FIFTH
ANNUAL PROGRESS REPORT

concerning

BREEDING AND DEVELOPMENT OF BENTGRASS

Submitted By:

Dr. M. C. Engelke
Associate Professor
Turfgrass Breeding and Genetics
and
Ms. Virginia G. Lehman
Research Associate
Turfgrass Breeding and Genetics

Texas Agricultural Experiment Station - Dallas
Texas A&M University System

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BREEDING AND DEVELOPMENT OF BENTGRASS

EXECUTIVE SUMMARY

FIFTH ANNUAL BENTGRASS REPORT 1989

BREEDING AND DEVELOPMENT OF BENTGRASS

Principle Investigator: M. C. Engelke

Research Associate: V. G. Lehman

Research Period of This Report: November 1988 to November 1989

The bentgrass breeding program is entering its sixth year of funding by the USGA/GCSAA - Bentgrass Research, Inc. Considerable progress has been made these past 4 plus years with three synthetic populations being advanced to breeder/foundation fields in Oregon in January 1989. New crossing blocks and hybridization nurseries were established in Oregon in 1988/89 and will be used for extensive single- and polycross matings beginning in 1990.

Foundation fields of the three synthetics suffered severe winter damage in February 1989 resulting in poor seed production this year. Regardless, sufficient seed of Syn 1-88 was produced on an older planting and was entered in the NTEP Bentgrass Test for Modified Soils and has been planted at 16 locations in the United States. The NTEP Bentgrass Trial with a total of 20 entries was planted on 10 Oct. at TAES-Dallas on a modified green.

Syn3-88 and Syn4-88 failed to produce sufficient seed to enter at all the NTEP trial sites. However, we have contracted with five key locations across the United States to include both of these in the NTEP trials for comparative evaluation. Additional transplants of all three synthetics were replanted into the foundation fields in Oregon in October 1989.

Quality evaluations of Syn1-88, Syn3-88, and Syn4-88, tested at Augusta, GA and Dallas, Texas indicate significant differences in performance of the first products of the program. The synthetics are distinct from each other and from the commercially available varieties. Quality ratings by the USGA research group evaluations on 18 July indicate that the three varieties from the program were in the top performance grouping for that date. Phenotypic stability ranking of quality ratings by TAES researchers also indicates progress in the breeding of bentgrasses from this program for use in the Southern United States.

The flexible tube procedure for screening root characters of bentgrass germplasm was completed during 1989. Based on parent-progeny regression analysis, heritability of root extension is 0.76, with significant correlations between root extension and root number, and root number and root area. Heritability estimates for tiller number and tiller dry weights was estimated at 0.31 and 0.32, respectively. Field observations, completed in August 1989, of bentgrass genotypes indicated a significant correlation between root extension and drought resistance.

Assessment of genotype performance continues in the greenhouse, field, and laboratory, with continued screening of germplasm. Superior plants are continually being identified and recycled in the breeding program. Invaluable cooperation continues from Pickseed West, with Mr. Kent Wiley and Dr. Jerry Pepin.

FIFTH ANNUAL BENTGRASS REPORT 1989

M. C. Engelke and V. G. Lehman

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 is the fifth annual bentgrass report and summarizes activities for the period of 1 Nov. 1988 to 1 Nov. 1989. This report, in conjunction with the semiannual report of 1 May 1989, constitutes the FIFTH ANNUAL BENTGRASS REPORT. A total of $227,222 has been granted to this program. Present level of funding is $64,000 per annum. The primary objective of the project is to develop heat resistant bentgrasses with improved adaptation to natural environmental stresses.

II. PROFESSIONAL AND TECHNICAL SUPPORT

Virginia Lehman, Research Associate, and Mark McCormack, Technician, continue in their respective positions with the program. Both are continuing their pursuit of higher educational degrees.

III. IMPLEMENTATION

A. GERMPLASM ACQUISITION

INTRODUCTION: Genetic variability is essential for cultivar improvement. Genetic recombination through hybridization of selected plants with desirable genetic characters will result in the accumulation of several characters in improved varieties.

OBJECTIVE: Assemble and characterize bentgrass germplasm, and increase the frequency of desirable genetic traits in the gene pool.

PROGRESS: The current Bentgrass Germplasm collection contains 375 unique vegetative accessions, 270 advanced generation selections, and 70 seeded accessions. During 1988-89, 1500 seedlings were produced from each of three seed lots, Syn 1-88, Syn 3-88, and Syn 4-88 (see 3A.6) for recombination and foundation seed production, and transplanted to isolated production blocks in Oregon.

Seed generated from single-cross, selfs, and polycross hybridizations which were made in Oregon (1988, 89) and Texas (1989), were germinated in the greenhouse during Sept. 1989. Of 85 seed lots, several hundred progeny have germinated and are awaiting transplant for germplasm assessment. The initial test will be conducted using parent-progeny combinations to assess heat tolerance using plug paks.

B. GERMPLASM ASSESSMENT

INTRODUCTION: Evaluation of plant materials is necessary to determine which traits may be effectively included in a breeding program. The evaluations, which include intensive artificial screening programs, are conducted in three arenas: the greenhouse, laboratory, and field.

1. GREENHOUSE

a. RESPONSE TO HIGH SOIL TEMPERATURES

OBJECTIVE: Determine the response of commercial bentgrass cultivars to high soil temperatures and to determine which characters are most significant and heritable for genetic manipulation.

