SIXTH YEAR

FINAL REPORT

concerning

PHYSIOLOGICAL INVESTIGATIONS

in

DEVELOPING WATER CONSERVING MINIMAL MAINTENANCE TURFGRASSES AND CULTURAL SYSTEMS

Submitted by:

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I. INTRODUCTION

The project on Developing Water Conserving, Minimal Maintenance Turfgrasses and Cultural Systems was funded for only six years of the original signed 10-year contract and master plan of research objectives. Thus, this is the final annual report. The progress and accomplishments during this six years have been personally quite rewarding for those of us involved in the research.

It is encouraging to note that some of the turfgrass breeders are starting to utilize the concepts we developed as well as the specific screening techniques. For example, Dr. Taliaferro is considering shifting his emphasis of bermudagrass breeding from enhanced rooting to improved dehydration tolerance/hardiness. Dr. Baltensperger at New Mexico State entered a set of his most advanced bermudagrass selections in our drought resistance study the past two summers with very positive results and has now submitted a set of selections for assessment of evapotranspiration rates at College Station, Texas. Similarly, we are working with Dr. Engelke of the Dallas Center on characterizations of four zoysiagrass and three St. Augustinegrass selections in terms of dehydration avoidance and drought resistance. Drs. Baltensperger and Riordan are following the canopy resistance-leaf area concept in selection for low water use rates.

In terms of the major research objectives: (A) We were successful in completing the first research objective of developing concepts that will assist the breeder in plant selection criteria and cultural systems to Minimize Water Use Rates, (B) In the area of Enhanced Rooting and Water Absorption, we made excellent progress including pioneering studies in the area of root hair characterizations; but at a much slower rate than originally planned due to the nature of the studies involved, (C) In the area of Improved Drought Resistance, the progress made to date has been excellent; we are well advanced in completing the research on warm-season turfgrasses and were ready to initiate mechanistic studies on the cool-season turfgrass species, (D) In the fourth area regarding the Mechanistic Basis of Minimal Maintenance Turfgrasses, we have some very excellent leads in the area of carbohydrate partitioning and were pursuing these in detail utilizing radioisotope studies, (E) Finally, in the area of Improved Water Stress Hardiness, the initial studies were underway.

The facilities at Texas A&M University are fully developed to pursue research in any of those major objectives and with supplemental financing the manpower could be made available. We have provided each of the participating breeders with a detailed financial schedule for costs of investigation of each parameter and stand ready to respond to their requests if funding is provided through the USGA Research Committee or other sources.

SUMMARY

This report represents the status report for the sixth year of intensive research activity devoted to developing water conserving, minimal maintenance turfgrasses and cultural systems. The primary objectives in this report are to present a status update on progress made during the past 12 months on the individual research objectives. Detailed results and specific data on each research objective and study are presented. The current status of the research objectives and individual studies under each research objective are summarized in the following table. A detailed summary report of the full six years efforts is being drafted and will be published within 60 days.

Feb. 1989 - Feb. 1990

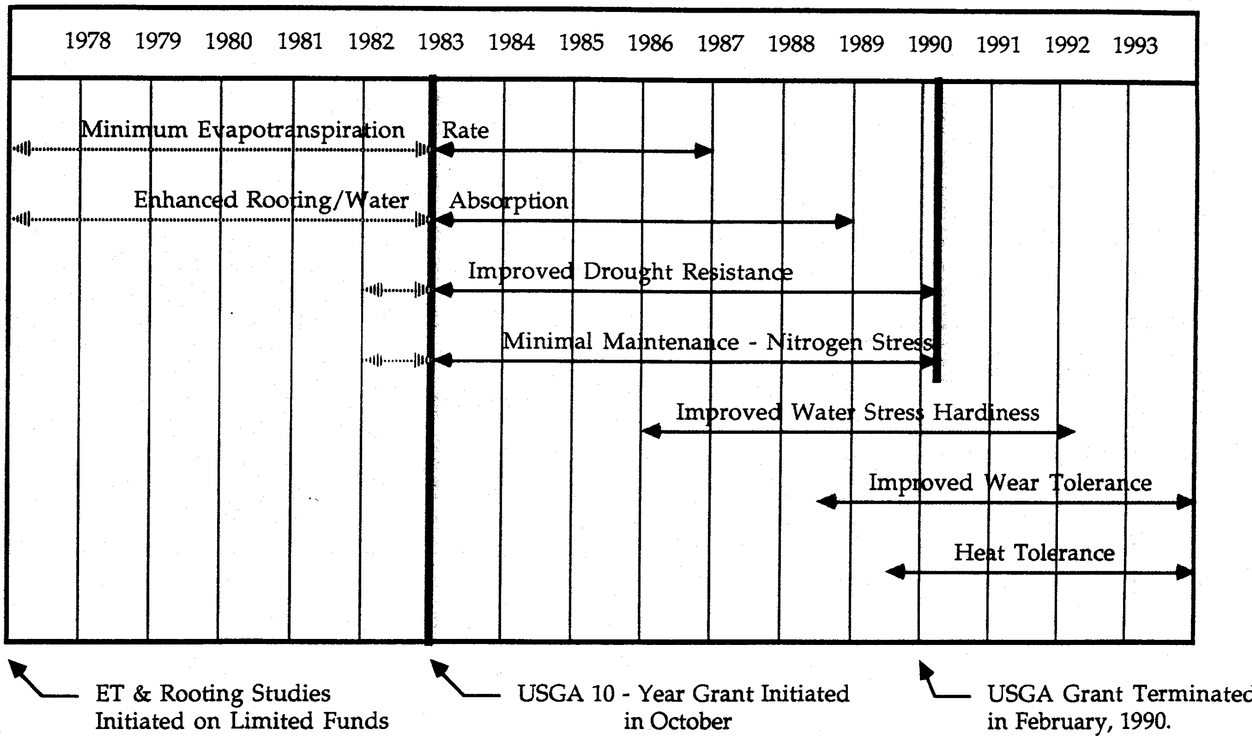
Research Objective	Scientific Papers Published	Scientific Papers in Preparation	Studies Completed	Studies Not Completed Due to Grant Termination
A. Minimal Water Use Rate	2	6	5	0
B. Enhanced Rooting/Water Absorption	1	4	8	5
C. Improved Drought Resistance	1	1	2	1
D. Basis of Minimal Maintenance Turfgrass-Nitrogen Stress	0	3	1	3
E. Improved Water Stress Hardiness	0	0	0	1

Oct. 1983 - Feb. 1990

Research Objective	Scientific Papers Published	Scientific Papers in Preparation	Studies Completed	Studies Not Completed Due to Grant Termination
A. Minimal Water Use Rate	6	10	15	0
B. Enhanced Rooting/Water Absorption	2	9	14	5
C. Improved Drought Resistance	1	4	6	5
D. Basis of Minimal Maintenance Turfgrass-Nitrogen Stress	0	5	2	7
E. Improved Water Stress Hardiness	0	1	1	6
F. Improved Wear Tolerance	2	0	2	6*
G. Heat Tolerance Enhancement Mechanisms	0	0	0	*

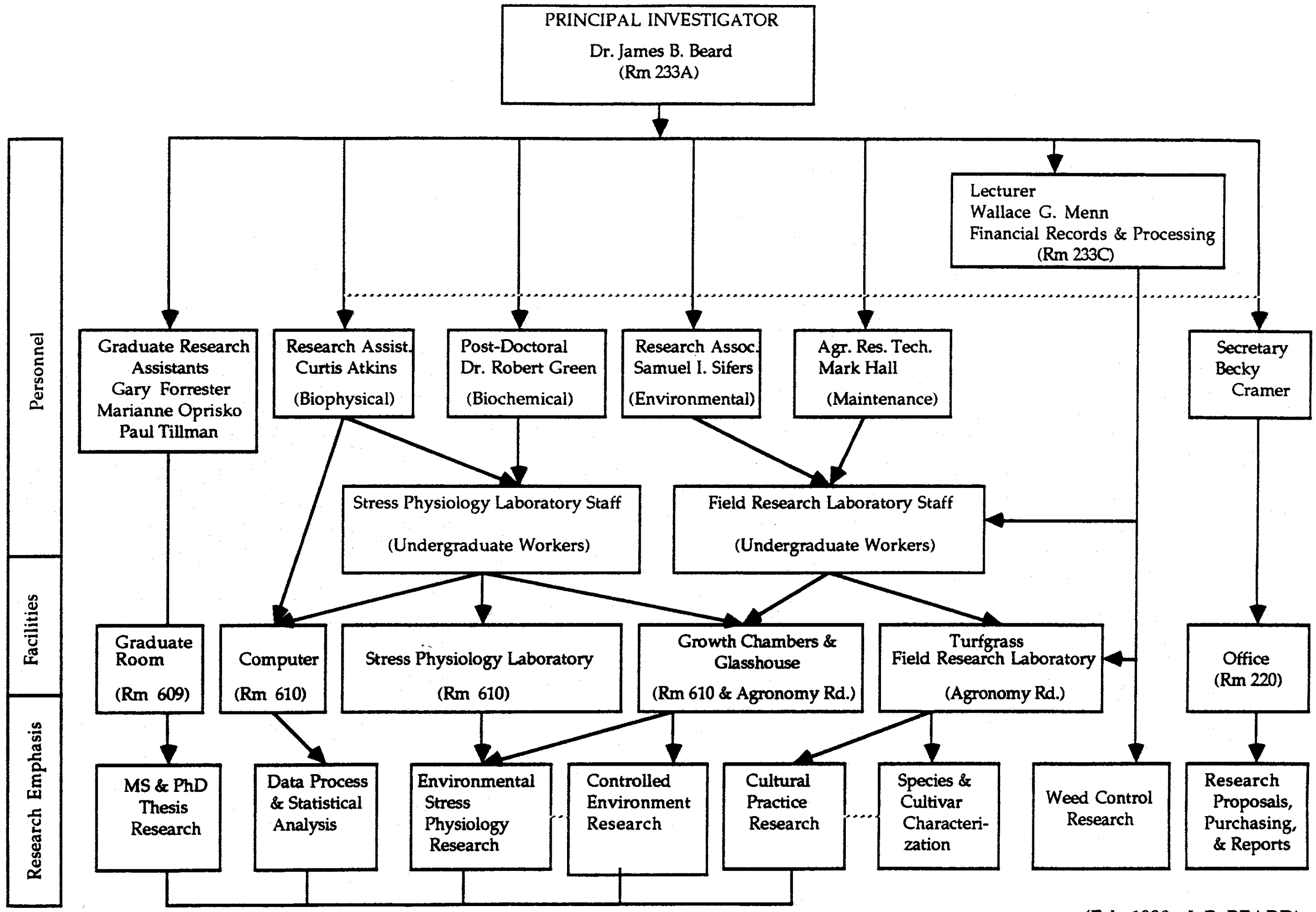
*Detailed research plan with number of studies required was not completed at time of termination notice.

SCHEDULE OF RESEARCH OBJECTIVES: FOR THE DEVELOPMENT OF WATER CONSERVING, MINIMAL MAINTENANCE TURFGRASSES AND CULTURAL PRACTICES



(Feb. 1990 - J. B. BEARD)

Turfgrass Research Project Organizational Structure, Texas A&M University, College Station, Texas



(Feb. 1990 - J. B. BEARD)

II. IMPLEMENTATION

A. Organization

The research staff organizational structure is shown on page 4. Although each individual has assigned areas of research responsibility, there must be and is much interactive cooperation among the group. As project leader I am very proud of the research staff that has been assembled. They are very dedicated to this project of developing water conserving, minimal maintenance turfgrasses. Each has a specific unique technical expertise that allows us to conduct a diverse range of in-depth pioneering type studies. The names of individuals assisting in each study area are listed following the objective statement.

B. Personnel

To prepare for the funding phase-down, the position held by Mr. William Richie was terminated in August of 1989. Also, five part-time student worker positions have been closed.

C. Facilities Development

The status of our physical facilities to pursue the key research objectives originally outlined in this project is good. As originally planned, the relative percentage of our experiments involving glasshouse and laboratory activities has increased, while the field dimension of our experimental activities has decreased. This reflects the normal evolution of research from the initial descriptive phase to the mechanistic phase.

TEXAS A&M UNIVERSITY
TURFGRASS RESEARCH FACILITIES

A. Turfgrass Stress Physiology Lab:

The 2,100 square feet complex includes a biochemistry volatiles lab, physical stress lab, isotope room, histology room, and dark room that have capabilities in carbohydrate, protein, lipid, and enzyme analyses. Equipment includes gas chromatography, open system for differential analysis of CO_2 exchange, disc gel and SDS electrophoresis, thin layer chromatography, column chromatography, spectrophotometers, refrigerated centrifuge, carbon^{14} isotope facilities, spectral radiometer, potentiometers, hygrometers, thermocouple psychrometers, porometers, etc.

B. Plant Growth and Stress Chambers:

Four high-light controlled environment plant growth chambers.
Programmed low temperature and chill stress chamber.
Heat and drought stress simulation chamber.

C. Glasshouse:

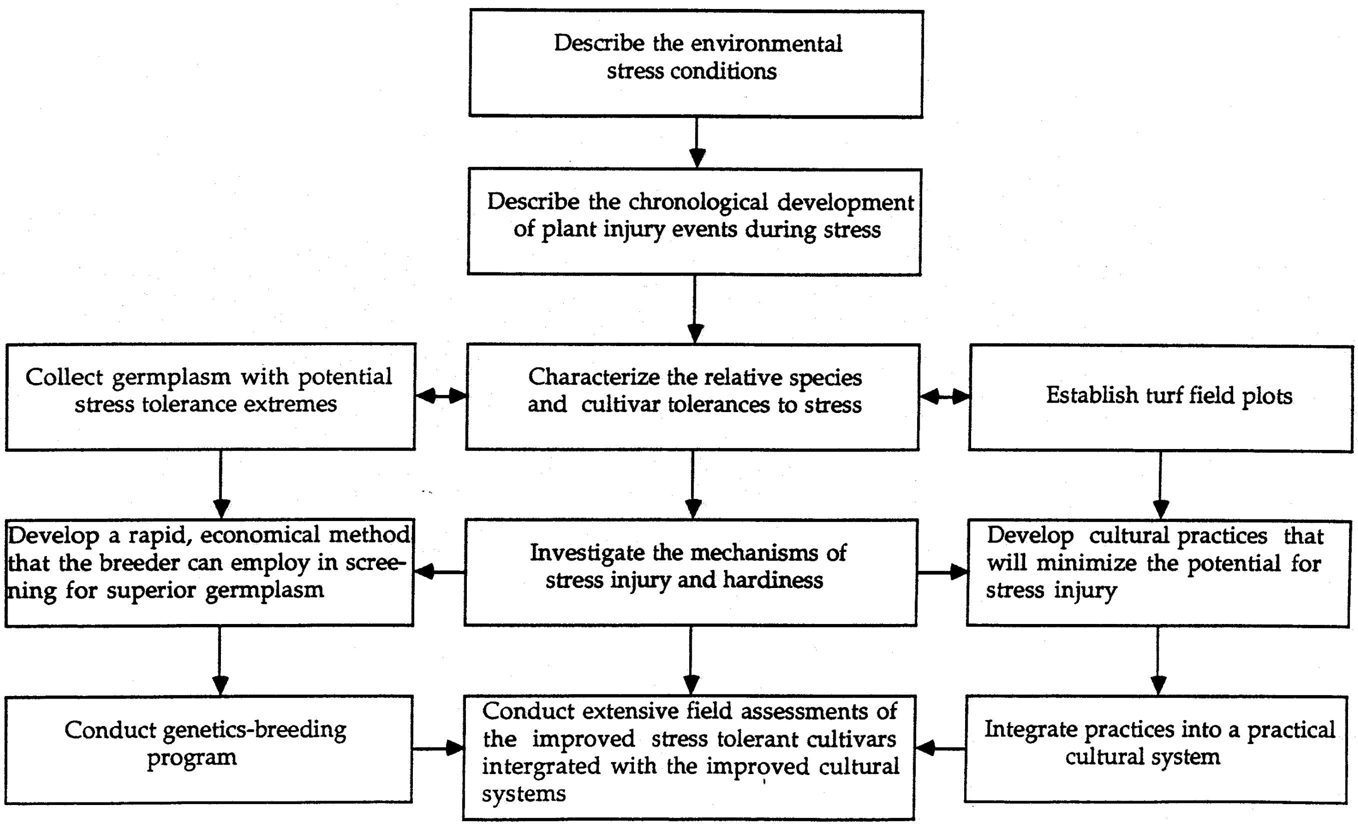
Have 1,600 square feet underglass with evaporative cooling and programmed mist irrigation that is comprised of a warm-season grass house, a cool-season grass house, and an isolation room with mist chamber; plus headhouse support facilities.

