THIRD YEAR

PROGRESS REPORT

concerning

PHYSIOLOGICAL INVESTIGATIONS

in

DEVELOPING WATER CONSERVING, MINIMAL MAINTENANCE TURFGRASSES AND CULTURAL SYSTEMS

Volume III

Submitted by:

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I. EXECUTIVE SUMMARY

The research accomplishments of the first two years were summarized in the Executive Summary contained in the Progress Report, Volume II, October, 1985. The following listing contains those research conclusion drawn during the third year of USGA funding.

1. Visual assessment via the high canopy resistance - low leaf area concept offers a rapid, economical approach for screening large numbers of mowed bermudagrass or mowed zoysiagrass clonal plantings under field conditions for low water use rates.

2. Observer training and enhanced experience with this technique will ensure the best possible accuracy.

3. Visual assessment via the high canopy resistance - low leaf area concept offers a rapid, economical approach for screening large numbers of unmowed bermudagrass clonal plantings for low evapotranspiration rates under field conditions.

4. A procedure for incorporating radioactive $^{14}CO_2$ into turfs and then assaying shoot and root sections for radioactivity has been successfully developed and tested for use in rooting studies.

5. A system for growing turf, enabling the harvest of the entire root system with undamaged root hairs has been successfully developed and tested.

6. Substantial differences in terms of root hair distribution and length are evident among 13 warm-season turfgrass species.

7. The eleven major warm-season turfgrass species and cultivars vary substantially in drought resistance.

8. The mechanism of drought resistance varies among the warm-season turfgrass species.

9. Of the species studied, zoysiagrass, centipedegrass, and bermudagrass are more drought resistant than St. Augustinegrass and seashore paspalum.

10. A high leaf water potential, extensive root system, and high wax cover over the stomata contribute a high level of drought avoidance in bermudagrass and centipedegrass. This was confirmed by the higher leaf firing in the polyethylene glycol solution.

11. Since zoysiagrass possessed a shallow root system and low leaf water potential, a high drought tolerance is probably the major mechanism contributing to drought resistance. Low leaf firing in the polyethylene glycol solution supports this conclusion.

12. Early stomatal closure, degree of wax accmulation, rooting potential, and leaf firing contribute significantly to the avoidance dimension of drought resistance in warm-season turfgrasses.

13. Zoysiagrasses possess especially strong drought resistance due primarily to internal drought tolerance mechanisms.

14. Root extension length did not appear to be the controlling factor in drought resistance or the avoidance dimension. Tifway bermudagrass and St. Augustinegrass had long extentions, but poor drought resistance. Conversely, Texturf 10 and Tifgreen bermudagrasses had long extension and good resistance. Total root dry weight and root shoot ratio were similarly split,and no firm conclusion can be made.

15. With the exception of the St. Augustinegrass, it appears that the total number of roots in the soil profile is what influences which species are the most drought resistant.

16. These tentative conclusions need to be further investigated by examining more cultivars in each species and by concluding the drought phase for these eleven turfgrass now in the root column facility.

17. Significant drought avoidance and resistance differentials were found among the cultivars of bermudagrass and St. Augustinegrass.

18. The centipedegrass and zoysiagrass cultivars showed very good drought avoidance and resistance.

19. Most warm-season species having good drought avoidance and/or resistance had showed closed stomata or stomata blocked by wax layers.

20. The drought susceptible warm-season turfgrass species maintained open stomata and/or less wax accumulation across the stomata.

21. An early rate of stomatal closure after the onset of an internal water stress and the ability to form extensive wax layers across the stomata during water stress are two contributing mechanisms to drought avoidance which prevent water loss via transpiration.

22. Genetic diversity in terms of minimal maintenance adaptation to low nitrogen fertility regimes exists among bermudagrass cultivars and can be observed differentially as morphological, anatomical, and physiological plant parameters that can be statistically evaluated.