JUSTIFICATION: Evaluation of the relative heat resistance of the commercially available bentgrass cultivars should provide much needed information regarding cultivar performance in high temperature stress areas, and aid in identification of cultivars suited to such environments.

PROGRESS: Eight commercially available cultivars were transplanted to the heat bench. Following a 4 week acclimation, soil temperatures were gradually increased over 2 week period to impose stress. Two studies have been completed in the heat bench with the commercially available cultivars. After 3 weeks of elevated soil temperatures, the mean firing of the eight cultivars was 90% (Table 1). The decline in plant growth was almost twice as fast as the decline that occurred in a duplicate study in 1988. In this group of cultivars, the range in variation in heat resistance is narrow. 'Duchess', an A. tenuis species, has consistently greater leaf firing than the other cultivars.

FUTURE WORK: The results from the 1988 and 1989 heat bench studies are inconclusive regarding genetic heat resistance. Ongoing laboratory and field studies (Sections 2B and 3A.3) are being utilized in attempts to elucidate genetic variation among cultivars.

b. CHARACTERIZATION OF ROOTS

OBJECTIVE: Root characterization of 'Seaside' and Seaside- RHT bentgrass populations.

JUSTIFICATION: A root system with greater extension will allow the bentgrass plant to access moisture deeper in the soil profile, allowing the plant to avoid secondary, heat-induced drought stress.

PROGRESS: A study was initiated in Jan. 1989 with 10 parental clones, 5 selected for root heat tolerance and 5 random or unselected clones with 4 progeny of each, grown in 6 replications in flexible tubes. As was reported in the 1989 semiannual report, the heritability of maximum root extension was 0.76. Further analysis of the data revealed significant correlations between root extension and root number, and root number and root area (Table 2). Heritability estimates for tiller number and tiller dry weights was estimated at 0.31 and 0.32, respectively (Table 3).

FUTURE WORK: Heritability estimates were calculated on root and shoot characters, and with these results, expectations are good for genetic progress in tiller number and root characters through mass selection.

Selection of parents for root and shoot characters to be included in polycross plantings may be routinely screened through the flexible tube procedure for use in the breeding program. Specific polycross hybridization nurseries will be established in Oregon to increase gene frequencies for these traits.

2. LABORATORY

a. TISSUE TOLERANCE TO HIGH TEMPERATURES - THERMOSTABILITY

INTRODUCTION: The ability of a plant to survive high temperature stress consists of resistance to either primary or secondary heat stress. Primary stress is a direct injury to the membrane, with secondary injuries occurring as a result of a primary injury elsewhere. Cell membranes are the sites of much of the physio-chemical reactions necessary for plant growth and development. To evaluate the thermostability of cell membranes, leaf tissue is extracted from mature plants and submerged in a high temperature water bath for a prescribed time period. This procedure is utilized to determine the severity of membrane damage as it related to release of cell contents. The greater the release of cytoplasm, the higher the electroconductivity (EC), and the lower the heat tolerance.

OBJECTIVE: Determine if selection for root heat tolerance has associated heat tolerance in leaf tissue.

JUSTIFICATION: Selection of plant materials for increased heat tolerance in root systems may contribute genes for heat resistance in an additive fashion to new cultivars.

PROGRESS: A total of 70 clones each of Seaside and Seaside-RHT have been screened for shoot heat tolerance. A major data analysis effort will be conducted during the winter of 1989-90 to determine the effectiveness of the technique. Future screenings depend on the outcome of the analysis.

b. ROOT HEAT TOLERANCE SELECTION

OBJECTIVE: Develop a screening technique capable of screening large numbers of plant materials for heat tolerance.

JUSTIFICATION: Variation in heat resistance is well documented within a number of turfgrass species. The efforts to determine the differences are expensive in terms of necessary equipment, time, and limiting in the numbers of plants that may be evaluated. Furthermore, the evaluations are often complicated by interaction of heat and moisture stress.

PROGRESS: The procedure consists of placing plant materials in a prestress environment for 3-5 days of 100% humidity at 30-35 C with 12-hour photoperiods. Several preliminary experiments indicate that a 5-day pretreatment followed by water bath temperatures at 54-60 C for 30-35 minutes adequately stress the populations to define plants with and without heat tolerance. During Sept. 1989, replicated plantings of the commercially available bentgrass cultivars were submitted to the procedure at 60 C for 40 minutes. It will be necessary to repeat the experiment because of a possible complication with disease.

Proof of any screening technique is necessary to verify the validity of the work. The heat tolerance of some Kentucky bluegrass (KBG) cultivars is well documented in the literature. Consequently, certain varieties of KBG varieties were utilized to refine the technique, and to make comparisons with previously documented research.

Greenhouse trays (177 cm^2) were seeded at a rate of 0.75 kg are^{-1} with each of 9 cultivars of KBG in a peat-vermiculite potting media on 14 Mar. 1989. On 15 May, single seedlings of each cultivar were transplanted into 2.4 x 3.8 cm plug trays, with a cotton plug in the bottom of each cell, 45 cells per tray, of peat-vermiculite potting media. Each tray represented a replication. Each row was established to five seedlings of a single cultivar, with the nine cultivars randomly arranged across the tray. The plants were maintained in a greenhouse at a cutting height of 5 cm., fertilized with 20-20-20 soluble fertilizer at a rate of 0.5 kg are^{-1}, split into 2 applications per month, and irrigated to prevent stress. On 18 June, the plants were drenched with ethazol to avoid pythium, placed in 28 x 38 x 15 cm clear covered trays, and placed in a growth room. Approximately 100% humidity was maintained by suspending the plants on racks above water, 1.5 cm in depth. An application of chlorothalonil was made on 19 June at label rates for prevention of Helminthosporium leaf spot. Photosynthetically active radiation at plant height was 120 $mols/s^{-1}/m^{-1}$, supplied by a metal halide lamp. During the 12 hour light period, temperature ranged from 35.7-41.3 C, with a mid-day mean of 36.8 C. The 12 hour dark period midpoint temperature mean was 30.2 C. The trays were removed at 1 hour intervals for water bath treatments.