D. Turfgrass Field Laboratory:

Consists of 14 acres of turf plots including 4 acres with a sand modified root zone, 55,000 square feet of 'green' type turf plots, 65,000 square feet of tree shaded turf plots, a linear gradient irrigation area, and a microclimate monitoring system. The plots are irrigated with a fully automatic, valve in head pop-up system with computer controlled master and satellite control units.

A 5,000 square foot Field Lab Building is composed of a diagnostic lab, microclimate-irrigation control center, growth room, equipment service and teaching shop, and a representative selection of turfgrass maintenance equipment.

AN ENVIRONMENTAL STRESS PHYSIOLOGY - GENETICS MODEL TO IMPROVE STRESS TOLERANCE IN TURFGRASSES



III. ANNUAL STATUS REPORT OF ONGOING RESEARCH CONDUCTED DURING THE SIXTH YEAR

This section summarizes ongoing research that has been conducted during the past year. Research that has been completed and is currently in the report/scientific article preparation stage is summarized in Section V. The summary of ongoing investigations for the seven major research thrusts is as follows.

A. Minimal Water Use Rates - Fifteen studies have been completed.

B. Enhanced Rooting/Water Absorption - Fourteen studies have been completed, and five will not be completed due to termination of funding.

C. Improved Drought Resistance - Six studies are completed, and three will not be completed due to termination of funding.

D. Mechanistic Basis of Minimum Maintenance Turfgrasses-Nitrogen Stress - Two studies are completed, and three will not be completed due to termination of funding.

E. Improved Water Stress Hardiness - This research was initiated in 1986 as part of the overall master plan. One study has been completed and six will not be completed due to termination of funding.

F. Improved Wear Tolerance - Project terminated about the time when these studies were being initiated.

G. Heat Tolerance Enhancement Mechanisms - Project terminated before scheduled initiation of studies.

A. OBJECTIVES FOR MINIMAL WATER USE RATE: RESEARCH STATUS AND RESULTS

This major research thrust relates primarily to the development of low evapotranspiration (water use) rates for turfs that are normally irrigated, thereby, contributing to water conservation. Also, the development of turfgrasses and cultural systems possessing reduced evapotranspiration rates will contribute one dimension to a drought avoidance strategy that is a component of drought resistance.

A-11 Investigate more critically the influences of cutting heights and nitrogen/potassium nutritional levels on turfgrass evapotranspiration rates. Initiated in 1985. S. Sifers, W. Menn, and M. Hall.

Status - Cultural treatments were continued on the Tifway bermudagrass turf along with visual ratings begun during late 1985. Cultural treatments included three cutting heights of 0.5, 1.0, and 1.5 inches, three nitrogen nutritional levels of 0.5, 1.0, and 1.5 pounds per 1,000 square feet per growing month, and three potassium levels of 0.5, 1.0, and 1.5 pounds per 1,000 square feet per growing month. These cultural treatments are combined in all possible combinations in three replications. The experimental site is a modified sand root zone with a subsurface drainage system. Specific water use rate (ET) measurements using the water balance method with mini-lysimeters began in 1989. Upon completion of these studies a drought resistance investigation is scheduled. These studies have been delayed due to decreased funding, however, the first test was completed in October 1989. (Improved Cultural Systems)

Results - Table A-11 shows the results of the first series of ET determinations. The 1989 data for ET indicates that no significant differences in ET occurs as height of cut, nitrogen fertility, or potassium fertility rate are varied. However, there was a trend toward higher ET with increased cutting height and nitrogen nutrition levels under less than optimum fall growth conditions. The leaf extension rate varied with height of cut and nitrogen fertility rate, but not with potassium rate. These data are preliminary and may not be indicative of the annual situation because it was obtained in October. More data needs to be obtained before firm conclusions can be reached. This project will continue at a reduced rate on TAES funds. A scientific paper will be written upon conclusion.

Table A-11. Comparisons of evapotranspiration (ET) rates and leaf extension rates (LER) of Tifway bermudagrass as influenced by height of cut, nitrogen level, and potassium fertility in October, 1989. College Station, Texas.

Height of Cut (inches)			Nitrogen (lb N/1000 ft^{-2})			Potassium (lb K/1000 ft^{-2})		
0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5
Evapotranspiration rate (mm/day)								
2.5 a*	2.7 a	2.8 a	2.6 a	2.7 a	2.7 a	2.7 a	2.7 a	2.7 a
Leaf Extension Rate (mm/day)								
1.8 a	2.8 ab	5.4 b	2.4 a	3.9 b	3.8 b	3.0 a	3.7 a	3.3 a

*Means with the same letter within the same row are not significantly different, T Test (LSD) procedure, alpha = 0.05.

A-13 Determine the comparative evapotranspiration (ET) rates for six centipedegrass cultivars. Initiated in 1986. S. Sifers, M. Hall, and C. Atkins.

Status - A three-year field study and a study in the controlled environment simulation chamber were completed in 1989. Results of the field study were reported in the Fifth Year Progress Report, but are herein combined with the simulator results in Table A-13.1. A scientific paper will be prepared.

Results - The range in ET rates for the field study is very small within each year and overall, as are the rates in the simulator, although there is a wide range in rates between years for the field study and between the field study and the simulator data. The data points are so close together that any differences are probably due to technique rather than the genotype. Apparently the germplasm of these commercially available and near-release centipedegrass cultivars is very narrow in terms of the characteristics contributing to evapotranspiration. This has not been evidenced in any other species studied. A scientific paper is being prepared.

Table A-13. The comparative evapotranspiration (ET) rates and leaf extension rates (LER) of six centipedegrass cultivars/genotypes determined under non-limiting soil moisture conditions in the field over three years and in the controlled environmental simulator chamber in 1989. College Station, Texas.

Centipedegrass	Field ($mm\ day^{-1}$)								Chamber ($mm\ day^{-1}$)	
	1986		1987		1988		Overall			
Genotype	ET	LER	ET	LER	ET	LER	ET	LER	ET	LER
AC-26	2.5 a	3.5 ab	5.0 a	4.5 ab	5.0 ab	2.6 a	4.2 a	2.1 b	8.5 a	6.7 a
AC-44	2.7 a	6.2 a	5.2 ab	4.2 ab	4.7 b	2.3 a	4.2 a	4.2 a	8.4 a	5.9 a
AC-17	2.6 a	0.4 b	5.4 ab	3.9 b	5.5 ab	2.0 a	4.5 b	2.1 b	8.1 a	4.7 a
Oklawn	2.8 a	5.1 a	5.5 a	5.9 a	5.2 ab	2.1 a	4.5 b	4.5 a	7.8 a	4.7 a
Tennessee Hardy	2.8 a	7.1 a	5.4 ab	4.5 ab	5.8 a	1.9 a	4.6 b	4.8 a	8.7 a	3.9 a
Common	3.0 a	4.5 ab	5.5 a	4.4 ab	5.6 ab	1.7 a	4.7 b	3.5 a	8.2 a	5.3 a
LSD 0.05	0.54	4.34	0.51	1.90	0.96	2.77	0.30	1.34	1.58	2.92

Mowing heights for 1986, 1987, and 1988 were 25.4, 38.1, and 38.1 mm, respectively.

[a]Means within the same column followed by the same letter are not significantly different, T Tests (LSD) procedure, alpha = 0.05.

Conclusions

1. **The gene pool of centipedegrasses available to us was not sufficient to detect major differences in ET rates, if differences in fact occur.**

A-14 Determine the comparative evapotranspiration (ET) rates for six bermudagrass cultivars submitted for testing by Dr. Arden Baltensperger, New Mexico State University, in a cognitive effort. The cultivars are Arizona Common, Tifgreen, Texturf 10, NM S-4, MN 30, and Nu Mex Sahara. S. Sifers, M. Hall, and R. Green.

Status - One year of field studies and a study in the controlled environment simulator were completed in 1989 on the six cultivars submitted by Dr. Baltensperger. The genotypes, in four replications, were grown in black plastic pots 22.0 cm diameter x 21.5 cm deep filled with fritted clay. Following establishment in April of 1989 the turfs were used for both field and simulator studies. Canopies were mowed weekly with a reel mower at a height of 2.5 cm and fertilized with 20-20-20 liquid at a rate equal to 1 lb N/1000 ft^{-2}/growing month. Evapotranspiration (ET) rate was determined by the water balance method with measurements made over a 24-hour period and leaf extension rates (LER) determined over a 48-hour period with LER then divided by two to convert to a 24-hour basis. Both studies were conducted with non-limiting water. No disease or insect damage occurred. Field temperature averaged 29.4°C with a relative humidity of 32% and average day-length of 13 hours, 24 minutes over the 62 days of study in July and August. Environmental simulator temperature averaged 28.6°C, relative humidity was 45%, wind speed was 0.66 ms^{-1}, and irradiance was 893 $\mu E\ m^{-2}s^{-1}$.

Results - Table A-14 data of the field study ET and LER for Texturf 10, Common, and Tifgreen correspond closely with data for these three cultivars reported in the Second Year Progress Report Table A-8, as does the simulator results in Table A-3.1 for Tifgreen and Common. Texturf 10 was not a selection in the earlier study. The similarity of these data appears to validate this study and indicates that NM30 is a very low, Nu Mex Sahara is moderate, and S-4 a high water user under well watered conditions. Further field studies are required to confirm these observations before a scientific paper can be prepared.

Table A-14. Comparative evapotranspiration (ET) rates and leaf extension rates (LER) for six bermudagrass cultivars from New Mexico State Universiaty as determined by field and environmental simulator studies at Texas A&M University, 1989. College Station, Texas.

Bermudagrass Genotype/Cultivar	FIELD ET ($mm \cdot day^{-1}$)	FIELD LER ($mm \cdot day^{-1}$)	CHAMBER ET ($mm \cdot day^{-1}$)	CHAMBER LER ($mm \cdot day^{-1}$)
NM 30	3.0 a	4.0 b	5.8 a	3.1 c
NM Texturf 10	3.8 b	4.6 ab	4.3 a	4.2 ab
NM Common	4.3 bc	5.6 a	6.0 a	5.2 a
NM Sahara	4.4 c	6.1 a	6.3 ab	4.1 bc
NM S-4	4.7 c	4.6 ab	7.2 b	3.9 bc
NM Tifgreen	4.8 c	5.2 ab	6.0 a	3.8 bc
LSD 0.05	0.55	1.41	1.01	1.03

Means within the same column followed by the same letter are not significantly different, T Tests (LSD) procedure, alpha = 0.05.

Conclusions

1. **The water balance method to determine evapotranspiration rate under well-watered conditions is a valid technique.**
2. **Statistically significant differences in ET and LER occur within the NM bermudagrass and between these cultivars and other commercially available cultivars.**
3. **Further evaluation is required.**

A-15 Determine the effect of a dull mower blade on evapotranspiration rate and several leaf and canopy morphological characteristics of St. Augustinegrass and bermudagrass. Initiated in 1988. R. Green, C. Atkins, and M. Hall.

● Status - Preliminary data were collected in the Fall, 1989. A complete study will be conducted in Spring-Summer 1990.

B. OBJECTIVES FOR ENHANCED ROOTING/WATER ABSORPTION: RESEARCH STATUS AND RESULTS

Development of an enhanced rooting capability will allow the turfgrass plant to absorb moisture from a greater portion of the soil profile. The relationship of rooting to the rate of moisture withdrawal must be quantified. Delineation of the rooting dimensions will contribute to both a reduced water use rate and to the avoidance dimension of drought resistance. Thus, these rooting investigations interface closely with two of the other concurrent research objectives, A and C.

B-3 Investigate the relationships of rooting to evapotranspiration rate under water stress conditions. S. Sifers.

Status - This investigation was not completed due to a lack of a functional rhizotron facility. Specific funds have not been identified for the construction of a rhizotron/lysimeter/rainout shelter facility. The actual site development work has been completed. (Mechanistic Study)

B-4 Conduct exploratory studies of turfgrass root enhancing agents. Initiated in 1984. S. Sifers.

Status - This study uses 30 cm long mini-root columns with a clear plastic viewing strip to allow detailed observation of the root system. Use of these columns allows us to conduct non-destructive assessments. Turfs were subjected to temperatures of 65°F (18°C), 75°F (24°C), 85°F (30°C), and 95°F (35°C) during the heat stress phases.

Preliminary data indicate that the iron and the seaweed extract do not enhance bentgrass root survival at sustained high temperatures, but that sucrose, oxamide, and a mixture of these, did show promise as root enhancing agents. Shoot die back at the high temperatures without accompanying root die back may be attributed to the high light intensity and lower humidity conditions of the chamber, but this phenomena needs further investigation. This study was not completed due to funding expiration. (Mechanistic and Cultural Studies)

B-5 Determine the cause of spring root decline (SRD) of warm-season turfgrasses as well as methods to minimize its potentially negative effects. Initiated in 1984, with the biochemical studies initiated in 1986. S. Sifers and R. Green.

Status - Initial experimentation was involved in the development of a technique for incorporating radioactive $^{14}CO_2$ into warm-season turfgrasses grown in PVC root columns, harvesting plants by leaf, crown, and root sections, and assaying for radioactivity by the scintillation method.

Following a successful first phase, the second phase of experiments involved replicated studies for determining the fate of radioactive carbon, assumed to be incorporated into carbohydrate, in St. Augustinegrass turfs labeled prior to shoot dormancy and then induced into greenup under either SRD or non-SRD conditions. Plants were harvested in four sections (leaf, crown, upper 10 cm roots and lower roots) at dormancy, maximum root decline, early root regeneration and late root regeneration. If movement of carbohydrate is involved with SRD, then movement of the radioactive labeled carbohydrate in SRD and non-SRD treatments should differ. See USGA Progress Report of Oct., 1988 for detailed results. Results showed that movement of ^{14}C was associated with SRD.

The third phase of experiments involves studies for determining the fate of radioactive carbon in St. Augustinegrass labeled prior to shoot dormancy and then induced into greenup under either SRD (greenup at 35°C) or non SRD conditions (greenup at 24°C).

Plants were harvested during active growth, dormancy, early root decline, maximum root decline and early root regeneration. In these experiments the amounts of radioactive carbon were determined in three carbohydrate components (sugars, starch, and structural carbohydrate) in each of five tissue structures (leaf, bud, stem, upper 10 cm roots, and lower 10 cm roots). Data from this experiment are presented in this report.

Results - Results from the sugar analysis are shown in Tables B-5.1A and B-5.1B. At shoot dormancy there was an accumulation of total nonstructural carbohydrates (TNC), especially in the stem. Eight days following shoot greenup initiation (8 DAG) there were dramatic morphological and physiological changes. Turfs at 35°C greenup that were beyond 50% shoot greenup, had early root dieback, and no new adventitious roots; while turfs at 24°C greenup were at about 30% shoot greenup, had no root dieback, and had new adventitious roots. Sugar analysis showed that turfs at 35°C greenup had a dramatic drop in stem TNC, bud TNC and root TNC while turfs at 24°C greenup had higher TNC levels. These lower TNC levels for SRD turfs were associated with rapid shoot greenup. These data also shows a direct relationship between low TNC levels and root dieback. The remaining sugar analysis data show a gradual increase in TNC levels for turfs at 35°C greenup until they are similar to turfs at 24°C greenup. It is interesting to note that plants at 35°C greenup did not initiate adventitious roots until 30 DAG. Previous research showed a 14-day delay in rooting (Sifers et al., 1985). This rooting delay (and also root dieback) for turfs at 35°C greenup is related to low TNC levels in stem, bud, and roots that may suggest a threshold value. These low TNC levels are the result of rapid shoot greenup.

^{14}C data is presented in Tables B-5.2A and B-5.2B. Though there was more variability in these data, relative to sugar analysis, the trends are basically the same.

Conclusions

1. **Spring root decline (SRD) is associated with low TNC levels in stem, bud, and root tissues.**
2. **Low TNC levels are the result of rapid shoot greenup.**
3. **Undoubtedly a hormonal control is involved.**
4. **The ramifications of SRD on turf cultural practices in the spring have been previously described.**

Table B-5.1A. Carbohydrate analyses of St. Augustinegrass subjected to 2 greenup temperatures.