23. Leaf extention rate, internode length, visual quality when the nitrogen fertility rate is known, and tissue nitrogen content are useful parameters in identifying bermudagrass cultivars possessing low nitrogen stress tolerance.

24. An internal plant mechanism, such as a hormone, may be involved in partitioning available nitrogen between roots and shoots to equally sustain survival until the available nitrogen is depleted.

25. Root mass relative to the shoot mass to be supported may be more important than root length in terms of survival under low nitrogen stress.

26. No final conclusions can be made at this time. However, considering the shoot proline level found during water stress and the shoot recovery of each plant, it appears that proline may contribute to the survival of plants during severe water stress.

27. The shoot proline content may be an indicator of proneness to drought stress injury. Those turfgrass species that are prone to drought injury usually exhibited more rapid proline accumulation than other species that are relatively less susceptible to drought injury. This can be partially explained by the relationship between the degree of leaf firing and the ratio between the shoot proline level before and after water stress.

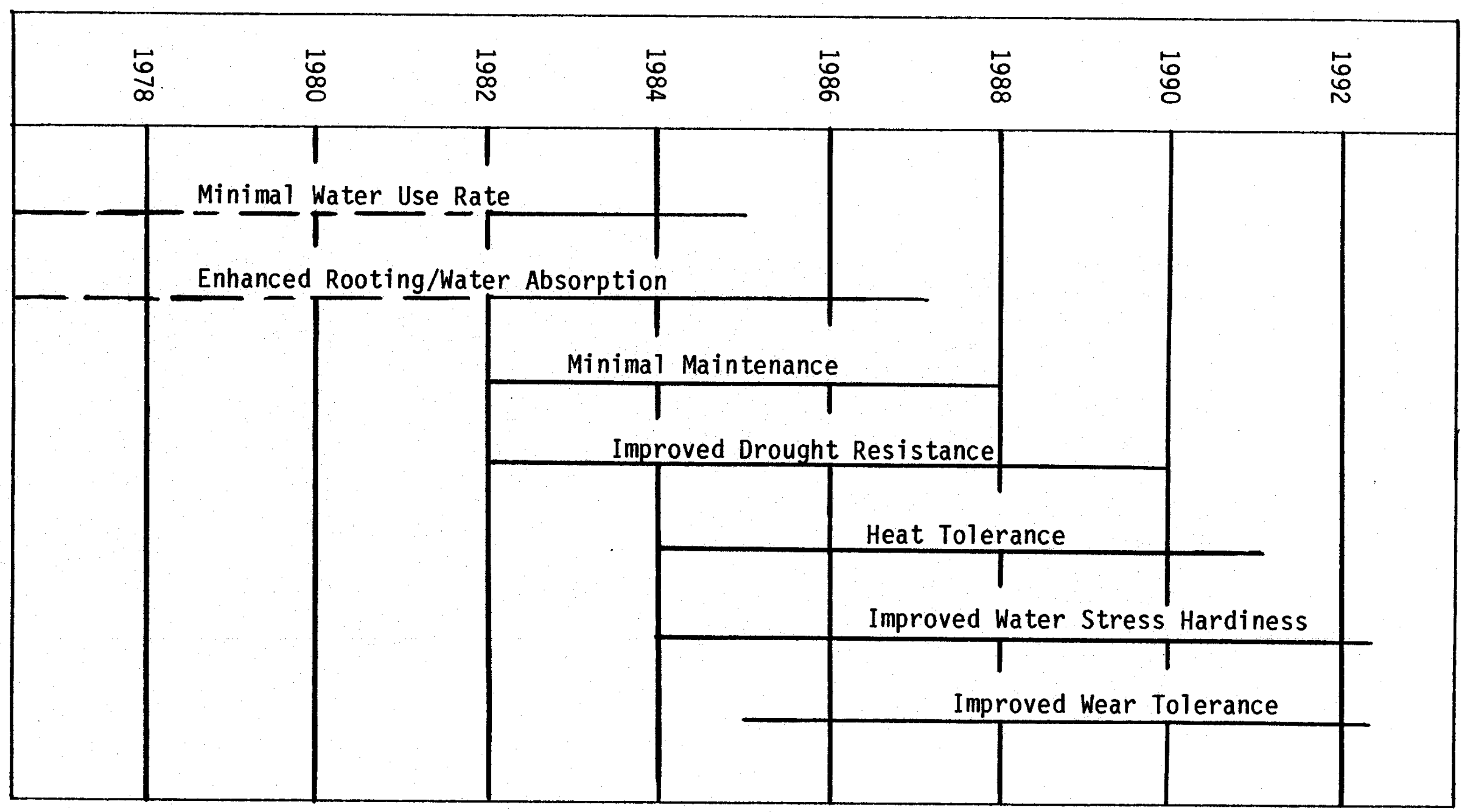
28. When considering the closing of stomata relative to the ABA content, it appears that the rate of ABA synthesis may contribute to stomata closure in these turfgrasses. Additional studies are needed for final confirmation.