The trays were paired into groups of 2, and placed in a circulating water bath, accurate to within 0.1 C. Trays were held at each temperature of 57, 58, 59, and 60 C. The subterranean plant parts were submerged to within 4 mm of crown level for 30 minutes. After treatment, the plants were placed in 22 C water to lower the soil temperature, and returned to the greenhouse. Two trays, designated controls, were placed in water at 22 C for 30 minutes, and returned to the greenhouse.

Significant differences existed among vigor of KBG cultivars at 8 and 14 days after treatment in the water bath (Table 4). The cultivar x temperature interaction was non-significant for vigor on either date, so means presented are averaged across 4 temperatures.

Spearman's rank correlation indicated no differences in the rank of mean tiller number between the heat stressed plants and those not heat stressed when evaluated at 14 days after water bath treatments.

The selection technique described here effectively separated cultivar response to heat and environmental moisture stress. The technique is inexpensive in terms of equipment, requiring a temperature controlled environment and a water bath capable of accommodating tray size, with minimal temperature fluctuations. Two hundred plants may be accommodated in an area of 26.7 x 53.3 cm, satisfying the demand for capability to screen large numbers of plants.

FUTURE WORK: This procedure holds more promise in evaluation of plant materials than many other techniques. This technique is being refined and will be submitted for publication in a referred journal when fully substantiated.

3. FIELD-AGRONOMIC ASSESSMENT

INTRODUCTION: The phenotypic expression (P) or observed plant performance is the product of a plant's genetic constitution (G), as it grows in a specific environment (E). Simplified, the expression is $P = G + E$. As the environment changes, the expression of a plant may also change. However, plant performance may also include an interaction between the environment and the genotype, and the equation is represented as $P = G + E + G \times E$. If the plant performs consistently across environments, then P is primarily controlled by G. However, P is often not consistent across environments. When such occurs, another element of the equation becomes important, i.e., the interaction of the G with the E. The magnitude of the G x E requires extensive testing in several environments to interpret, and the purpose of the breeding program is to strengthen the genetic component (G) of the interaction, and to reduce the contribution of the environment in the phenotypic expression. The stronger the G component the higher the heritability (H) of the trait. Accurately predicting H is imperative in defining a strong breeding objective.

a. OBJECTIVE: Identify genotypes with superior agronomic traits on a sand green with management similar to a putting green.

JUSTIFICATION: Evaluation of plant materials on a sand green identifies superior genotypes under a given environment.

PROGRESS: As reported in the 1989 semiannual report, parental materials tested from 1985 to 1988 were utilized in production of 3 potential varieties, Syn 1-88, Syn 3-88, and Syn 4-88. For comparison purposes, variety evaluation trials were seeded on 31 Oct. 1988 with 9 commercial varieties at Dallas. A similar study was seeded at Augusta National Golf Club, Augusta, GA in Nov. with the cooperation of Dr. Gil Landry, Extension Specialist, University of Georgia. The varieties were seeded in 1.2 x 1.8 m plots at a seeding rate of 0.45 kg/ha. Mowing height was established at 0.3 cm in June, and was retained at that height through the summer. Total N was applied at rate of 3.6 kg/ 93 m^2 through Sept. 1989. Significant differences existed in percent stand as establishment occurred, and was discussed in the 1989 semiannual report. The cultivars are exhibiting a wide range in quality (Table 5, Figures 1 and 2). Visitors to the Bentgrass Breeding Program are invited to independently rate the evaluation, and are also finding significant differences in quality (Table 6a, 6b). On 18 July 1989, the program was fortunate to host the USGA summer meetings, and all participants were invited to evaluate the plots and the progress of the bentgrass breeding program. The quality rating of the different cultivars was dependent upon two factors, the evaluator and the cultivar. The ratings by the 22 evaluators indicated that Syn 1-88, Syn 3-88, and Syn 4-88 are superior to some of the cultivars currently on the market (Table 7). The varieties are also exhibiting significant differences in Georgia (Table 8).

b. OBJECTIVE: Identify creeping bentgrass genotypes adapted to native Texas soils and fairway conditions.

JUSTIFICATION: Creeping bentgrass provides a high quality, fine textured turf with the potential for 12 months active growth, since it does not undergo low temperature discoloration or dormancy in much of the Southern United States.

PROGRESS: Plants were placed in the field in May 1986. Considerable data has been accumulated on this planting (see previous reports). During Jan. 1989, Mr. Jerry Fine, Technician I on the turfgrass project, constructed a traffic machine to stress the germplasm introduction nursery and the fairway planting. The "Fine Traffic Machine" consists of two rollers rotating at slightly different speeds (17% differential) and embedded with golf spikes (Figure 3). The differential slip creates a tearing action with the spikes. The rollers impose compaction. The plants are being routinely traversed three times per week, with periodic quality ratings to assess performance.

