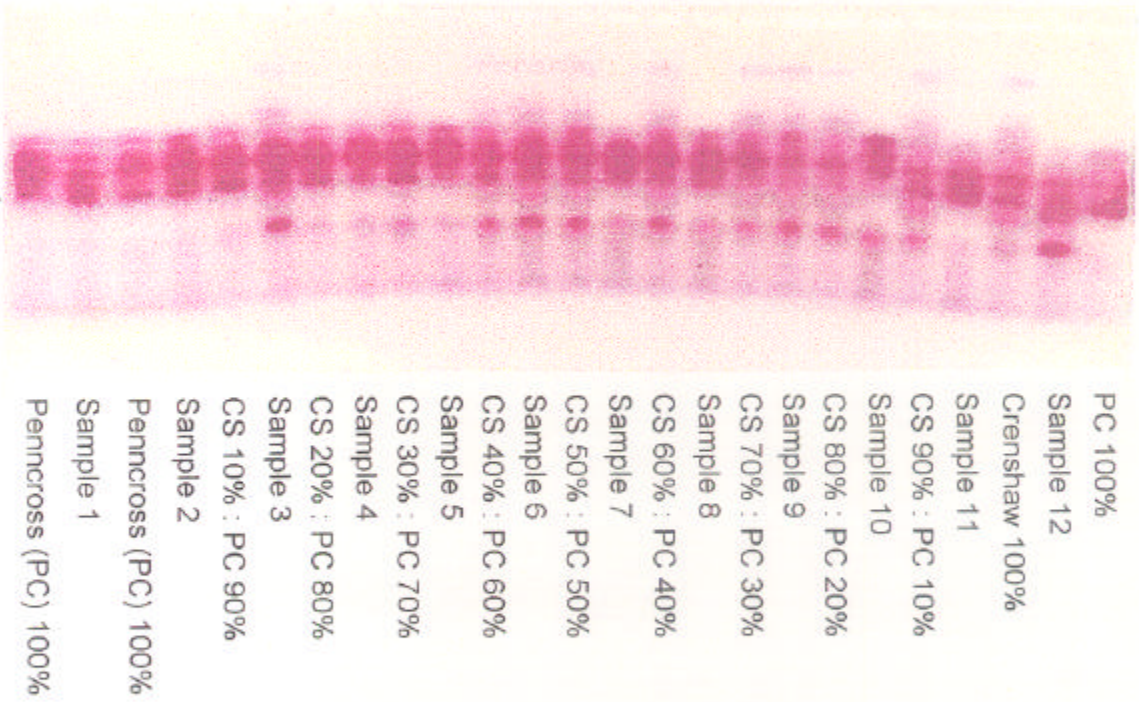

Fig. 2. PGI phenotype comparisons between standard blends and samples taken from Site 1 12 month after interseeding.

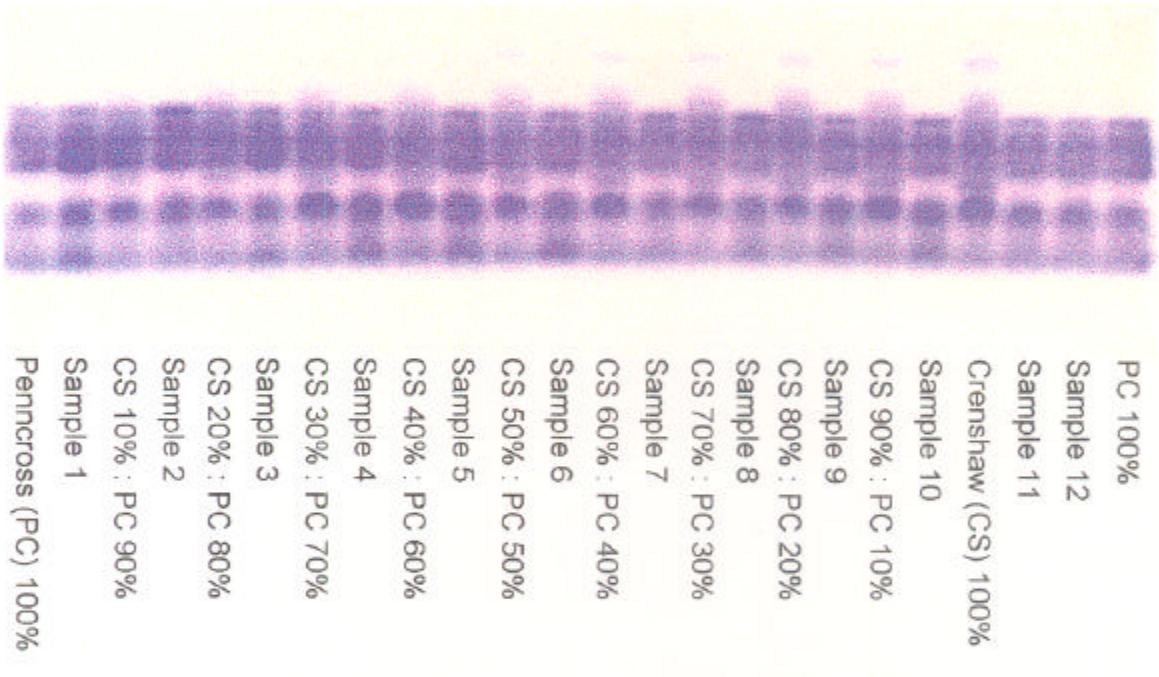

Fig. 3. PGI phenotype comparisons between standard blends and samples taken from Site 2 6 month after interseeding.