Harvest	Concd. ($\mu g\ mg^{-1}$)			Weight	Total carbohydrate $part^{-1}$ (mg)			Percent = ratio x 100		
Time	Sugars[1]	Starch	TNC[2]	(g)	Sugars	Starch	TNC	Sugar $part^{-1}$ / Sugar $plant^{-1}$	Starch $part^{-1}$ / Starch $plant^{-1}$	TNC $part^{-1}$ / TNC $plant^{-1}$
						Leaf part				
Act. growth	18	18	35	2.05	38	36	72	11	6	8
Shoot dorm.	35	22	58	1.83	64	40	104	10	3	6
8DAG[4] 24C	25	29	58	2.34	59	76	143	18	7	10
8DAG 35C	19	5	24	2.80	54	15	71	30	4	14
30DAG 24C	19	24	41	2.75	52	63	111	25	11	14
30DAG 35C	18	14	32	3.32	59	43	101	26	15	21
39DAG 24C	18	31	49	2.60	47	92	138	21	14	15
39DAG 35C	21	20	39	5.14	105	101	200	36	20	25
$LSD_{0.05}$	5	NS[3]	NS	1.30	34	NS	NS	13	NS	11
						Stem part				
Act. growth	32	68	101	5.85	191	406	599	57	65	62
Shoot dorm.	79	183	261	5.66	444	1046	1487	69	86	80
8DAG 24C	40	190	234	3.96	164	756	936	49	72	66
8DAG 35C	21	49	69	3.68	76	179	254	43	63	55
30DAG 24C	26	73	99	3.96	105	283	388	44	53	51
30DAG 35C	27	29	56	3.83	104	110	213	45	43	44
39DAG 24C	28	106	134	4.47	123	463	588	55	60	59
39DAG 35C	26	44	70	5.19	138	230	367	44	43	44
$LSD_{0.05}$	14	40	44	1.26	101	297	373	16	18	15

[1]Sugars soluble in 80% boiling ethanol.
[2]Total nonstructural carbohydrates.
[3]Nonsignificant harvest effect.
[4]DAG = days after greenup initiation.

Table B-5.1B. Carbohydrate analyses of St. Augustinegrass subjected to 2 greenup temperatures.

Harvest	Concd. ($\mu g\ mg^{-1}$)			Weight	Total carbohydrate part^{-1} (mg)			Percent = ratio x 100		
Time	Sugars[1]	Starch	TNC[2]	(g)	Sugars	Starch	TNC	Sugar part^{-1} / Sugar plant^{-1}	Starch part^{-1} / Starch plant^{-1}	TNC part^{-1} / TNC plant^{-1}
					Bud part					
Act. growth	20	61	81	1.31	26	80	106	8	13	11
Shoot dorm.	65	105	167	1.01	66	110	175	10	9	9
8DAG[4] 24C	23	80	104	2.44	57	189	247	18	19	19
8DAG 35C	10	30	40	2.32	22	77	99	12	23	19
30DAG 24C	15	73	88	2.10	31	151	182	13	30	26
30DAG 35C	19	50	68	1.81	33	86	119	15	32	24
39DAG 24C	12	72	84	2.37	29	169	198	13	23	21
39DAG 35C	15	87	102	2.00	30	179	209	10	32	25
$LSD_{0.05}$	7	NS[3]	55	0.62	13	NS	NS	4	14	10
					Root part (upper 15 cm)					
Act. growth	15	19	34	2.44	37	47	83	11	8	9
Shoot dorm.	35	11	44	1.16	40	13	51	6	1	3
8DAG 24C	30	14	45	0.83	25	12	37	8	1	3
8DAG 35C	17	16	33	0.92	15	15	30	9	6	7
30DAG 24C	22	19	41	1.15	26	21	47	11	4	6
30DAG 35C	15	13	29	1.01	16	13	29	7	5	6
39DAG 24C	17	18	35	0.76	13	14	27	6	2	3
39DAG 35C	18	15	34	0.80	15	12	27	5	2	3
$LSD_{0.05}$	5	NS	9	0.39	6	19	21	NS	5	5
					Root part (lower 15 cm)					
Act. growth	16	17	33	2.61	41	47	88	12	7	9
Shoot dorm.	36	13	49	0.72	25	10	35	4	1	2
8DAG 24C	33	15	48	0.72	23	11	34	8	1	3
8DAG 35C	15	13	29	0.71	11	9	20	6	4	4
30DAG 24C	23	14	36	0.69	16	10	25	7	2	4
30DAG 35C	18	14	32	0.77	14	11	25	6	4	5
39DAG 24C	18	14	32	0.65	12	9	21	5	1	2
39DAG 35C	19	14	32	0.65	12	10	21	4	2	3
$LSD_{0.05}$	6	NS	7	0.66	12	15	26	4	3	3

[1]Sugars soluble in 80% boiling ethanol.
[2]Total nonstructural carbohydrates.
[3]Nonsignificant harvest effect.
[4]DAG = days after greenup initiation.

Table B-5.2A. ^{14}C analyses of St. Augustinegrass labeled prior to shoot dormancy and subjected to 2 greenup temperatures.

Harvest Time	Total counts part[-1] (DPMx1000)				Percent = ratio x 100		
	Sugars[1]	Starch	TNC[2]	Residual[3]	Sugar DPM part[-1] / Sugar DPM plant[-1]	Starch DPM part[-1] / Starch DPM plant[-1]	TNC DPM part[-1] / TNC DPM plant[-1]
				Leaf part			
Shoot dorm.	7	5	11	9548	30	28	30
8DAG[4] 24C	15	5	20	12276	41	32	38
8DAG 35C	9	6	14	9102	33	41	37
30DAG 24C	8	4	12	8891	34	25	31
30DAG 35C	5	3	8	2146	26	27	26
39DAG 24C	1	2	4	3415	9	18	12
39DAG 35C	5	1	7	771	50	32	45
$LSD_{0.05}$	NS[5]	NS	NS	NS	NS	11	NS
				Stem part			
Shoot dorm.	12	8	20	3681	48	50	49
8DAG 24C	9	6	15	3017	30	38	33
8DAG 35C	9	3	12	4720	35	25	31
30DAG 24C	10	7	17	5528	36	40	37
30DAG 35C	9	4	13	6590	45	37	42
39DAG 24C	10	6	15	4548	58	50	55
39DAG 35C	2	1	4	1423	26	34	28
$LSD_{0.05}$	NS	NS	NS	NS	16	15	13

[1]Sugars soluble in 80% boiling ethanol.
[2]Total nonstructural carbohydrates.
[3]Tissue following sugar and starch extractions.
[4]DAG = days after greenup initiation.
[5]Nonsignificant harvest effect.

Table B-5.2B. ^{14}C analyses of St. Augustinegrass labeled prior to shoot dormancy and subjected to 2 greenup temperatures.

Harvest Time	Total counts part^{-1} (DPMx1000) Sugars[1]	Starch	TNC[2]	Residual[3]	Percent = ratio x 100: Sugar DPM part^{-1} / Sugar DPM plant^{-1}	Starch DPM part^{-1} / Starch DPM plant^{-1}	TNC DPM part^{-1} / TNC DPM plant^{-1}
				Bud part			
Shoot dorm.	3	2	5	2376	13	13	13
8DAG[4] 24C	7	5	12	6544	21	24	22
8DAG 35C	6	3	9	5940	24	26	24
30DAG 24C	6	4	10	5316	22	23	22
30DAG 35C	4	2	7	3846	21	24	22
39DAG 24C	5	2	7	3746	27	25	26
39DAG 35C	2	1	3	1332	20	26	22
$LSD_{0.05}$	NS[5]	NS	NS	NS	NS	NS	NS
				Root part (upper 15 cm)			
Shoot dorm.	1.2	0.8	2.0	698	6	6	6
8DAG 24C	1.2	0.8	2.0	709	3	4	3
8DAG 35C	1.0	0.7	1.7	1168	4	5	4
30DAG 24C	1.6	1.8	3.4	1755	5	9	6
30DAG 35C	0.9	0.8	1.7	1652	5	8	6
39DAG 24C	0.6	0.5	1.1	507	3	5	4
39DAG 35C	0.2	0.2	0.4	134	2	5	3
$LSD_{0.05}$	NS	NS	NS	1029	2	NS	2
				Root part (lower 15 cm)			
Shoot dorm.	1.0	0.6	1.6	1048	3	3	3
8DAG 24C	1.2	0.6	1.8	499	3	3	3
8DAG 35C	0.8	0.4	1.2	783	3	3	3
30DAG 24C	0.8	0.6	1.4	739	3	4	3
30DAG 35C	0.7	0.5	1.2	1010	3	5	4
39DAG 24C	0.5	0.3	0.8	313	3	3	3
39DAG 35C	0.2	0.1	0.3	100	2	3	2
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS

[1]Sugars soluble in 80% boiling ethanol.
[2]Total nonstructural carbohydrates.
[3]Tissue following sugar and starch extractions.
[4]DAG = days after greenup initiation.
[5]Nonsignificant harvest effect.

B-6 Assess the interspecific rooting potentials of twelve major cool-season turfgrasses under non-limiting moisture conditions. Initiated in 1985. S. Sifers.

Status - This study was not successfully completed due to facility limitations that precluded a sufficient low temperature duration to allow for full rooting potential of these cool-season turfgrasses. Four attempts were made before this assessment was abandoned. (Interspecies Comparisons)

B-7 Assess the interspecific rooting potentials of twelve major cool-season turfgrass species under heat stress and non-limiting moisture conditions. Initiated in 1984. S. Sifers.

Status - See B-6. (Interspecies Comparisons)

B-10 Assess the intraspecific rooting potentials of 24 bermudagrass cultivars under non-limiting moisture conditions. Initiated in 1986. S. Sifers.

Status - Two long duration studies to assess the intraspecific rooting potentials of 24 bermudagrass cultivars have been completed under non-limiting moisture conditions in a Root-Column Facility constructed in the Turfgrass Laboratory Glasshouse at Texas A&M. The first test was harvested in 1987 after 160 days of growth by sectionalizing the tube every 30 cm, counting the root intersections at 30, 60, 90, 120, 150, 180, and 210 cm intervals, obtaining shoot dry weight, total root dry weight, and the root dry weight for roots in each 30 cm segment. The 24 bermudagrass cultivars were each grown from single 2.54 cm shoots with 5 cm of roots; that had been planted in individual growth cones and transplanted into the larger 7.6 cm x 210 cm tubes in three replications when established. Rooting media was a washed mortar sand. Fertility was applied at a rate of 2 lbs N/1000'^{2}/month using 20-20-20 ratio liquid. Turfs were clipped weekly at 2.5 cm, with clippings removed. A drip watering system was used and water was applied via a timed sequence to insure non-limiting moisture. No disease or insect damage was detected. The glasshouse temperatures were maintained between 25 and 35°C throughout this study.

The second study was completed in 1989 with all conditions and turfs being identical, except that the growth period was 210 days. A scientific paper will be prepared on the results of these studies.

Results - Results of these two tests are reflected in Tables B-10.1 and B-10.2. An earlier study of rooting potential of warm-season turfgrasses, which was reported in the Second Year Progress Report as B-2, contained four of the same bermudagrass cultivars, FB-119, Tifgreen, Tifway, and Texturf 10. The duration of this earlier study was 130 days and the longest root extension reported as 183 cm for FB-119. Other bermudagrass roots lengths, were 155 cm for Tifgreen, 138 cm for Texturf 10, and 122 cm for Tifway. These data are similar to results of the 160-day study of Table B-10.1 and indicates that neither of these studies were of sufficient duration to adequately describe the full rooting potential of these turfs. The results of these three studies confirmed that there is significant intraspecies and interspecies differences in rooting potential of warm-season turfgrasses under non-limiting water conditions.

The 210 cm maximum rooting length possible in these tests was obtained by at least one cultivar of *Cynodon dactylon*, *C. dactylon* x *C. transvaalensis*, and *C. magennisii*. Therefore, the cultivar's genera does not appear to dictate rooting potential. Likewise, total shoot or root weight does not appear to be the determining factor in rooting potential as several cultivars such as Tifdwarf, Midway, Vamont, and Tifway had substantial root and shoot dry weights, but less rooting length. Rooting depth and density do appear to be factors in the dehydration avoidance mechanism evident in bermudagrasses. A comparison with the 1989 and 1988 drought resistance data show Everglades, Tifway II, Tufcote, Midway and U-3 less than 100% recovered from drought stress after 30 days following rewatering, while all cultivars with rooting depth greater than 180 cm after 210 days were 100% recovered.

Table B-10-1. Comparison of the intraspecific rooting potentials of twenty-four bermudagrass cultivars under non-limiting moisture conditions following 160 days of growth in rooting columns as reflected by total shoot and root dry weights, number of roots intersecting each 30 cm, and root dry weight for each 30 cm segment of roots. 1989, College Station, Texas.

Cultivar**	Shoot dry wt (g)	Root dry wt (g) Total	Root dry wt (g) 0-30 cm	Root Int @ 30 cm	Root dry wt (g) 30-60 cm	Root Int @ 60 cm	Root dry wt (g) 60-90 cm	Root Int @ 90 cm	Root dry wt (g) 90-120 cm	Root Int @ 120 cm	Root dry wt (g) 120-150 cm	Root Int @ 150 cm	Root dry wt (g) 150-180 cm	Root Int @ 180 cm	Root dry wt (g) 180-210 cm	Root Int @ 210 cm
Ormond	4.62a*	8.08a	2.78	21	3.78	22	0.87	21	0.50	10	0.15	2	--	--	--	--
U-3	3.47a	9.01a	1.4	15	2.73	10	2.08	7	1.6	6	1.2	0	--	--	--	--
Vamont	2.23a	2.33b	0.50	5	0.52	5	0.76	4	0.32	2	0.23	1	--	--	--	--
Texturf 10	1.45a	1.97b	0.88	9	0.67	5	0.17	4	0.17	4	0.08	2	--	--	--	--
FB-119	0.43a	0.84b	0.25	5	0.15	3	0.22	3	0.12	2	0.10	2	--	--	--	--
Midway	3.88a	8.32a	0.92	10	0.35	6	3.85	6	3.2	6	--	--	--	--	--	--
Tiffine	3.68a	3.22b	0.98	8	0.88	4	0.80	9	0.50	5	--	--	--	--	--	--
Tifgreen II	2.57a	4.02b	1.10	7	1.2	5	1.42	4	0.30	3	--	--	--	--	--	--
Texturf 1F	1.53a	1.75b	0.76	10	0.47	7	0.27	6	0.25	6	--	--	--	--	--	--
Everglades	1.53a	1.35b	0.80	6	0.35	4	0.10	3	0.10	1	--	--	--	--	--	--
Tifgreen	1.13a	1.58b	0.45	4	0.30	3	0.38	2	0.40	1	--	--	--	--	--	--
Common	1.07a	1.18b	0.60	4	0.20	4	0.30	3	0.08	3	--	--	--	--	--	--
Sunturf	1.07a	1.63b	0.83	7	0.25	3	0.30	6	0.25	2	--	--	--	--	--	--
Tiflawn	0.72a	0.89b	0.33	7	0.18	3	0.28	4	0.10	3	--	--	--	--	--	--
Santa Ana	3.29a	0.87b	0.22	3	0.15	4	0.50	1	--	--	--	--	--	--	--	--
A-22	1.63a	2.04b	1.21	7	0.78	3	0.05	1	--	--	--	--	--	--	--	--
A-29	1.08a	1.08b	0.38	4	0.40	3	0.30	2	--	--	--	--	--	--	--	--
Bayshore	1.05a	1.00b	0.43	5	0.22	4	0.35	4	--	--	--	--	--	--	--	--
Pee Dee	0.68a	0.53b	0.22	4	0.21	3	0.10	0	--	--	--	--	--	--	--	--
Tifway	0.67a	0.50b	0.25	4	0.15	2	0.10	2	--	--	--	--	--	--	--	--
Midiron	0.55a	0.60b	0.32	3	0.23	2	0.05	1	--	--	--	--	--	--	--	--
Tifway II	1.20a	0.85b	0.50	4	0.35	4	--	--	--	--	--	--	--	--	--	
Tifdwarf	0.53a	0.28b	0.21	2	0.07	0	--	--	--	--	--	--	--	--	--	--
Tufcote	0.35a	1.17b	1.17	3	--	--	--	--	--	--	--	--	--	--	--	

*Means with the same letter are not significantly different T Tests (LSD) at PR > F 0.0336.