FUTURE WORK: In consideration of concerns regarding traffic during the germplasm evaluation phase, the trafficking of plants has become a routine procedure.

c. OBJECTIVE: Identify between and within cultivar variation of commercially available bentgrasses.

JUSTIFICATION: After exposure to high soil temperatures for an extended time period, the surviving plants of the different cultivars began to exhibit variation in plant type. Definition of the plant type of the survivors may aid in selection of heat tolerant genotypes.

PROGRESS: Tiller number per core was counted and leaf blade widths measured from these plants during October 1989. Analysis of this information will be conducted to determine if shifts in plant morphology have occurred in response to selection pressure.

FUTURE WORK: Evaluation of these plants in the field is continuing. Additional stresses will be applied to distinguish superior plant types in this collection.

d. OBJECTIVES: Evaluate the effectiveness of the greenhouse flexible tube screening procedure for root extension and distribution compared to plant persistence under field conditions.

JUSTIFICATION: Flexible tubes are an effective tool to characterize individual plant roots. For this approach to be useful in identifying plants with more extensive root systems, it is necessary to determine the correlation of field and greenhouse performance.

PROGRESS: Significant correlations were determined between field and greenhouse procedures (Annual 1988), providing confidence in the greenhouse procedure. In Aug. 1989, root extension and volume were sampled from the 13 clones in Turfgrass Root Investigation Facility. On 28 Aug., experiments were initiated to determine the performance of genotypes under water stress. Leaf canopy temperatures were determined with an infrared gun with simultaneous net radiometer readings. A hydraulic press was used to determine leaf water potentials. Estimates of percent permanent damage were made by visual observation.

The genotypes varied in root extension (Table 9), and in the percent permanent canopy damage (Figure 4a, 4b). Spearman's rank correlation between root extension, ranked from highest to lowest, and percent damage, ranked from lowest to highest, was significant (r^s=0.63, p=0.05). Extensive analysis of data remains to be done, however, the information gained from this study indicates that root extension is correlated with drought avoidance. Coupled with the high heritability value for root extension, rapid progress may be made in breeding for bentgrass root systems.

FUTURE WORK: The heritability value is predicated upon a value in the equation for the environment (H=G/P when P=G+E+GxE). A major factor that should be considered is the impact of mowing height upon root extension, and how the root systems and associated heritabilities respond. The major use of the flexible tube system will be to screen germplasm and utilize the germplasm in the breeding program to produce varieties with improved root extension.

e. OBJECTIVE: Characterize new bentgrass accessions in Germplasm Introduction Nursery (GPIN).

JUSTIFICATION: The GPIN serves to screen and eliminate the less desirable bentgrass accessions from further, expensive testing.

PROGRESS: Evaluation of this nursery is an ongoing process. Thirty of the superior genotypes were sent to Oregon in Jan. 1989, for spring planting. The plants did not flower during 1989, but should produce inflorescences in 1990. Of the 30 plants, three clones remained in the highest performance group during 1989. A different grouping of 19 plants was identified with high quality during 1989, and will be considered for further evaluation. The shifts in quality emphasize the importance of long term field evaluations.

f. OBJECTIVE: Produce seed of three synthetic varieties, Syn 1-88, Syn 3-88, and Syn 4-88.

JUSTIFICATION: Approximately 8 pounds of seed was needed for entry into the 1989 NTEP Bentgrass Evaluation.

PROGRESS: As related in the 1989 semiannual report, 1500 plants of each of the three synthetics were transplanted into Oregon. The unusually severe winter was destructive to the plantings, despite the construction of cold frames by our cooperators with Pickseed West. As of 26 May 1989, approximately 700 plants had survived the winter in each synthetic and were well established.

FUTURE WORK: An additional 700 plants had been established in the greenhouse of each of the three synthetics, and were transplanted to Oregon during October 1989.

g. OBJECTIVE: Participate in the NTEP Bentgrass Evaluation, with planting of the commercially available bentgrass varieties under both greens and fairway conditions.

JUSTIFICATION: This evaluation will compare performance of the commercially available bentgrasses, including Syn 1-88, at all locations of the modified greens test. Mr. Kevin Morris, National Director NTEP, indicated the modified greens test will be planted at 16 locations in the United States. Syn 3-88 and Syn 4-88 will be planted at five locations of the modified greens test. The NTEP modified greens test will be planted at TAES-Dallas and at Banyan Golf Club, West Palm, Florida. The NTEP bentgrass fairway evaluation will be planted at Dallas on native Blackland soils.

PROGRESS: The first green built by Bentgrass Research Inc. has been renovated, including removal of plant material, methyl bromide fumigation, and resurfacing. The area was planted on 10 Oct. to the modified greens test (Figure 5). The fairway test is scheduled for planting on 1 Nov.

FUTURE WORK: The Florida planting is targeted for 13 Nov. 1989 in cooperation with Mr. Dan Jones, Superintendent, and Mr. J. J. Murray, NTEP technical coordinator now living in Tampa, FL. Notes will be taken on establishment rates, and periodically, on quality thereafter.

ACKNOWLEDGMENT. This research, as previously indicated, is conducted under a grant through the USGA/GCSAA Research Committee. In addition to the excellent financial support provided by this committee, a local group, Bentgrass Research Inc., has also provided $20,000 per year in financial support through USGA, as well as considerable support in constructing research greens and obtaining turf equipment. The various supporters of BRI for 1989 are listed in Table 10. Their support, with the USGA/GCSAA committee, is duly recognized as greatly appreciated. Thanks so much for your faith and continued support.