II. INTRODUCTION

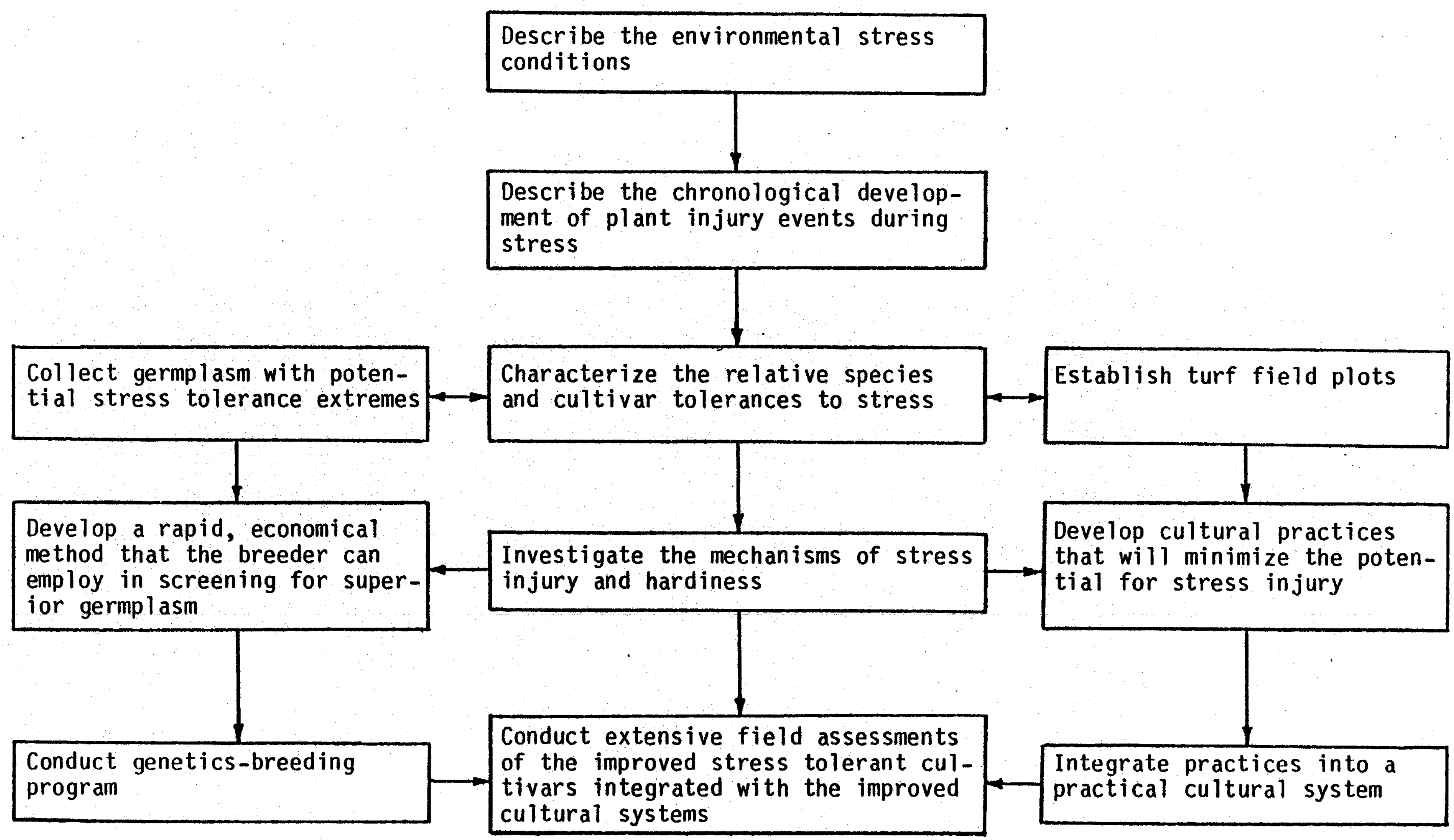
The original proposed time schedule for the major research objectives in developing water conserving, minimal maintenance turfgrasses and cultural systems follows. Our current progress is reasonably close to the original schedule. This cannot be sustained in the upcoming years, however, as the projected funds available are being reduced over the original plan. Thus, the time frame to complete ongoing studies will be extended. In addition, it may not be possible to pursue in depth the areas of heat and wear tolerance.