**Cultivars are listed in order determined by length of root, then greatest shoot dry weight when root lengths are equal.

Table B-10-2. Comparison of the intraspecific rooting potentials of twenty-four bermudagrass cultivars under non-limiting moisture conditions following 210 days of growth in rooting columns as reflected by total shoot and root dry weights, number of roots intersecting each 30 cm, and root dry weight for each 30 cm segment of roots. 1989, College Station, Texas.

Cultivar	Shoot dry wt (g)	Root dry wt (g) Total	Root dry wt (g) 0-30 cm	Root Int @ 30 cm	Root dry wt (g) 30-60 cm	Root Int @ 60 cm	Root dry wt (g) 60-90 cm	Root Int @ 90 cm	Root dry wt (g) 90-120 cm	Root Int @ 120 cm	Root dry wt (g) 120-150 cm	Root Int @ 150 cm	Root dry wt (g) 150-180 cm	Root Int @ 180 cm	Root dry wt (g) 180-210 cm	Root Int @ 210 cm
Ormond	12.8a*	5.55a	2.53	16	0.86	14	0.92	11	0.63	8	0.29	7	0.19	5	0.12	3
Tiflawn	10.3ab	4.03b	1.51	19	0.93	14	0.66	10	0.31	8	0.26	5	0.15	3	0.21	2
Santa Ana	7.1bc	5.56a	2.07	20+	1.54	17	0.88	13	0.36	9	0.25	6	0.40	7	0.06	2
Sunturf	6.7bcde	5.44a	2.15	18	1.08	17	0.95	13	0.72	9	0.22	8	0.25	5	0.07	3
Bayshore	5.4cdef	2.55cd	0.91	19	0.58	16	0.39	9	0.18	6	0.27	5	0.09	4	0.13	3
A-29	5.2cdef	4.62ab	1.86	18	1.10	13	0.77	9	0.44	7	0.34	5	0.07	3	0.04	2
FB-119	4.5cdef	5.59a	2.32	16	1.02	13	0.84	12	0.50	8	0.43	5	0.32	4	0.16	3
Texturf 1F	3.9cdef	5.07a	1.62	20+	1.19	17	1.04	13	0.70	9	0.36	6	0.09	3	0.07	2
Texturf 10	3.9cdef	4.73ab	1.46	20+	1.10	20	0.60	10	0.74	6	0.39	5	0.28	4	0.16	3
Tifgreen	3.1def	3.03bc	0.91	11	0.53	6	0.37	3	0.47	5	0.35	2	0.40	2	--	--
Common	5.2cdef	3.42bc	1.94	15	0.74	10	0.35	4	0.14	3	0.24	2	0.01	1	--	--
Tiffine	4.2cdef	2.53cd	1.08	16	0.73	10	0.38	5	0.10	4	0.24	3	--	--	--	--
U-3	3.3cdef	2.71cd	0.99	6	0.87	7	0.21	3	0.27	1	0.37	3	--	--	--	--
Tifgreen II	4.9cdef	2.70cd	1.00	15	0.66	10	0.37	6	0.27	4	0.40	2	--	--	--	--
Tufcote	1.4f	2.98cd	1.53	11	0.52	9	0.54	5	0.29	5	0.10	2	--	--	--	--
Midway	5.5bcde	3.32bc	1.53	16	0.88	9	0.51	6	0.31	3	0.09	--	--	--	--	--
Tifdwarf	8.3bc	3.79bc	2.19	20+	0.77	15	0.43	7	0.38	5	0.02	--	--	--	--	--
Vamont	4.9cdef	3.08bc	1.20	14	0.86	12	0.43	4	0.33	2	0.26	--	--	--	--	--
Tifway	4.8cdef	2.84cd	1.91	9	0.53	6	0.25	3	0.15	4	--	--	--	--	--	--
Pee Dee	1.8ef	1.58d	0.96	9	0.39	6	0.16	2	0.07	2	--	--	--	--	--	--
Tifway II	0.7f	1.28d	0.51	4	0.23	4	0.39	8	0.15	2	--	--	--	--	--	--
A-22	1.4f	2.04cd	0.81	10	0.62	4	0.36	1	0.25	--	--	--	--	--	--	--
Everglades	2.7def	1.28d	0.68	9	0.30	4	0.36	1	0.25	1	--	--	--	--	--	--
Midiron	4.8cdef	3.59bc	1.56	20+	1.14	7	0.89	4	--	--	--	--	--	--	--	--

*Means with the same letter are not significantly different T Tests (LSD) at PR > F 0.0336.

Conclusions

1. **Rooting depths, total root weights, and shoot weights of major warm-season turfgrasses vary substantially in terms of interspecies and intraspecies genetic rooting potentials.**
2. **A duration in excess of 160 days is required to conduct a reliable assessment of genetic potential for rooting.**
3. ***Cynodon* spp. has a genetic rooting potential of at least 210 cm (7 foot) in depth.**
4. **Rooting potential of *Cynodon* spp. is a major contributor to the overall drought resistance mechanism of this species.**
5. **Shoot biomass is not a reliable marker in selecting deep rooting plants within *Cynodon* spp.**

B-11 Assess the intraspecific rooting potentials of 11 zoysiagrass cultivars under non-limiting moisture conditions. Initiated in 1987. S. Sifers.

<u>Status</u> - A long duration study was completed in the 210 cm Root Column Facility in 1989. The cultivars surveyed were identical to those assessed in Objective A-10. Procedures followed were identical to B-10.

<u>Results</u> - Significant differences occurred in shoot dry weight and total root dry weight. No root intersections were found below 90 cm (3 foot) depth and only four cultivars had rooting below 60 cm. Most of the rooting occurred in the first 30 cm segment which tends to confirm that *Zoysia* species have short but very fibrous roots. The hybrid cultivar Emerald was poorest in all categories. A scientific paper will be prepared.

Table B-11. Comparisons of the intraspecific rooting potentials of eleven zoysiagrass cultivars under non-limiting moisture conditions following 270 days of growth in rooting columns as reflected by total shoot and root dry weights, number of intersecting roots at each 30 cm, and root dry weight for each 30 cm segment of roots, 1989. College Station, Texas.

Zoysiagrass Cultivar	Shoot dry wt (g)	Root dry wt (g)	Root dry wt 0-30 cm	Root int. @ 30 cm	Root dry wt 30-60 cm	Root int. @ 60 cm	Root dry wt 60-90 cm	Root int. @ 90 cm	Root dry wt 90-120 cm	Root int. @ 120 cm
PI 231146	2.44 a*	2.61 a	2.14	6	0.19	3	0.27	1	0.009	0
KLS-11	0.91 cd	1.00 a	0.74	2	0.14	3	0.08	5	0.04	0
Korean Common	0.83 cd	0.78 a	0.56	3	0.16	1	0.06	1	0.004	0
41-21-5	1.90 b	1.33 a	1.07	5	0.21	2	0.05	2		
FC 13521	1.28 c	1.82 a	1.38	3	0.26	3	0.18	2		
KLS-05	1.16 cd	0.99 a	0.88	2	0.11	1	0.002	0		
Belaire	1.05 cd	0.70 a	0.46	4	0.17	3	0.07	0		
Meyer	0.96 cd	0.98 a	0.79	5	0.15	1	0.04	0		
KLS-13	0.73 d	1.02 a	0.79	5	0.22	1	0.009	0		
El Toro	1.05 cd	0.92 a	0.92	5	0.001	0				
Emerald	0.18 e	0.24 a	0.15	1	0.09	0				

<u>Conclusions</u>

1. **There were not large intraspecies differences in rooting potential among the 11 *Zoysia* spp.**
2. **Zoysia spp. appear to be shallow rooted with limited potential to obtain moisture at depths below 60 cm.**
3. ***Zoysia* spp. root/shoot ratios approach equality, which indicates a dense, fibrous root system.**
4. ***Zoysia* spp. possess moderate to high drought resistance potential. The data confirm that the primary mechanism contributing to drought resistance in these <u>Zoysias</u> is not dehydration avoidance through enhanced water uptake, but rather dehydration tolerance.**

B-12 Assess the intraspecific rooting potentials of 11 St. Augustinegrass cultivars under non-limiting moisture conditions. Initiated in 1989. S. Sifers.

Status - A long term study was completed in 1989 using the 210 cm Root Column Facility. The genotypes studied included six commercially available cultivars widely used in the southern U.S., and five experimental cultivars developed at Texas A&M College Station or Texas A&M Dallas. Procedures followed were identical to those in B-10 and B-11.

Results - Two cultivars, Floralawn and Bitter Blue, had root intersections the full length of the 210 cm deep column, Tx8208 rooted to 180 cm, 6 others had rooting to 150 cm, 2 to 120 cm, and only one was limited to the 30-60 cm segment. However, unlike the zoysiagrasses and bermudagrasses, the root dry weight per segment was very light, by approximately a factor of ten. This deep rooting and light weight per segment would describe a long, but not dense or fibrous, root system. As St. Augustinegrass has excellent drought resistance, the described root system would indicate the resistance mechanism involves dehydration avoidance through the ability of the root system to probe deeper into the root zone to extract available moisture. A scientific paper will be prepared.

Conclusions

1. **The intraspecies differences in rooting potential are very significant as regards depth of rooting but not root density. Breeding for increased root depth appears possible.**
2. **St. Augustinegrasses have long, but not dense root systems.**
3. **Shoot dry weight is approximately double the total root weight.**
4. **The long root length aids in drought resistance of St. Augustinegrass through the dehydration avoidance mechanism. Dehydration tolerance is also a key contributing component.**

Table B-12. Comparison of the intraspecific rooting potentials of eleven St. Augustinegrass cultivars under non-limiting moisture conditions following 270 days of growth in rooting columns as reflected by total shoot and root dry weights, number of intersecting roots at each 30 cm, and root dry weight for each 30 cm segment of roots, 1989. College Station, Texas.

St. Augustinegrass Cultivar	Shoot dry wt (g)	Root dry wt (g)	Root dry wt 0-30 cm	Root int @ 30 cm	Root dry wt 30-60 cm	Root int @ 60 cm	Root dry wt 60-90 cm	Root int @ 90 cm	Root dry wt 90-120 cm	Root int @ 120 cm	Root dry wt 120-150 cm	Root int @ 150 cm	Root dry wt 150-180 cm	Root int @ 180 cm	Root dry wt 180-210 cm	Root int @ 210 cm
Floralawn	1.51 abc*	0.88 a	0.12	4	0.16	4	0.09	3	0.14	3	0.12	3	0.13	3	0.12	1
Bitter Blue	1.25 bcd	0.72 a	0.19	2	0.07	2	0.04	2	0.06	1	0.05	1	0.15	4	0.18	1
Tx 8208	1.69 ab	0.80 a	0.19	3	0.18	3	0.09	3	0.17	5	0.13	3	0.04	2		
Texas Common	1.88 a	0.95 a	0.27	11	0.19	11	0.12	2	0.12	2	0.25	0				
Floratam	1.14 cde	0.70 a	0.28	3	0.13	2	0.07	4	0.12	2	0.10	1				
Dalsa 8403	0.87 de	0.42 a	0.14	4	0.15	3	0.08	2	0.04	1	0.01	0				
Seville	0.65 ef	0.52 a	0.11	2	0.18	2	0.14	1	0.04	1	0.16	0				
Dalsa 8401	0.59 ef	0.37 a	0.11	2	0.09	2	0.06	1	0.02	1	0.09	0				
Raleigh	0.88 de	0.34 a	0.10	2	0.09	4	0.11	2	0.04	0						
Dalsa 8402	0.65 ef	0.32 a	0.11	3	0.04	2	0.09	3	0.08	4						
Tx 8262	0.29 f	0.15 a	0.07	2	0.08	0										

B-13 Assess root hair location, density, size, and viability among 13 cool-season turfgrasses under non-limiting moisture conditions. Initiated in 1987. R. Green.

Status - This study was cancelled due to grant termination.

B-15 Determine the root hair viability among the major warm-season and cool-season turfgrasses. Initiated in 1987. R. Green and M. Oprisko.

Status - The paper describing the search for a root hair vital stain will be published in Crop Science July-August 1990 issue with the title: Vital Staining of Root Hairs in Warm-Season Perennial Grasses. A paper confirming the accuracy of Evan's blue as a vital stain is being prepared for submission to Stain Technology in March 1990. This latter paper will include data on the storability of root hairs for later evaluation and the confirmation of Evan's blue viability accuracy with a sucrose drench. These data are presented in this report. Studies confirming root hair viability among the major warm-season turfgrasses have concentrated on one cultivar from each species. This work is in progress and will be reported in a Master's Thesis by June 1990. Other studies, comparing the absence or presence of a nucleus with root hair viability and the testing of Evan's blue as a whole root vital stain have been put on hold. All studies with cool-season turfgrasses have been cancelled due to grant termination.

Results - Table 15.1 shows that when compared to sucrose induced collapse, a standard test of viability, Evan's blue produces viabilities that are 95% of those shown by the standard sucrose. Table 15.2 shows that for all cultivars tested, viability increases from 0 to 3 wks, significantly for Tifway bermudagrass and Tx. Common St. Augustinegrass. This increase varies in magnitude depending where the sample was removed along the root. Table 15.2 also shows an increase from 0 to 3 wks in root hair number. This is a more dramatic increase, except in the crown region of Tx. Common St. Augustinegrass.

It appears that roots cannot be stored for later use in determining root hair density or viability due to growth of root hairs. One possible explanation is that the level of phosphate is too high in our medium, since root hairs have been known to increase with increasing levels of phosphate ion. The overall trend of root hair number from 0 to 6 wks in Tx. Common St. Augustinegrass may reflect the use of phosphate in the medium. This is the first time an increase in the root hair viability has been shown under similar circumstances. Table 15.3 shows regression equations produced from these data. These equations once confirmed may be used to take the results from stored data to produce an estimate of the results from fresh material.

Conclusions

1. **Evan's blue has shown itself to be an accurate vital stain when compared to the standard sucrose induced collapse.**
2. **Furthermore, since Evan's blue is a mordant stain it can be used in ongoing experiments without affecting plant material.**

Table B-15.1. A comparison of methods used to determine root hair viability: Evan's blue vs. sucrose.

	HO: Slope (b_0) = 1			HO: Intercept (b_1) = 0		
Species/Cultivar	Slope	P/F*	± STD error	Intercept	PR>T	± STD error
Bahiagrass:						
Pensacola	0.9485	F	0.01611	0.0540	0.0003	0.01489
Bermudagrass:						
Texturf 10	0.9581	P	0.0428	0.0332	0.4310	0.04203
Tifway	1	P	--	0	--	--
St. Augustinegrass:						
Tx. Common	0.9579	F	0.0201	0.03623	0.0599	0.01916
Zoysiagrass:						
Meyer	0.9054	F	0.0258	0.0736	0.0024	0.02398

*P/F indicates whether or not the real value of the slope passed a T Test comparison with the ideal slope ($b_0 = 1$) using the equation $t_{df} = |b_0 - 1|/s_{bo}$, where s_{bo} is the STD error of the real slope.

Table B-15.2. The effect of storage on root hair viability and number for three warm-season perennial turfgrasses.

Species Cultivar Part	Viability			Total		
	0 wks	3 wks	6 wks	0 wks	3 wks	6 wks
Bahiagrass:						
Pensacola						
Plant	0.9927 a	0.9952 a	0.9997 a	29.975 b	53.363 a	57.986 a
Crown	0.9924 a	0.9975 a	1.0000 a	39.051 b	74.498 a	75.822 a
Mid	0.9944 a	0.9911 a	0.9992 a	29.504 b	45.627 a	52.349 a
Cap	0.9913 b	0.9971 ab	0.9988 a	21.369 b	39.964 a	45.787 a
Bermudagrass:						
Tifway						
Plant	0.8003 b	0.9387 a	0.9611 a	5.371 b	12.255 a	14.176 a
Crown	0.7495 b	0.9201 a	0.9624 a	6.372 b	18.111 a	16.045 a
Mid	0.8101 b	0.9666 a	0.9723 a	4.822 b	9.576 ab	13.893 a
Cap	0.8873 a	0.9443 a	0.9521 a	4.503 b	7.242 ab	11.123 a
St. Augustinegrass:						
Tx. Common						
Plant	0.9177 b	0.9921 a	0.9903 a	9.750 b	18.614 a	9.842 b
Crown	0.9352 b	0.9970 a	0.9901 a	9.354 b	10.491 b	20.639 a
Mid	0.9120 b	0.9972 a	0.9911 a	10.662 b	17.685 a	9.907 b
Cap	0.8982 b	0.9809 a	0.9884 a	8.935 b	17.157 a	9.048 b

*The same letter within the rows of plant and plant part are not significantly different, Duncan's Multiple Range Test, alpha = 0.05.