Table 1. Percent firing of eight bentgrass cultivars exposed to high soil temperatures in a greenhouse bench, 1989.

Cultivar	Week 1	Week 2	Week 3
	% Firing		
Cobra	6.3 abc*	37.1†ns	89.7 ab*
Duchess	17.8 ab	52.1	99.0 a
Emerald	4.7 c	20.2	90.2 ab
National	25.2 a	53.8	96.5 ab
Penncross	6.3 bc	20.9	84.0 b
Penneagle	3.3 c	23.4	81.3 b
Pennlinks	11.8 abc	37.9	97.7 a
Prominent	21.0 a	42.1	83.7 a

*F protected LSD (p=0.06).
†ns = non-significant.

Table 2. Correlation coefficients of selected shoot and root characters of bentgrass in flexible tubes, spring 1989.

Character	Root Number	Tiller Number	Tiller Weight	Root Area
Root extension	0.58**	0.06	0.14	0.09
Root number		0.24	0.37**	0.49**
Tiller number			0.76**	0.32**
Tiller weight				0.33**

** Correlation coefficients are significantly different from 0 at $P \leq 0.01$. Computed using replication means for progeny (N=240) and parent values of each replication (N=60).

Table 3. Tiller number, dry weights at harvest, and cummulative clipping weight of 10 bentgrass parental clones and 24 progeny of each in flexible tubes.

Clone	Tillers		Tiller dry weight		Clipping weight	
	Parent	Progeny	Parent	Progeny	Parent	Progeny
			mg			
503A	43.7	38.2	42.4	34.0	16.1	12.2
404A	24.9	35.6	24.1	33.5	10.9	13.9
505A	35.7	31.5	32.0	29.7	11.6	10.8
304R	32.2	29.8	27.2	28.5	11.0	10.9
401R	38.8	32.2	29.5	27.1	12.0	11.4
307A	32.8	28.8	23.7	27.4	10.2	10.1
604R	34.4	26.4	28.1	26.8	13.5	9.6
703A	18.1	24.3	23.7	22.4	8.5	8.7
204R	26.3	22.8	19.2	20.3	9.7	7.5
2735	46.8	23.0	41.5	21.0	10.5	8.0
LSD†	5.7	10.0	6.4	10.7	2.9	3.5
h^2‡	0.31		0.32		0.19	

†F protected LSD (P=0.05).
‡estimated narrow-sense heritability.

Table 4. Mean vigor rating and tiller number of nine Kentucky bluegrass cultivars after heat stress tests, 1989.

Cultivar	Vigor		Tillers	
	30 June	6 July	heat stressed	non-stressed
Midnight	4.9 a*	4.50 a	5.8 a[1]	8.5 a[1]
Adelphi	4.7 a	3.83 ab	4.9 ab	6.3 abc
Merion	4.5 ab	3.75 b	4.2 bcd	7.7 ab
Wabash	4.4 ab	3.85 ab	4.1 bcd	6.9 abc
Bronco	4.2 abc	3.55 b	3.7 cd	6.3 abc
America	3.9 bc	3.35 b	5.0 ab	7.4 ab
Huntsville	3.8 bc	3.60 b	3.2 d	4.6 c
Nugget	3.7 cd	3.60 b	4.4 bc	7.3 ab
Fylking	3.0 d	2.63 c	3.4 cd	5.9 bc

*Means within the same column followed by the same letter are not significantly different using the Waller-Duncan multiple comparison procedure (k ratio=100).
[1]Counted 7 July 1989.

Table 5. Quality ratings of 3 experimental varieties and 9 cultivars of creeping bentgrass, TAES-Dallas, 1989, by TAES researchers.

Cultivar	28 Jan	29 Jan	30 Mar	27 Apr	11 Jun	28 Jun	21 Jul	22 Aug	26 Sept	Phenotypic[1] Stability
	Quality									#
Syn3-88	7.3 a*	7.3 a	7.5 a	7.5 a	7.5 a	8.0 a	6.8 a	6.8 a	6.1 abc	9
Syn1-88	6.8 a	7.8 a	5.3 bcd	3.5 ef	3.5 ef	5.5 de	4.3 de	5.9 ab	7.1 a	4
Penncross	6.8 a	6.8 a	5.3 bcd	4.5 de	4.5 de	4.8 ef	4.0 e	3.3 c-e	4.5 bcd	2
SR1019	6.0 ab	7.3 a	5.5 bc	6.0 bc	6.0 bc	7.8 ab	5.5 bc	5.8 ab	5.4 a-d	5
SR1020	5.0 b	6.3 ab	5.8 ab	7.0 ab	7.0 ab	8.3 a	6.3 ab	5.0 a-d	4.8 bcd	7
PSU126	5.0 bc	5.8 ab	5.3 b-d	5.5 cd	5.5 cd	6.8 bc	5.0 cd	4.5 b-e	5.9 abc	2
National	4.8 bc	6.0 ab	3.5 de	3.0 fg	3.0 fg	3.5 gh	3.5 e	4.8 a-e	5.9 abc	3
Cobra	4.5 bc	6.3 ab	5.3 bcd	5.3 cd	5.3 cd	6.0 cd	5.0 cd	4.9 a-e	5.6 a-d	3
Southshore	4.5 bc	6.0 ab	5.3 bcd	4.5 de	4.5 de	4.3 fgh	4.0 e	2.8 e	3.5 d	0
Seaside	4.5 bc	6.3 ab	3.3 e	2.0 g	2.0 g	3.3 h	2.5 f	3.1 de	4.1 cd	1
Syn4-88	4.25 c	6.8 a	6.8 ab	7.0 ab	7.0 ab	8.5 a	6.3 ab	6.3 ab	6.5 ab	8
Putter	3.5 c	4.5 b	3.8 cde	3.5 ef	3.5 ef	4.5 efg	5.3 c	5.4 abc	5.3 a-d	2

*Means within a column followed by the same letter are not significantly different using the Waller-Duncan multiple comparison procedure (K ratio=100). Rated on a scale of 1-9 with 9 = best.