The research thrust in the area of Minimal Water Use Rates has already resulted in the development of techniques for turfgrass breeders to use in selecting for low water use rate turfgrasses. This is a major accomplishment. The second major thrust in the area of Enhanced Rooting/Water Absorption is more than 50% along the way to meeting the original objectives. This area requires an extended time frame because the propagation of roots within the 8-foot long column observation facility requires a minimum of 4 months for each study. In the third major thrust of Improved Drought Resistance, quite good progress is being made. Hopefully, these successes will continue in the next year. Finally, in the major area of Physiological Basis of Minimal Maintenance Turfgrasses, the preliminary descriptive work is well underway. This is a complex area where very little information exists, even from other plant species.

SCHEDULE OF RESEARCH ACTIVITIES BASED ON THE PROJECTED BUDGET LEVEL



An environmental stress physiology - genetics model to improve stress tolerance in turfgrasses.



III. IMPLEMENTATION

A. Organization

The research project organizational structure remains the same as for the initial three years. A reduction in funding level for the upcoming three years has necessitated a reduction in one full-time position and a reassignment of work across the remaining staff. This means that the amount of work that they will be able to achieve in the assigned areas under a given major research objective will be somewhat less than in the first three years. However, the staff is committed to making the maximum progress possible. Our facilities remain good, and we are hopeful that supplemental funds from an expanded research program of the Texas Agricultural Experiment Station will allow us to pursue the overall research goals of the project with a minimum amount of disruption.