Table B-15.3. Regression estimation of original root hair viability and number from stored material using the equation, $y = b_0 + b_1x$.

Species/Cultivar	Viability				Total			
	3 wks	STD error	6 wks	STD error	3 wks	STD error	6 wks	STD error
Bahiagrass:								
Pensacola								
Intercept (b_0)	1.168	0.158	1.709	1.594	13.707	6.712	15.610	7.003
Slope (b_1)	-0.176	0.159	-0.717	1.595	0.305	0.120	0.248	0.115
Bermudagrass:								
Tifway								
Intercept (b_0)	0.955	0.366	-0.062	0.839	4.254	0.531	4.495	0.698
Slope (b_1)	-0.148	0.387	-0.912	0.872	0.084	0.037	0.054	0.045
St. Augustinegrass:								
Tx. Common								
Intercept (b_0)	0.213	0.646	0.110	0.667	7.618	0.989	8.492	1.424
Slope (b_1)	0.708	0.652	0.813	0.674	0.110	0.049	0.118	0.139

B-17 Determine the effects of nitrogen and temperature on seasonal carbohydrate partitioning within the whole plant of a warm-season perennial turfgrass. Initiated in 1988. G. Forrester. This dual study also relates to Objective D - Mechanisms of Minimal Maintenance Turfgrass.

Status - Initial experimentation involved harvesting plugs from the Texas A&M University Field Laboratory each month for one calendar year. These plants were separated into leaf, stem, bud, root, and residual material. Soluble sugar and starch concentrations were assayed for in each plant part. See results section for data concerning this initial phase of experimentation.

The second phase of experiments involved placing ^{14}C-labeled St. Augustinegrass grown in PVC columns under three N levels (0.5, 1.0, and 1.5 lbs N 1000 ft^{-2} mo^{-1}) into simulated environmental growth chambers and subjected to two levels of chill stress. A severe stress involved placing a replication of turfs from each N level into a 5°C chamber to simulate a rapid decline in temperature. The remaining turfs were placed in a growth chamber where the temperature was gradually reduced from 30°C to 5°C. In these experiments plants were harvested at an actively growing phase, 50% shoot discoloration and at 100% shoot discoloration. The turf was separated into leaf, stem, bud, upper 15 cm roots, lower 15 cm roots, miscellaneous material consisting of sheaths and leaf blades not harvested with the leaf material, and residual material consisting of plant material in various stages of decomposition. Tissue analysis consisted of quantifying available carbohydrate concentrations (sucrose, glucose, and fructose) along with the storage carbohydrate (starch) concentration. Radioactivity was determined in three components (soluble sugars, starch, and residual material) in all tissue sections by the scintillation method. See results section for data concerning this phase of experimentation.

Results - Results of experimentation are as follows:

1. Growth Chamber Study

a. During the actively growing phase, a large percentage of the plant available and reserve carbohydrates were located in the leaf, stem, and bud sections (Figs. B-17.1, B-17.2, Table B-17.1). Evaluating the distribution of carbohydrates in each individual part, at active growth, shows that higher concentrations are located in the starch fraction (Table B-17.2). As a percentage of plant part TNC, the stem and bud sections had approximately three times more starch than soluble sugar while the leaf fraction had twice as much starch and the root fraction had nearly an equal distribution (Table B-17.1).

b. Analysis at 50% slow dormancy shows there was a significant increase in the soluble sugar concentration in the leaf, stem, and bud tissue (Fig. B-17.3, Table B-17.2). This increase in available sugars is offset by a decrease in starch concentration (Fig. B-17.4, Table B-17.2). The conversion was most pronounced in the stem and leaf tissue (Fig. B-17.4, Table B-17.2). Analysis for total plant carbohydrates shows that there was a significant decrease in the soluble sugar percentage with respect to plant sugars in the leaf and root with a significant increase in the bud fraction (Fig. B-17.1, Table B-17.1). Plant part starch with respect to whole plant starch shows a significant increase in the stem and bud with a significant decrease in the leaf (Fig. B-17.2, Table B-17.1).

Soluble sugar concentrations at 50% rapid dormancy shows the same trends as in the stem and bud sections for slow dormancy, however, the leaf and root fraction show a decrease (Fig. B-17.3, Table B-17.2). This increase in sugar concentration, however, is less pronounced. A similar tend can be seen in the decrease of starch, however, the decrease is more dramatic (Fig. B-17.4, Table B-17.2). Percentages of sugar and starch to part TNC in individual fractions at 50% rapid dormancy shows a greater conversion in the stem and bud tissue than at 50% slow dormancy with the leaf and root sections showing less of an increase (Table B-17.1). When analyzing for part nonstructural carbohydrates at 50% rapid dormancy as a percent of plant nonstructural carbohydrates, there is a decrease in both the available and reserve fraction in all plant fractions except the bud where an increase in carbohydrate percentage is evident (Figs. B-17.1, B-17.2, Table B-17.1).

c. Analysis at 100% dormancy showed that the concentration of starch was significantly reduced in all plant parts with rapid dormancy being more pronounced than slow dormancy (Fig. B-17.4, Table B-17.2). At 100% dormant, the soluble sugar concentration showed a significant overall increase from active growth in the stem and bud tissue for both temperature treatments with the root tissue showing a significant decrease during rapid dormancy (Fig. B-17.3, Table B-17.2). The leaf tissue at 100% slow dormancy showed a significant increase in soluble sugar concentration (Fig. B-17.3). With respect to 50% dormancy, the soluble sugar concentration showed a significant decrease in the bud and root section for both temperature treatments. The soluble sugar concentration in the leaf and stem sections remained the same or slightly decreased during slow dormancy and slightly increased during rapid dormancy (Fig. B-17.3). As a percentage of plant soluble sugar, there was a significant decrease in the leaf and root tissues for both temperature treatments when compared to the active growth stage while the stem and bud tissues showed a significant increase (Fig. B-17.1, Table B-17.1). As during slow dormancy, there was a significant increase in the stem, bud, and root sections with the leaf fraction decreasing slightly (Fig. B-17.2, Table B-17.1).

2. Field Study

a. Analyzing tissue harvested from the field shows that soluble sugar percentages increase in the leaf and root tissues and decreases in the stem and bud tissue as temperatures warm for spring greenup (Fig. B-17.5). During this phase the stem and bud tissue respond identically. As the season progresses into late summer and fall, sugar percentages decline slightly in the leaf and root fraction as the starch content increases in the stem section (Figs. B-17.5, B-17.6). The bud and stem tissues act inversely to each other during this phase. An increase can be seen in the soluble sugar percentage of the bud tissue as colder temperatures of winter approach (Fig. B-17.5).

Conclusions - Carbohydrate Partitioning:

1. **During active growth the major percentage of carbohydrates in the plant can be found in the starch fraction.**
2. **As the plant is subjected to chilling temperatures there is a rapid conversion of starch to soluble sugars increasing the amount of solutes in the plant liquid phase thereby depressing the freezing point. A slow dormancy shows a higher concentration of soluble sugars in all plant parts when compared to a rapid dormancy. The rapid dormancy showed a much greater loss of starch in all parts.**
3. **The ability of a plant to convert its starch to sugars when exposed to chilling temperatures may determine its cold temperature survivability.**
4. **At dormancy there is a very low concentration of total nonstructural carbohydrates in the root fraction. Any cultural practice during greenup that inhibits the plants' ability to translocate carbohydrates to the root may cause an energy stress to be placed upon that plant fraction.**

Table B-17.1. Summary of carbohydrate percentages in plant sections affected by temperature.

	RATIO X 100			
Temperature Treatment	Sol Sug Prt^{-1} / TNC Prt^{-1}	Starch Prt^{-1} / TNC Prt^{-1}	Sol Sug Prt^{-1} / Sol Sug Plnt^{-1}	Starch Prt^{-1} / Starch Plnt^{-1}
		Leaf		
Act Gro[1]	37.96 c*	62.06 a	18.87 a	12.86 b
50% Slo Dor[2]	62.35 a	37.36 c	14.07 b	8.37 c
100% Glo Dor[3]	59.13 b	40.78 b	17.39 a	12.41 b
50% Rap Dor[4]	59.00 b	41.35 b	11.54 c	12.49 b
100% Rap Dor[5]	62.08 ab	37.59 c	15.24 b	15.07 a
		Stem		
Act Gro	24.42 e	75.82 a	20.12 b	25.57 b
50% Slo Dor	39.50 d	60.49 b	20.87 b	31.35 a
100% Slo Dor	46.49 c	53.45 c	26.45 a	31.94 a
50% Rap Dor	52.80 b	47.05 d	16.69 c	22.81 b
100% Rap Dor	60.86 a	39.58 e	28.59 a	29.10 a
		Bud		
Act Gro	24.96 e	75.13 a	22.70 b	28.36 c
50% Slo Dor	50.26 d	49.56 b	35.88 a	34.50 a
100% Slo Dor	57.12 c	42.82 c	39.51 a	31.39 b
50% Rap Dor	66.94 b	33.83 d	36.70 a	28.57 c
100% Rap Dor	79.58 a	19.77 e	40.42 a	17.44 d
		U. Root		
Act Gro	43.61 c	56.44 b	6.72 a	3.59 c
50% Slo Dor	59.08 a	41.54 d	5.25 b	3.66 c
100% Slo Dor	36.51 d	63.41 a	3.31 c	5.97 b
50% Rap Dor	53.28 b	46.72 c	3.92 c	5.32 b
100% Rap Dor	36.06 d	63.91 a	3.25 c	9.08 a

*Means in the same column in the same plant section followed by the same letter are not significantly
different, Duncan's multiple range test, alpha = 0.05.
[1]Actively growing.
[2]50% slow dormancy.
[3]100% slow dormancy.
[4]50% rapid dormancy.
[5]100% rapid dormancy.

Table B-17.2. Summary of carbohydrate concentration in plant sections affected by temperature treatments.

Temperature Treatment	Soluble Sugar Concentration (μg/mg)	Starch Conc. (μg/mg)	Total Nonstructural Carbohydrate Conc. (μg/mg)
	Leaf		
Act Gro[1]	38.36 b*	60.91 a	97.30 a
50% Slo Dor[2]	48.15 a	27.90 b	76.31 b
100% Slo Dor[3]	46.85 a	30.13 b	75.31 b
50% Rap Dor[4]	34.85 b	24.97 c	60.56 c
100% Rap Dor[5]	35.69 b	22.57 c	58.34 c
	Stem		
Act Gro	39.22 c	118.00 a	156.90 b
50% Slo Dor	71.14 a	109.48 a	183.18 a
100% Slo Dor	69.38 a	72.94 b	141.71 b
50% Rap Dor	52.27 b	47.25 c	98.82 c
100% Rap Dor	65.52 a	42.60 c	107.93 c
	Bud		
Act Gro	45.15 c	134.39 a	178.61 b
50% Slo Dor	122.79 a	119.28 b	242.34 a
100% Slo Dor	101.87 b	76.32 c	176.13 b
50% Rap Dor	117.85 a	58.58 d	172.11 b
100% Rap Dor	92.59 b	25.53 e	121.08 c
	U. Root		
Act Gro	12.98 b	17.06 a	30.02 a
50% Slo Dor	17.06 a	12.33 c	29.22 a
100% Slo Dor	8.51 c	14.54 b	23.13 b
50% Rap Dor	12.03 b	10.56 d	23.17 b
100% Rap Dor	7.39 c	13.42 bc	20.92 b

*Means in the same column in the same plant section followed by the same letter are not significantly different, Duncan's multiple range test, alpha = 0.05.
[1]Actively growing.
[2]50% slow dormancy.
[3]100% slow dormancy.
[4]50% rapid dormany.
[5]100% rapid dormancy.

Figure B-17.1. Part soluble sugar as a percentage of plant soluble sugar for growth chamber study.

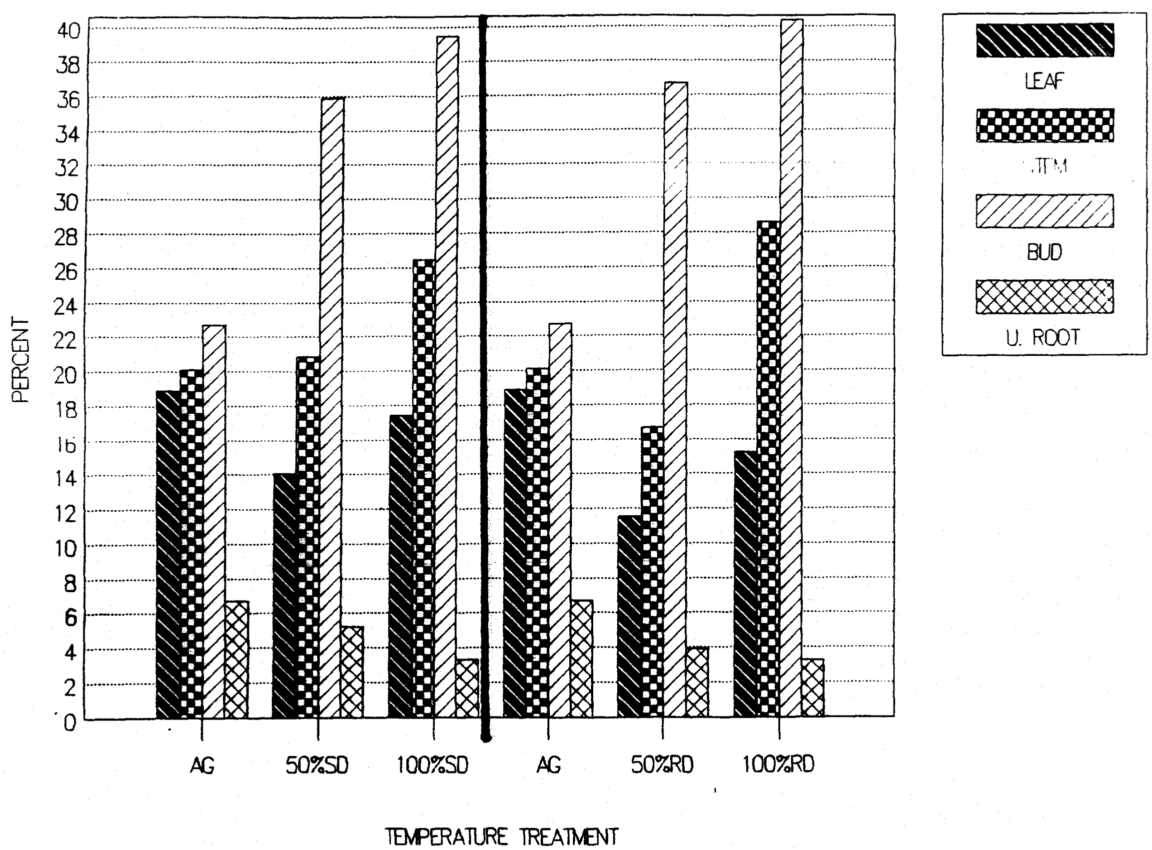


Figure B-17.2. Part starch as a percentage of plant starch for growth chamber study.