[1]Phenotypic stability = number of occurrences a genotype was in top quality group for each date.

Table 6a. Quality ratings of 3 experimental varieties and 9 cultivars of creeping bentgrass, TAES-Dallas, 1989, by independent evaluators.

Cultivar	Evaluator SG	RH	RH	SO	RW	DH	SM	WT	MM	Phenotypic[1] Stability
	Date 3-1	3-29	3-30	4-3	4-4	4-7	5-31	6-20	6-20	#
	Quality									
Syn 3-88	4.5 cd*	6.5 a	7.5 a	5.6 ab	7.0 ab	7.8 a	8.0 a	7.7 a	7.8 a	8
Syn 1-88	7.3 a	5.3 ab	5.3 de	5.6 ab	6.5 abc	6.0 cd	3.8 de	7.2 a	6.0 e	5
Penncross	6.8 a	5.8 ab	6.3 a cd	5.9 a	6.0 abc	6.8 abc	5.0 cd	7.3 a	6.4 cde	7
SR1019	4.5 cd	6.0 ab	6.8 ab	5.3 ab	6.3 abc	7.0 abc	7.3 ab	7.2 a	7.1 a-d	8
SR1020	6.0 ab	5.5 abc	6.3 bcd	5.8 ab	5.8 bcd	7.5 ab	7.8 ab	7.5 a	7.3 abc	7
PSU126	3.5 de	5.0 bc	5.5 cde	4.8 ab	5.0 cde	6.5 abc	6.3 bc	7.1 a	7.4 ab	4
National	5.0 bc	3.3 d	4.0 f	5.0 ab	4.3 de	6.0 cd	4.5 d	7.4 a	4.9 f	2
Cobra	4.3 cd	5.0 bc	5.3 de	5.0 ab	5.3 cde	6.8 abc	6.3 bc	7.7 a	6.8 b-e	3
Southshore	4.0 cd	5.0 bc	6.5 abc	5.4 ab	5.8 bcd	6.3 bc	4.5 d	7.3 a	6.3 de	3
Seaside	3.5 de	3.5 d	4.0 f	4.6 ab	3.8 e	6.5 abc	2.8 ef	7.0 a	4.5 f	3
Syn 4-88	3.8 cd	6.0 ab	6.8 ab	5.3 ab	7.5 a	7.3 abc	7.0 ab	7.7 a	8.0 a	8
Putter	2.3 e	4.3 cd	5.0 ef	4.3 b	1.0 f	4.8 d	2.0 f	7.3 a	7.8 a	2

*Means within a column followed by the same letter are not significantly different using the Waller-Duncan multiple comparison procature (K ratio = 100). Rated on a scale of 1-9 with 9 = best.

[1]Phenotypic Stability = number of occurrences a genotype was in top quality group for each date.

Table 6b. Quality ratings of 3 experimental varieties and 9 cultivars of creeping bentgrass, TAES-Dallas 1989, by independent evaluators.

Cultivar	Evaluator										Phenotypic[1] Stability
	PM	DN	TD	BC	KS	DD	SS	JB	WB	MS	
	Date										#
	7-12	7-12	8-27	9-8	9-8	9-8	9-8	10-4	10-4	10-4	
Syn 3-88	6.8 ab*	8.0 a	3.3 cd	8.0 ab	8.0 ab	8.0 a	7.5 a	3.8 e	3.0 bc	5.3 bc	6
Syn 1-88	5.1 def	5.5 d	4.3 abc	8.3 ab	8.3 ab	8.0 a	8.3 a	7.8 a	6.8 a	7.8 a	8
Penncross	4.9 ef	5.5 d	4.3 abc	8.0 ab	8.0 ab	7.0 a	7.3 a	5.5 b-e	4.5 abc	6.0 abc	7
SR1019	5.6 cde	6.5 c	3.5 bcd	8.3 ab	8.3 ab	7.0 a	7.5 a	4.5 cde	2.8 bc	5.8 abc	4
SR1020	6.3 abc	7.0 bc	2.8 d	8.5 a	8.5 a	7.8 a	7.5 a	4.0 de	1.8 c	4.5 c	5
PSU 126	6.0 a-d	6.8 c	3.8 a-d	8.0 ab	8.0 ab	7.5 a	7.0 a	5.8 bcd	4.3 abc	6.3 abc	8
National	5.1 def	4.8 de	4.8 ab	8.0 ab	8.0 ab	8.0 a	8.5 a	7.3 ab	6.5 a	7.3 ab	8
Cobra	4.9 ef	5.5 d	3.8 a-d	8.3 ab	8.3 ab	7.3 a	7.3 a	5.3 cde	4.3 abc	5.5 bc	6
~~Southshore~~	~~5.8 b-e~~	~~5.5 d~~	~~4.3 abc~~	~~7.3 b~~	~~7.3 b~~	~~7.3 a~~	~~7.3 a~~	~~5.5 b-e~~	~~3.8 abc~~	~~5.8 abc~~	5
Seaside	3.0 g	4.3 e	5.0 a	7.3 b	7.3 b	7.0 a	7.8 a	6.0 abc	5.3 ab	7.0 ab	6
Syn 4-88	7.0 a	7.8 ab	3.0 cd	8.5 a	8.5 a	8.0 a	7.3 a	5.3 cde	4.8 abc	6.8 ab	8
Putter	4.3 g	6.8 c	3.3 cd	8.5 a	8.5 a	8.0 a	8.3 a	5.5 b-e	4.0 abc	6.8 ab	6