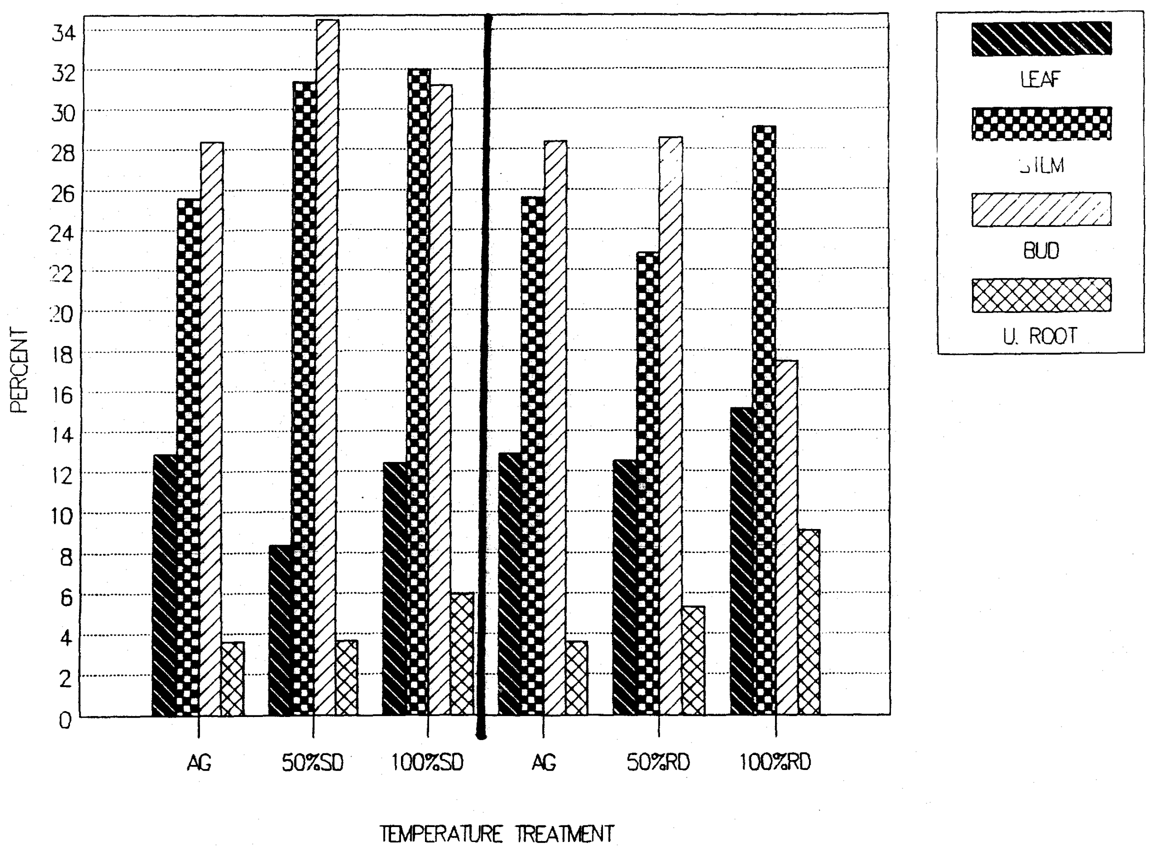


Figure B-17.3. Plant part soluble sugar concentration.

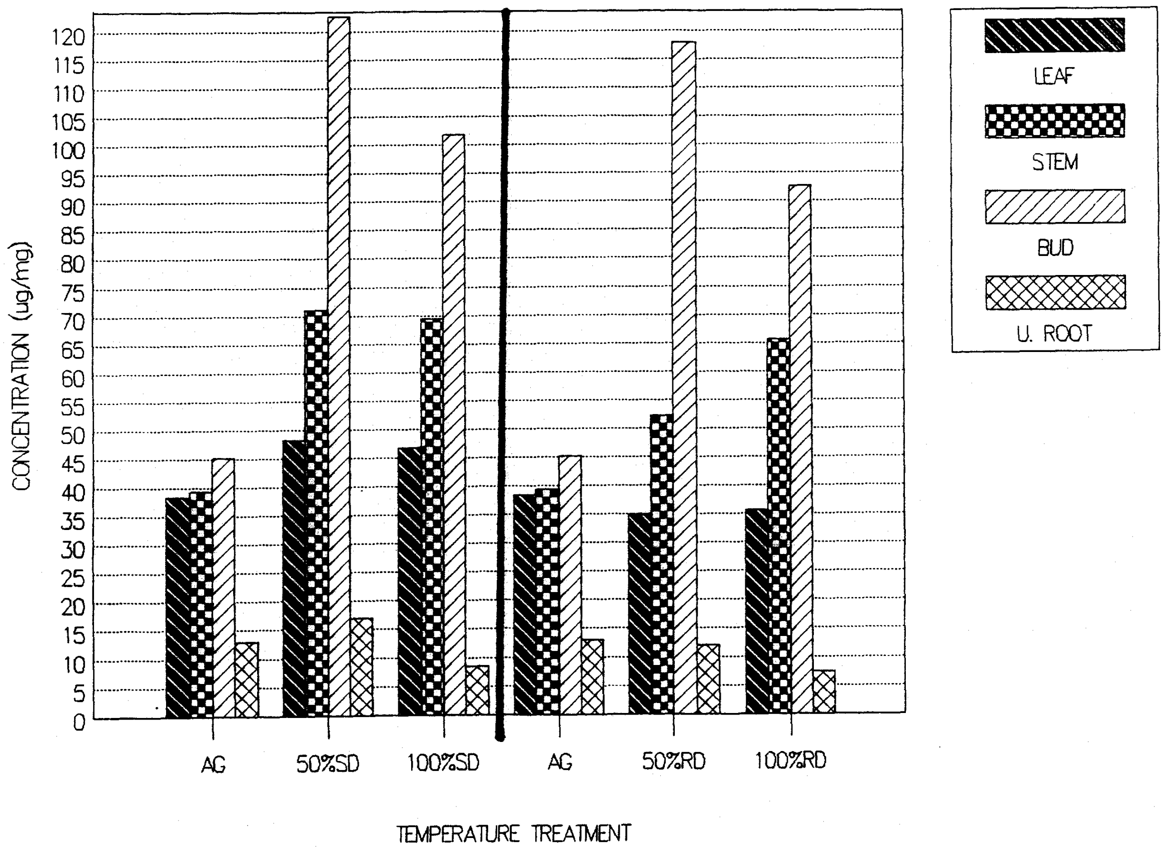


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Figure B-17.4. Plant part starch concentration.

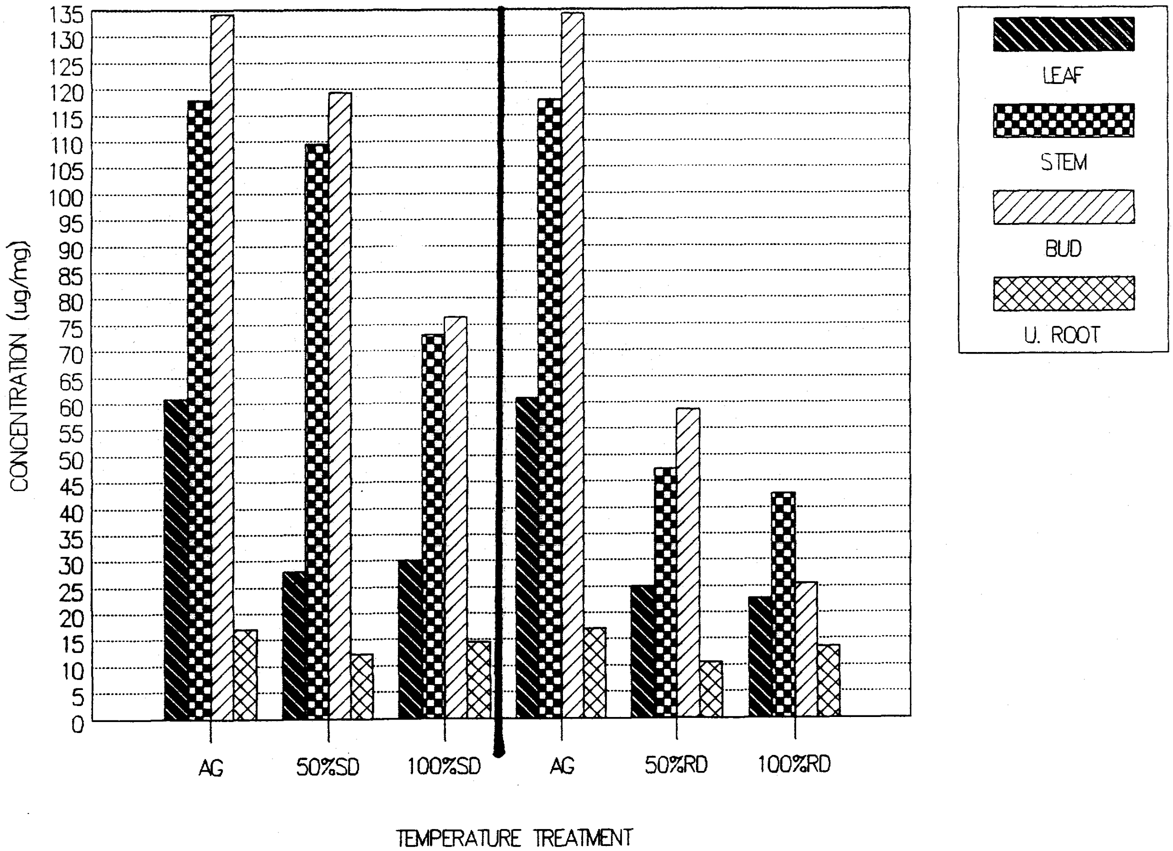


Figure B-17.5. Part soluble sugar as a percentage of plant soluble sugar for field study.

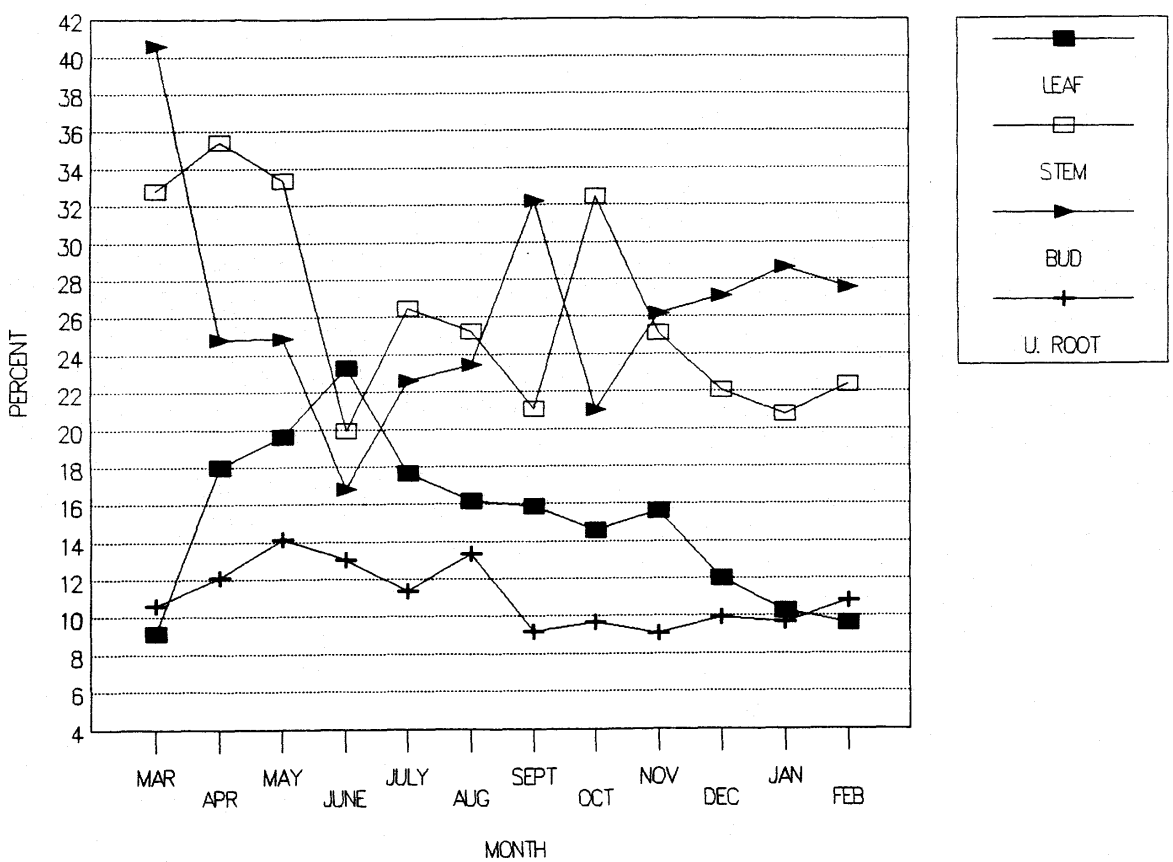
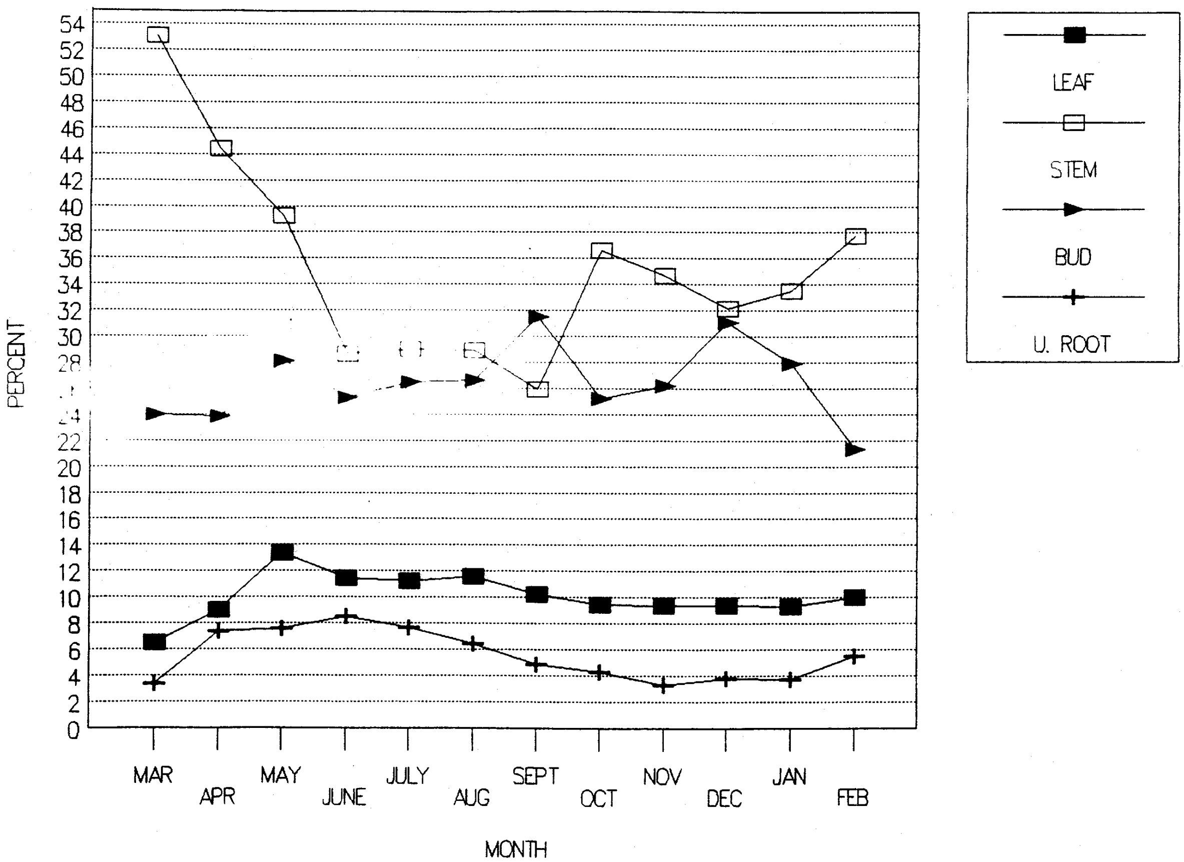


Figure B-17.6. Part starch as a percentage of plant starch for field study.



B-18 Determine if the carbon movement associated with spring root decline (SRD) can be altered by applications of plant growth regulators and hormones. Initiated in 1988. R. Green.

● Status - This study was cancelled due to grant termination. There is an urgent need to complete this study if funding can be secured.

B-19 Determining the effect of moisture stress on root hair density and viability in warm-season turfgrasses. Initiated in 1989. R. Green and M. Oprisko.

Status - This study has been changed to a field study on plants grown in a LIGIS plot. Two cultivars, 'Texturf 10' bermudagrass and 'Meyer' zoysiagrass, are being evaluated in the field. Data will be reported in a Master's Thesis, June 1990.

B-20 Assess root hair density, size and viability among field grown, warm-season turfgrasses. Initiated in 1989. R. Green and M. Oprisko.

Status - This study is in progress and the data being collected will be reported in a Master's Thesis, June 1990. Cultivars are 'Pensacola' bahiagrass, 'Meyer' zoysiagrass, 'Texturf 10' bermudagrass, 'Texas Common' St. Augustinegrass and 'Tifway' bermudagrass. In addition, the effect of height of cut on root hair density and viability will be determined on 'Tifway' bermudagrass.