*Means within a column followed by the same letter are not significantly different using the Waller-Duncan multiple comparison procedure (K ratio = 100). Rated on a scale of 1-9 with 9 = best.

[1]Phenotypic Stability = number of occurrences a genotype was in top quality group for each date.

Table 7. Mean quality ratings of 3 experimental varieties and 9 cultivars of creeping bentgrass, TAES-Dallas, 1989, by 22 participants in the USGA summer research meetings.

Cultivar	Rating
Syn 3-88	5.7 bcd*
Syn 1-88	5.8 bc
Penncross	5.1 ef
SR1019	4.8 f
SR1020	5.6 cd
PSU126	5.4 de
National	5.3 de
Cobra	5.4 de
Southshore	5.1 ef
Seaside	3.9 g
Syn 4-88	6.7 a
Putter	6.0 b

*Means followed by the same letter are not significantly different using the Waller-Duncan multiple comparison procedure (K ratio = 100). Rated on a scale of 1-9 with 9 = best.

Table 8. Mean quality ratings of 3 experimental varieties and 7 cultivars of creeping bentgrass, Augusta, GA, 1989.

	Quality Rating				Density
Cultivar	5 July	30 Aug.	27 Sept.	Mean	27 Sept.
Syn 3-88	7.0 ab*	7.0 a	6.0 a	6.7 a	6.7 a
Syn 1-88	5.0 de	5.0 bcd	4.8 cd	4.9 c	4.7 c
Penncross	5.0 de	4.8 bcd	4.7 cd	4.8 cd	4.2 cd
SR1019	6.3 bc	5.5 bc	5.0 bc	5.6 b	4.8 c
SR1020	7.5 a	5.7 b	5.5 ab	6.2 a	5.7 b
PSU126	4.8 e	4.7 cd	4.7 cd	4.7 cd	4.8 c
Cobra	4.8	4.8 bcd	4.3 de	4.7 cd	4.2 cd
Seaside	5.0 de	4.3 d	3.8 e	4.4 d	3.7 d
Syn 4-88	6.7 abc	5.2 bcd	4.7 cd	5.5 b	4.5 c
Putter	5.8 cd	4.3 d	4.5 cd	4.9 cd	4.2 cd

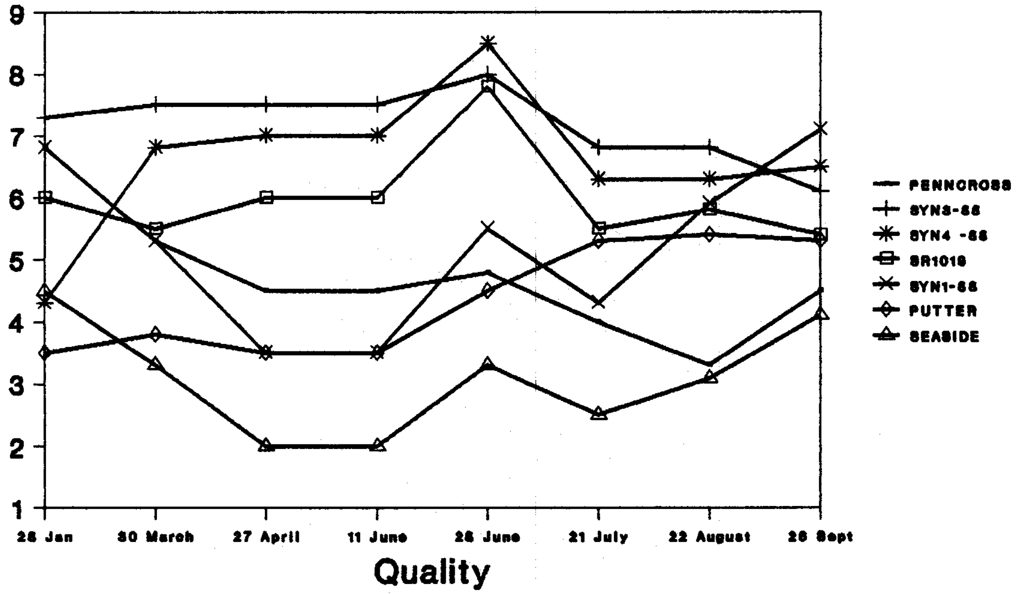
*F protected LSD ($p \leq 0.05$).

Table 9. Percent permanent damage assessed by visual observation of firing as a result of water stress and maximum root extension of thirteen bentgrass clones, August 1989 from TRIF.