C. OBJECTIVES FOR IMPROVED DROUGHT RESISTANCE: RESEARCH STATUS AND RESULTS

Following the onset of soil drought, a grass plant exhibits leaf rolling, firing of the outer lower leaves, eventually a cessation of growth, and finally total browning of the aboveground shoot tissues. At this point, it is defined as being in a state of dormancy. Once rainfall occurs, most perennial turfgrasses have varying degrees of ability to reinitiate new shoot growth, depending on the particular species and duration of drought stress. **Drought resistance** is broadly defined as the ability of a plant to survive an extended soil drought. Note that a turfgrass that has a low water use rate is not necessarily drought resistant. These are two entirely different physiological parameters.

An important component of drought resistance is termed **dehydration avoidance**. It encompasses such characteristics as a reduced evapotranspiration rate and deeper rooting which, respectively, slows the rate of water loss from the shoots and increases the ability to absorb moisture from a greater portion of the soil profile. As a result, the point at which a plant enters dormancy is delayed and, therefore, the potential period of time when a plant is subjected to severe moisture stress during dormancy is shortened. Thus, it can be seen that Objective A, concerning Minimal Water Use Rates, and Objective B, concerning Enhanced Rooting/Water Absorption, will provide information concerning two key dimensions of dehydration avoidance.

C-2 Characterize the morphological, anatomical, and physiological plant parameters associated with dehydration avoidance among 11 major warm-season turfgrass species. Initiated in 1984. K. Kim and S. Sifers.

Status - A two-year field study of the comparative dehydration avoidance among 11 warm-season grasses was completed on a newly constructed modified sand root zone. In 1985, a greenhouse study was completed to determine the contribution of rooting to dehydration avoidance. Subsequently a controlled environmental growth chamber study and a field study were conducted to determine if there were any stomatal associations with the dehydration avoidance mechanism of each grass. A polyethylene glycol (PEG) study was conducted in the greenhouse to insure a uniform root media water potential, by eliminating the rooting contribution. This approach could indicate the relative importance of the rooting and the stomatal contributions of each grass. The data were analyzed and summarized in a Doctoral Thesis which was mailed to each USGA Research Committee member and to the USGA Library in Far Hills, New Jersey.

● Another PEG study needs to be conducted in the glasshouse to assess the performance of each grass under 100% RH and a controlled PEG solution. This study is on hold due to grant termination, but urgently needs to be completed.

C-4 Assess the relationship between rooting characteristics and drought resistance of twelve major warm-season perennial turfgrasses. Initiated in 1984. S. Sifers and K. Kim.

Status - The initial study under non-limiting soil moisture conditions was completed during the winter of 1985 in the greenhouse and the data were analyzed in relation to dehydration avoidance. A Doctoral Thesis covering the data was mailed to each USGA Research Committee member.

● The rooting potential of the same grasses when under water stress has been investigated in PVC root columns that were established in the glasshouse. The study needs to be repeated due to problems encountered during the first experiment. Study is on hold due to grant termination.

C-7 Assess the relationship between rooting characteristics and drought resistance of 12 major cool-season turfgrasses. S. Sifers.

● Status - Study was not completed due to facility limitations and funding termination. (Mechanistic Study)

C-8 Assessment of dehydration tolerance studies using PEG and Manitol techniques on bermudagrass and St. Augustinegrass. Initiated in 1989. R. Green and M. Oprisko.

● Status - Study on hold. We urgently need to completed this study if grant funding can be secured. (Mechanistic Study)

C-9 Dehydration avoidance studies involving assessments of the rate of stomatal closure and wax formation using scanning electron microscope techniques on bermudagrass and St. Augustinegrass. Initiated in 1989. M. De Pew.

● Status - Leaf samples were collected along an identified gradient of differential water stress during the fall of 1989. Samples were prepared for mounting on aluminum stubs. Specimens are now ready for mounting and SEM observations. Investigator is finishing SEM training to be completed this spring. This is a critical study which we hope to complete in early summer.

D. OBJECTIVES FOR MECHANISTIC BASIS OF MINIMAL MAINTENANCE TURFGRASS: RESEARCH STATUS AND RESULTS

A basic premise of this overall research project thrust is that those turfgrasses that have greater water conservation characteristics also will possess characteristics contributing to turfgrasses that, from an overall standpoint, can be described as minimal maintenance types. Minimal maintenance implies the least possible resource requirements in terms of water and nutrients, plus low maintenance inputs such as labor, energy, and pesticides. One of the first priorities in investigations concerning minimal maintenance turfgrasses is to determine the morphological, anatomical, and physiological factors associated with a species possessing minimal maintenance traits. These traits can then be utilized by turfgrass breeders to provide a more sound basis for selecting minimal maintenance turfgrasses.

To date the results point to nitrogen stress tolerance as the key controlling factor. We have made good progress in understanding the physiological mechanism involved in nitrogen stress tolerance. The goal is to guide the grass breeder as to the selection criteria for low nitrogen requiring grasses. These grasses would reduce nitrate threats to ground water quality as the amount of nitrogen fertilization would be reduced substantially.

D-2 Assess the morphological, anatomical, and physiological plant characteristics associated with adaptation to low nitrogen requirements and their relationship to the drought resistance and recuperative potential of bermudagrasses. Initiated in the spring of 1986. S. Sifers.

Status - A preliminary field study has been completed in conjunction with objective C-5. Leaf extension rate, internode length, root mass relative to shoot mass, and visual quality were the parameters being measured and observed. The preliminary study was coordinated with objective C-5 which was beneficial. However, a separate study will now be required to allow plant nitrogen depletion and stress to occur before the drought and recuperation events.

A more detailed study was initiated. Turfs of Tifway, Santa Ana, Texturf 10, A-22, Midway, and FB-119 bermudagrass have been planted in 30 cm plastic pots. This selection of genotypes was based on field drought resistance data accumulated over the last four years. Two cultivars were selected from each of the relative classifications of high, medium, and low for leaf firing and shoot recovery. This study was not completed due to termination of grant funding. (Mechanistic Study)

D-3 Investigate the morphological, anatomical, and physiological plant parameters associated with minimal maintenance characteristics of zoysiagrass cultivars. Initiated in 1986. S. Sifers.

Status - A glasshouse study was initiated. Root observation columns were planted with Meyer, Emerald, and El Toro zoysiagrasses in the greenhouse. These cultivars were selected because they possess leaf width differentials from narrow to broad plus a variety of rooting characteristics. This study is a duplication of objective D-1, except the target species is zoysiagrass rather than bermudagrass. The study was not completed due to termination of grant funding. (Intraspecies Comparison and Mechanistic Study)

D-4 Investigate mechanisms associated with the adaptation of bermudagrass and zoysiagrass cultivars to regimes of low nitrogen availability (nitrogen stress) that permit cultivars to adapt to a minimum maintenance environment. Planned in 1986. S. Sifers.

Status - This study was placed on hold due to higher priority studies and funding reductions that resulted in a lack of available manpower. (Mechanistic Study)

D-6 See B-17 as this is an extensive dual objective study.

E. OBJECTIVES FOR IMPROVED WATER STRESS HARDINESS: RESEARCH STATUS AND RESULTS

Objective C is devoted to improve drought resistance from the aspect of dehydration avoidance and those external plant characteristics contributing to a low water use rate, enhanced rooting,and survival through dormant structures during extended periods of water stress. In contrast,

Objective E addresses the dimension of **dehydration tolerance**. This involves those internal plant characteristics that enable certain plant tissues to survive the water stress once the dehydration avoidance phase is terminated and the plant enters severe internal tissue moisture stress. Such dimensions as osmotic regulation, inherent internal tissue hardiness and plasticity, cellular structure, and certain physiological dimensions, such as proline/ABA synthesis need to be investigated in relation to dehydration tolerance. This research objective is critical to the development of improved dehydration tolerance/drought resistance in cool-season turfgrasses.

E-2 Investigate the cellular structure of turfgrass species and associated changes that occur during water stress, and characterize the possible relationship to the dehydration tolerance mechanism.

● Status - This study was designed to investigate the inter- and/or intracellular structure of warm-season turfgrass species before and after water stress. This major area of investigation has been placed on hold due to grant termination. (Mechanistic Study)

IV. SIXTH YEAR STATUS REPORT OF COMPLETED RESEARCH BEING PREPARED FOR PUBLICATION

The major research objectives and associated individual studies that are currently being written and submitted for publication in scientific journals are summarized in this section. A research project is really not fully completed until it has been written and published in both a scientific and a trade journal. The process includes (a) drafting and multiple revisions of a manuscript; (b) internal departmental review by three colleagues; (c) submission to the Texas Agricultural Experiment Station for a final review and assignment of a TAES manuscript number; (d) submission to the USGA Research Committee for review and approval; and (e) submission to the appropriate scientific journal where it is then reviewed by three peers in the field. Then following any revisions suggested by the reviewers, it is published in the scientific journal. Normally, this process requires from 8 to 18 months, depending on the extent of revisions suggested by the reviewers.

Major emphasis is being placed on manuscript preparation. Currently, this research project has in the publication phase the following.

A. Minimal Water Use Rate - 8 publications

B. Enhanced Rooting/Water Absorption - 4 publications

C. Improved Drought Resistance - 2 publications

D. Basis of Minimal Maintenance Turfgrass - 2 publications

E. Improved Water Stress Hardiness - 1 publication

A. MINIMAL WATER USE RATE: RESEARCH COMPLETED AND PUBLICATION STATUS

A-3 Compare the stomatal characteristics, densities, and distribution among ten major warm-season and twelve major cool-season turfgrasses under controlled environment growth chamber conditions. Initiated in 1983. D. Casnoff and R. Green.

Status - The warm-season turfgrass interspecies study was completed in 1985, and the scientific paper appears in the Sixth International Turfgrass Research Conference Proceedings 6:129-131. (Species Comparisons and Mechanistic Study)

A-5 Determine the comparative potential evapotranspiration rates of twelve major cool-season turfgrasses. Initiated in 1983. S. Griggs and R. Green.

Status - A detailed series of experiments was completed in the water/heat stress environmental simulator in 1986. A scientific paper has been accepted for publication in HortScience. (Species Comparisons)

A-6 Determine the potential for using turfgrass leaf growth inhibitors in water conservation. Initiated in 1983. K. Kim and R. Green.

Status - The greenhouse research involving two studies was completed in 1987. The scientific paper has been accepted for publication in HortScience. (Improved Cultural Systems)

A-7 Compare the influences of cutting height and nitrogen rate on the evapotranspiration rates of eleven major warm-season turfgrasses. Initiated in 1983. K. Kim and S. Sifers.
Status - Field studies over two years were completed in 1986. A scientific paper has been written and submitted to the Texas Agricultural Experiment Station for review. Revisions are now in process. (Improved Cultural Systems)

A-8 Determine the comparative genetic variability in evapotranspiration rates of 24 bermudagrass cultivars under non-limiting moisture conditions. Initiated in 1984. S. Sifers and K. Kim.

Status - A three-year study was completed in 1987, and the results were processed and analyzed. A scientific paper has been drafted and submitted for departmental review. Revisions are now in process. (Intraspecies Comparisons)

A-9 Assess the validity and relative accuracy of visual estimates of evapotranspiration rates using the canopy resistance - leaf extension concepts on mowed bermudagrass and zoysiagrass cultivars. Initiated in 1984. S. Sifers, G. Horst, and M. Engelke.

Status - A two-year study has been completed for mowed bermudagrass and zoysiagrass cultivars. Visual rankings for 24 bermudagrasses and 11 zoysiagrasses have been statistically compared to actual evapotranspiration rates. All data are now processed, and detailed statistical analyses were conducted by G. Horst. The scientific paper is being prepared with the research from objectives A-9 and A-12 being combined into one paper. (Breeding Markers)

A-10 Determine the comparative evapotranspiration rates for eleven zoysiagrasses that have a diverse array of canopy densities, leaf orientations, and leaf extension rates. Initiated in 1985. S. Sifers, R. Green, and C. Atkins.

Status - A manuscript has been submitted to HortScience. (Intraspecies Comparisons)

A-12 Assess the validity and relative accuracy of visual estimates of evapotranspiration on unmowed bermudagrass turfs using the high canopy resistance - low leaf area concept as it would be applied in a turfgrass breeding program. Initiated in 1985. S. Sifers, M. Engelke, and G. Horst.

Status - Greenhouse and field studies were completed assessing 24 unmowed bermudagrass cultivars grown in mini-lysimeters in 1987. Three evaluators, Dr.'s Beard, Engelke, and Horst, visually estimated the evapotranspiration rates across three replications of each turf cultivar. These assessments were compared statistically to the actual evapotranspiration rates by G. Horst. A scientific paper is being prepared by the collaborators. See A-9. (Breeding Markers)

A-16 Determine the comparative evapotranspiration rates for 10 St. Augustinegrasses. Initiated in 1985. S. Sifers, R. Green, and C. Atkins.

Status - A manuscript has been completed and is ready for departmental review.

B. ENHANCED ROOTING/WATER ABSORPTION: RESEARCH COMPLETED AND PUBLICATION STATUS

B-1 Characterize the root systems of 11 major warm-season turfgrass species under non-limiting and water stressed conditions. Initiated in 1984. D. Casnoff and S. Griggs.

Status - The research techniques for detailed characterization of grass roots have been developed as described in the 1985 Progress Report. Thus, more specific objectives are being pursued as outlined in Objectives B-8 and B-9. The techniques developed will be described in the paper published under B-2. (Techniques Study)

B-2 Assess the interspecific rooting potentials of 11 major warm-season turfgrasses under non-limiting moisture conditions. Initiated in 1984. D. Casnoff and S. Sifers.

Status - Research was completed in 1985, which included two glasshouse studies using the root-column facility. The scientific paper has been written, approved by the USGA Research Committee, and submitted to Agronomy Journal for publication. It is entitled "Assessment of the Interspecific Rooting Potentials of Eleven Warm-Season Perennial Turfgrasses under Non-limiting Moisture Conditions". The paper has been reviewed by the ASA editors and has been returned for revision. (Species Comparisons)

B-5 Determine the cause of spring root decline (SRD) of warm-season turfgrasses as well as methods to minimize its potentially negative effects. Initiated in 1984; with the biochemical studies initiated in 1986. S. Sifers and R. Green.

Status - Carbohydrate movement was found to be associated with SRD in St. Augustinegrass. This finding involved two replicated studies to determine the fate of radioactive carbon in St. Augustinegrass leaf, crown, and root tissue labeled prior to shoot dormancy and then induced into greenup under either SRD or non-SRD conditions. A manuscript of this work is in advanced preparation following turf project staff review. (Mechanistic Study)

B-8 Assess root hair location, density, size, and viability among 13 warm-season turfgrasses under non-limiting moisture conditions. Initiated in 1985. R. Green and M. Oprisko.

Status - Root hair studies I, II, III, and IV are completed and the data analyzed. A manuscript covering this work is ready for Departmental review. (Species Comparisons and Mechanistic Study)

B-14 Assess the extent of mycorrhiza development on the roots of four major warm-season turfgrasses and their relationship to evapotranspiration rates. Initiated in 1987. D. Knox.

Status - Assessments made on turfs from the TAMU Turfgrass Field Research Laboratory and from representative turf collected in the College Station, Bryan, Houston, and Dallas areas revealed very extensive mycorrhizal development on all the major warm-season turfgrasses. Inoculation experiments were conducted during the summer of 1987 in the greenhouse investigating the effect of mycorrhizal infection on evapotranspiration rates of the major warm-season turfgrasses. The water balance method, previously described, was used in this experiment which was completed in July. The data showed the presence of mycorrhiza increased the evapotranspiration rate significantly. Dr. Knox has returned to his faculty position in South Africa and we await his draft of a paper to be published as a TAES Report. (Mechanistic Study)

B-15 Determine the root hair viability among the major warm-season and cool-season turfgrasses. Initiated in 1987. R. Green and M. Oprisko.

Status - A manuscript covering the first phase of this project has been accepted by Crop Science. A manuscript of a second scientific paper has been completed and is ready for Departmental review before submission to Stain Technology.

B-16 Carbohydrate partitioning of warm-season turfgrasses from actively growing phase through shoot dormancy to shoot greenup phase as related to spring root decline. Initiated 1987. R. Green. A bound report was given to visiting USGA research committee members in the Spring, 1989. No further publications are planned.