Clone	Damage %	Damage Rank	Root Extension cm	Extension Rank
503A	74.6 a*	13	23.6 cd	12
401R	70.1 ab	12	26.1 abc	19
107R	67.2 ab	11	28.1 abc	7
304R	67.2 ab	10	15.8 d	13
2735	66.6 abc	9	24.9 bc	10
502A	63.6 a-d	8	33.7 a	1
701R	61.7 a-d	7	24.8 bc	11
505A	57.6 bcd	6	27.8 abc	8
404A	52.8 cd	5	31.4 ab	4
604R	51.9 d	4	32.7 a	2
703A	25.4 e	3	29.8 abc	5
204R	22.6 e	2	29.3 abc	6
307A	19.4 e	1	32.1 ab	3

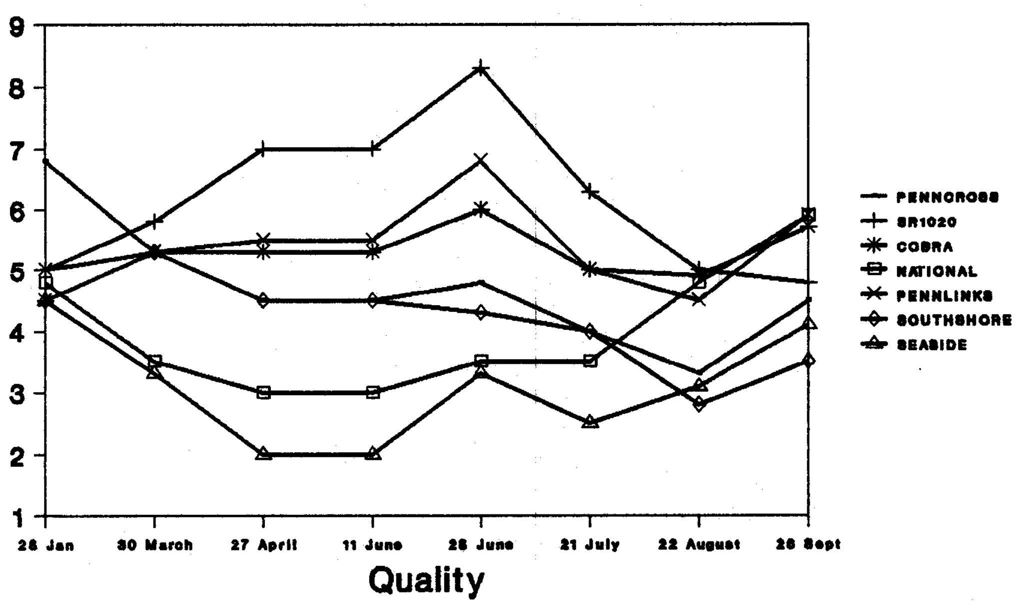
*F protected LSD ($p \leq 0.05$).

Figure 1. Bentgrass Variety Trial
USGA Modified Soil Green
TAES-DALLAS (1989)



Established 31 October 1988

Figure 2. Bentgrass Variety Trial
USGA Modified Soil Green
TAES - DALLAS (1989)



Established 31 October 1988

Figure 3. Traffic machine constructed by Mr. Jerry Fine to impose stress upon bentgrass field plantings.

Figure 4a. Bentgrass clones in the Turfgrass Research Root Investigation Facility (TRIF) just beginning to show differential response to drought stress.

Figure 4b. Bentgrass clones in TRIF demonstrating differential drought resistance.

Figure 5. Planting the NTEP bentgrass greens trial on a modified soil base at TAES-Dallas.

APPENDIX

TAES

TEXAS A&M UNIVERSITY
RESEARCH AND EXTENSION CENTER AT DALLAS
The Texas Agricultural Experiment Station

17360 Coit Road Dallas, Texas 75252-6599 PHONE (214) 231-5362

August 1, 1989

Mr. Bill Bengeyfield
Box 3375
Tustin, CA 92681

Dear Bill:

It was a pleasure having the USGA research group tour our research facilities. During your afternoon session on Tuesday, it was mentioned that funds are available by request in the cultivar evaluation fund for our varietal research cooperators. Dr. Gil Landry (See attached release form.) established a trial at Augusta National Golf Club last fall which included 3 of our bentgrass synthetics. Data from this planting was included in the summer report distributed at our field tour. It would be appreciated if Dr. Landry would be reimbursed at the agreed upon rate of $300 per variety, for a total of $900. Dr. Landry's address is listed below.

Dr. Gil Landry
Extension Turf Specialist
Soil Test and Plant Analysis Laboratory
2400 College Station Road
Athens, GA 30601

If there is any question regarding this request, please contact me, or, Dr. Engelke will be back from Japan on August 11.

Sincerely,

Virginia Lehman

V. Lehman
Research Associate
Turfgrass Breeding/Genetics

VL/bh

cc: M. C. Engelke

Las Colinas
SPORTS CLUB

INTER OFFICE MEMORANDUM

TO: Dr. M. C. Engelke

FROM: Tom A. Diamond

DATE: October 24, 1989

SUBJECT:

As per your request we are enclosing list of all participants for the Bentgrass Research Inc. tournament.

Dallas ATheltic Club

Indian Creek Golf Course

Dallas Country Club

Stonebriar Country CLub

Bent Tree Country CLub

Hot Springs Village REsort

Northwood Country Club

Colonial Country CLub

Four Seasons Resort and Club

Preston Trails Country Club

Columbian Country Club

Royal Oaks Country Club

Bear Creek Golf Course

Sports Turf Supply

Jacobson Turf

Goldthwaites of Texas

Chemical and Turf Specialty Co

Watson Distributing Company

Paul Cato Jr.