C. IMPROVED DROUGHT RESISTANCE: **RESEARCH COMPLETED AND PUBLICATION STATUS**

C-1 Characterize the comparative drought avoidances, drought tolerances, and drought resistances of eleven warm-season turfgrass species. Initiated in 1984. K. Kim.

Status - Two years of field study on a newly constructed modified sand root zone, as well as in the glasshouse and in a controlled environment growth chamber utilizing mini-lysimeters have been completed. The data were analyzed and a Doctoral Thesis has been published. Copies were mailed to each USGA Research Committee member and to the USGA Library at Far Hills, New Jersey. Scientific papers have been prepared, submitted for Departmental review, and are now in advanced revision. (Species Comparison)

C-3 Characterize the morphological, anatomical, and physiological plant parameters associated with the drought resistance (i.e., recuperative ability) of eleven major warm-season turfgrass species following subjection to severe drought stress. Initiated in 1984. K. Kim.

Status - Three sets of preliminary studies were completed in both the field and glasshouse in 1984, followed by an extensive field study in 1985 and 1986. Shoot recovery was the primary response used in assessing the attributes related to drought resistance. Since drought resistance is the combination of dehydration avoidance and dehydration tolerance, the relative importance of factors contributing to drought resistance was investigated and assessed in relation to the results from dehydration avoidance study C-2. A more detailed physiological and anatomical investigation was conducted during the fall and winter of 1987-88. A paper has been drafted and is now in the revision phase. (Mechanistic Study)

C-5 Characterize the comparative drought resistances of the major warm-season turfgrass cultivars including 24 bermudagrasses, 6 zoysiagrasses, 6 centipedegrasses, and 5 St. Augustinegrasses. Initiated in 1985. S. Sifers and K. Kim, and J. Walker.

Status - Four years of field studies on a newly constructed modified sand root zone were completed, and the data were analyzed and summarized. In the third year of the study, new experimental selections were added to the field plot. They included 3 bermudagrasses from New Mexico State University; 3 cool-season turfgrasses (Kentucky 31 tall fescue, Adelphi Kentucky bluegrass, Pennfine perennial ryegrass) from the University of Nebraska; and 3 St. Augustinegrasses, 2 buffalograsses, and 4 zoysiagrasses from the Texas Agricultural Experiment Station at Dallas. A paper is in final editing after Departmental review. (Intraspecies Comparisons)

C-6 Characterize the ultrastructure and wax accumulation on the leaf surfaces and over the stomata, when under water stress, that are associated with drought resistance of warm-season turfgrass species. Initiated in 1985. K. Kim.

Status - The initial study with three species was conducted in a controlled environmental growth chamber during the winter of 1985, followed by an extensive study with eleven turfgrasses during the summer of 1986 conducted in the field. Leaf samples were freeze-dried and photographed with a scanning electron microscope to observe the stomatal characteristics and wax accumulation on both sides of the leaf blade. The results were analyzed and interpreted in relation to dehydration drought avoidance mechanisms of each turfgrass in a Doctoral Thesis that was mailed to each USGA Research Committee member. The draft of a scientific paper is in revision from Departmental review. (Mechanistic Study)

D. MECHANISTIC BASIS OF MINIMAL MAINTENANCE TURFGRASS: RESEARCH COMPLETED AND PUBLICATION STATUS

D-1 Investigate the morphological, anatomical, and physiological plant parameters associated with minimal maintenance-low nitrogen stress tolerance characteristics of bermudagrass cultivars. Initiated in 1984. S. Sifers.

Status - Both field and greenhouse studies were completed in 1986, including analyses of tissue fractions for nitrogen content. The data analyses are also completed. A Masters Thesis has been published and a copy mailed to each USGA Research Committee member. A draft of a scientific paper is in review for Departmental approval. (Intraspecies Comparisons and Mechanistic Study)

D-5 Investigate the nitrogen economy of 10 warm-season turfgrasses by ^{15}N-isotope and N-balance methodology. Initiated in 1987. R. Green.

Status - Analysis is completed and a manuscript is being written. (Mechanistic Study)

E. OBJECTIVES FOR IMPROVED WATER STRESS HARDINESS: RESEARCH COMPLETED AND PUBLICATION STATUS

E-1 Characterize the physiological changes occurring in the turfgrass leaf during water stress to determine possible dehydration tolerance (hardiness) mechanisms of the major warm-season turfgrasses. Initiated in 1985. K. Kim.

Status - An initial study was conducted during the winter of 1985 in a controlled environmental growth chamber with three species, followed by a greenhouse study with eleven turfgrasses. Leaf firing, shoot recovery and tissue proline content were examined. Data were collected, analyzed and interpreted in relation to the dehydration tolerance level of each grass. A proline investigation also was conducted in the field in the summer of 1986 to confirm the results from the previous studies. A research paper is now in review. (Mechanistic Study)

V. BUDGET STATUS

Cost containment has continued to be a high priority during the past 12 months.

VI. PUBLICATIONS

The scientific publication activity has been summarized in Section IV. In addition to the technical research papers being drafted, oral reports and published abstracts of research supported by the USGA were presented at the American Society of Agronomy Meetings in December of 1988, in Anaheim, California. They are as follows:

A. PAPERS PRESENTED AND ABSTRACTS PUBLISHED IN 1988:

1. The effects of flurprimidol and mefluidide on ET, leaf growth and quality of St. Augustinegrass grown at two soil moisture levels. R. L. Green, K. S. Kim, and J. B. Beard. 1988 Agronomy Abstracts, p. 151.

2. An assessment of vital and mortal stains for research of root hair viability of 12 warm-season perennial grasses. M. J. Oprisko, J. B. Beard, and R. L. Green. 1988 Agronomy Abstracts, p. 154.

B. PAPERS PRESENTED AND ABSTRACTS PUBLISHED IN 1989:

1. Turfgrass water stress: drought resistance components, physiological mechanisms, and species-genotype diversity. J. B. Beard. Invited Plenary Paper. VI International Turfgrass Research Conference. Tokyo, Japan. August, 1989.

2. Leaf blade stomatal densities of ten warm-season perennial grasses and their evapotranspiration rates. D. M. Casnoff, R. L. Green, and J. B. Beard. VI International Turfgrass Research Conference. Tokyo, Japan. August, 1989.

3. Contribution of root hairs to total root length in warm-season turfgrasses. R. L. Green, M. J. Oprisko, and J. B. Beard. American Society of Agronomy Annual Meetings. Las Vegas, Nevada. October, 1989.

4. Use of Evan's blue as a vital stain for root hairs. M. J. Oprisko, R. L. Green, and J. B. Beard. American Society of Agronomy Annual Meetings. Las Vegas, Nevada. October, 1989.

5. Comparative intraspecies and interspecies dehydration resistance of six major warm-season turfgrass species. S. I. Sifers and J. B. Beard. American Society of Agronomy Annual Meetings. Las Vegas, Nevada. October, 1989.

6. Seasonal photosynthate partitioning in St. Augustinegrass as influenced by nitrogen and temperature. G. Forrester, J. B. Beard, and R. L. Green. American Society of Agronomy Annual Meetings. Las Vegas, Nevada. October, 1989.

B. TAES PROGRESS REPORTS PUBLISHED:

Progress reports of research supported by the United States Golf Association were released to the public via Texas Turfgrass Research which is published annually by the Texas Agricultural Experiment Station. They are as follows:

1. "Comparative Evapotranspiration Rates of Thirteen Turfgrasses Grown Under Both Non-Limiting Soil Moisture and Progressive Water Stress Conditions" by K. S. Kim, J. B. Beard, L. L. Smith, and M. Ganz. Texas Turfgrass Research - 1983. p. 39.

2. "Spring Root Decline Induction Studies" by S. I. Sifers and J. B. Beard. Texas Turfgrass Research - 1984. pp. 8-14.

3. "The Effects of Nitrogen Fertility Level and Mowing Height on the Evapotranspiration Rates of Nine Turfgrasses" by K. S. Kim and J. B. Beard. Texas Turfgrass Research - 1984. pp. 77-81.

4. "Assessment of the Genetic Potentials for Root Growth of Eleven Warm Season Perennial Turfgrasses under Non-limiting Moisture Conditions" by D. M. Casnoff and J. B. Beard. Texas Turfgrass Research - 1985. pp. 10-14.

5. "Leaf Blade Stomatal Characterizations of Ten Warm Season C-4 Perennial Grasses and Their Association to the Water Use Rate" by D. M. Casnoff, J. B. Beard, D. G. Verwers, and S. D. Griggs. Texas Turfgrass Research - 1985. pp. 15-18.

6. "Spring Root Decline (SRD): A Research Summary" by S. I. Sifers, J. B. Beard, and K. S. Kim. Texas Turfgrass Research - 1985. pp. 19-30.

7. "Comparative Assessment of Wilting Tendency of Warm Season Turfgrasses" by K. S. Kim and J. B. Beard. Texas Turfgrass Research - 1985. pp. 143-148.

8. "Criteria for Visual Prediction of Low Water Use Rates of Bermudagrass Cultivars" by S. I. Sifers, J. B. Beard, and K. S. Kim. Texas Turfgrass Research - 1986. pp. 22-23.

9. "Morphological and Physiological Plant Parameters of Bermudagrass Cultivars with Low Nitrogen Requirements" by S. I. Sifers and J. B. Beard. Texas Turfgrass Research - 1986. p. 22.

10. "Comparative Drought Resistance Among the Major Warm-Season Turfgrass Species and Cultivars" by K. S. Kim, S. I. Sifers, and J. B. Beard. Texas Turfgrass Research - 1986. pp. 28-30.

11. "Leaf Blade Stomatal Characterization and Potential Evapotranspiration Rates of 12 Cool-Season, C-3 Turfgrasses" by R. L. Green, J. B. Beard, and D. M. Casnoff. Texas Turfgrass Research - 1986. pp. 8-9.

12. "Investigations of Root Hair Size, Number, and Distribution of Seven Species of Warm-Season Turfgrasses" by R. L. Green and J. B. Beard. Texas Turfgrass Research - 1987. pp. 1-4.

13. "Turfgrass Morphological Characteristics Associated with the Evapotranspiration Rate" by K. S. Kim and J. B. Beard. Texas Turfgrass Research - 1987. pp. 18-19.

14. "An Assessment of Cutting Height and Nitrogen Fertility Requirements of Adalayd Seashore Paspalum" by S. I. Sifers, J. B. Beard, K. S. Kim, and J. R. Walker. Texas Turfgrass Research - 1987. pp. 33-34.

C. SCIENTIFIC PAPERS PUBLISHED:

1. Johns, D., J. B. Beard, and C. H. M. van Bavel. 1983. Resistance to evapotranspiration from a St. Augustinegrass turf canopy. Agronomy Journal 75(3):419-422.

2. Beard, J. B. and M. C. Engelke. 1985. An environmental genetics model for turfgrass improvement: physiological aspects. Proceedings International Turfgrass Research Conference, France 5:107-118.

3. Engelke, M. C., J. B. Beard, and P. F. Colbaugh. 1985. An environmental genetics model for turfgrass improvement: developmental aspects. Proceedings International Turfgrass Research Conference, France 5:127-136.

4. Sifers, S. I., J. B. Beard, and J. M. DiPaola. 1985. Spring root decline (SRD): discovery, description, and causes. Proceedings International Turfgrass Research Conference, France 5:777-788.

5. Kim, K. S. and J. B. Beard. 1988. Comparative turfgrass evapotranspiration rates and associated plant morphological characteristics. Crop Science 28(2):328-331.

6. Beard, J. B. 1989. Turfgrass water stress: drought resistance components, physiological mechanisms, and species-genotype diversity. Proceedings International Turfgrass Research Conference, Japan 6:23-28.

7. Casnoff, D. M., R. L. Green, and J. B. Beard. 1989. Leaf blade stomatal densities of ten warm-season perennial grasses and their evapotranspiration rates. Proceedings International Turfgrass Research Conference, Japan 6:129-131.

VII. DISSEMINATION OF RESEARCH FINDINGS

Visibility for the USGA's support of our turfgrass water conservation research program has been achieved through speaking at key national and regional turfgrass conferences during the past year. The general topic is usually in the area of water conservation strategies and research updates related to rooting, water use rates, and drought stress. Addresses for 1988-89 have been or will be given before the following.

1. Symposium on Turfgrass Water Conservation in the Arid Southwest, Las Vegas, Nevada. November, 1988, by J. B. Beard.

2. Texas Turfgrass Conference, Fort Worth, Texas. December 1988, by S. I. Sifers.

3. Texas Turfgrass Conference, Fort Worth, Texas. December 1988, by R. L. Green.

4. Massachusetts Turfgrass Conference, Springfield, Massachusetts. March 1989, by J. B. Beard.

5. International Turfgrass Research Conference, Tokyo, Japan. August 1989, by J. B. Beard.

6. International Turfgrass Research Conference, Tokyo, Japan. August 1989, by J. B. Beard.

7. American Society of Agronomy Annual Meetings. October 1989, by R. L. Green.

8. American Society of Agronomy Annual Meetings. October 1989, by S. I. Sifers.

9. American Society of Agronomy Annual Meetings. October 1989, by M. J. Oprisko.

10. American Society of Agronomy Annual Meetings. October 1989, by G. Forrester.

APPENDIX

FEE STRUCTURE FOR TURFGRASS CULTIVAR/SELECTION EVALUATON

Department of Soil and Crop Sciences
Texas A&M University

A. FIELD PLOT TURF EVALUATION IN WARM-HUMID CLIMATE:

(4 year minimum, 6 by 15 foot plot size, 3 replications)

Assessments:

Establishment rate (Evaluations at 15-day intervals)
Seasonal turf quality (Evaluations at 15-day intervals)
Spring greenup
Fall low temperature color retention
Shoot density (annual)
Leaf extension rate (annual)
Morphological characteristics (annual)
Thatching tendency (third, fourth, and beyond)

Annual Fee Structure:

$1,800.00* - one entry of a species, plus standard
$900.00* - each additional entry of same species

B. TURFGRASS ENVIRONMENTAL STRESS ASSESSMENTS:

1. **Conducted in stress simulation facilities on potted turfs:**

   a) Evapotranspiration Rate
   (maximum ET assessed in simulation chamber)

   $750.00 - one entry of a species, plus standard
   $390.00 - each additional entry of same species

   Four months assessment time

   b) Drought Resistance/Dehydration Avoidance
   (conduct for two years, with three years preferred)

   $320.00 - one entry of a species, plus standard
   $200.00 - each additional entry of a species

   c) Genetic Rooting Potential
   (6 month minimum growth period in greenhouse columns)

   $590.00 - one entry of a species, plus standard
   $265.00 - each additional entry of a species

   Ten months assessment time

2. **Established turf field plots, as described in section A, are required for the following assessments:**

a) Evapotranspiration Rate
(field environment of one year duration minimum)

$850.00 - one entry of a species, plus standard
$420.00 - each additional entry of same species

Three month assessment time in summer, with two years assessment recommended

b) Cold Hardiness
(turfs drawn from field plots in December or January)

$620.00 - one entry of a species, plus standard
$220.00 - each additional entry of a species up to a total of ten, then start rate over

Two months assessment time, should be in winter to get natural field hardening

c) Wear Tolerance/Recuperative Potential
(simulation on field plots, with turf preferably 3 to 4 years old)

$1,000.00 - one entry of a species, plus standard
$500.00 - each additional entry of a species

Three month assessment time

d) Sod Strength
(harvested from established field turfs, preferably 1 year old)

$110.00 - one entry of a species, plus standard
$110.00 - each additional entry of a species

Six day assessment time, conducted during summer growing period

e) Transplant Sod Rooting

$250.00 - one entry of a species, plus standard
$250.00 - each additional entry of a species

Fifty day assessment time

All fees include a standard TAM System overhead charge:

All instrumentation, stress simulation, and field plot research facilities are in place. Fees will not be used for purchase of base facilities. Research Associates experienced with the techniques also are in place.

INQUIRIES ON ASSESSING BREEDER SELECTIONS

University of Nebraska:
- Drought resistance
- Dehydration avoidance
- ET rate
- Canopy characterization

New Mexico State University:
- Drought resistance
- Dehydration avoidance
- ET rates
- Canopy characterization

University of Arizona
- Rooting characteristics

Texas A&M University (Dallas):
- Zoysia characterization
- Drought resistance
- Dehydration avoidance