B. Personnel

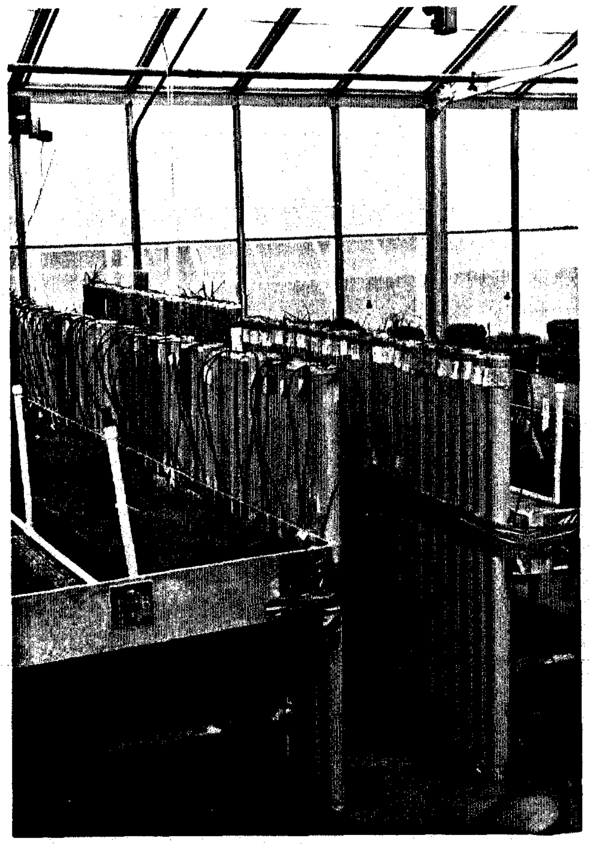
Some changes have been made in the research staff during the past year. Specifically, Mr. Steve D. Griggs accepted employment as Regional Agronomist with ChemLawn in California. His position has been filled by Mr. Ki Sun Kim, who has completed the coursework for his Ph.D. Mr. Kim is providing primary leadership in the area of drought resistance, including both avoidance and tolerance dimensions. He also has assumed responsibility for the statistical analyses and computer operations, which at this phase in the research are fairly extensive. A new graduate student, Mr. Paul H. Vermeulen, has joined us during the past year. He is pursuing a Master's degree and is working in the area of minimal maintenance turfgrasses.

C. Facilities Development

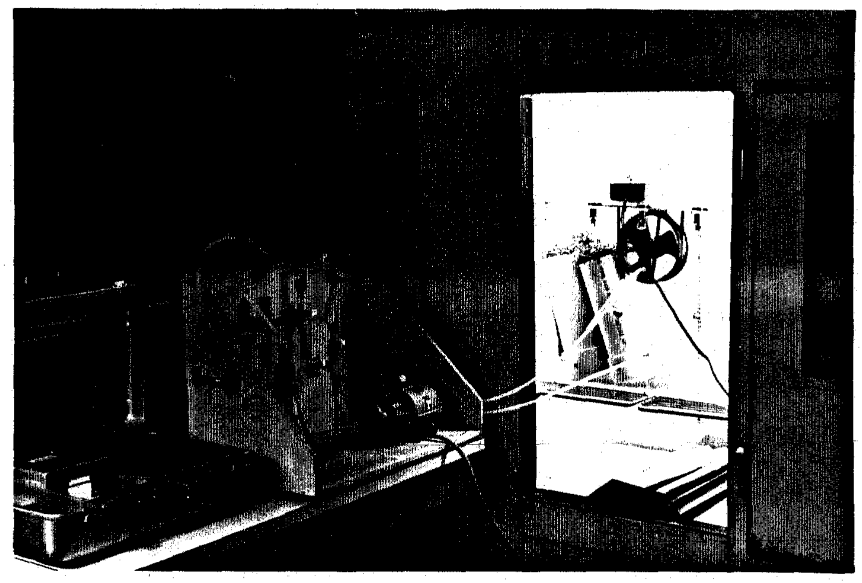
The status of our physical facilities to pursue the research objectives outlined for this project are quite good. Equipment breakdowns have been minimal during the year, except for one two-month period needed to repair the environment stress simulation chamber. Two new research facilities developed during the year include a mini-root column facility for root hair research and a $^{14}CO_2$ generation unit and exposure chamber for studies of carbohydrate partitioning during spring root decline and dimensions of drought resistance.

Root Hair Observation Facility. Columns are made of weathered PVC tubing, 5 cm in diameter by 122 cm long, and housed flexible plastic tubing, 5 cm in diameter by 121 cm long, which contain screened, washed masonry sand. The plastic tubing is stretched over a 5 cm-diameter ring and suspended within the PVC column. Pre-rooted, uniform propagules are planted, watered with automatic drip irrigation, and fertilized semi-weekly. At harvest, the flexible plastic tubing is removed from the PVC column and then cut away from the soil core. The entire root system is separated from the soil core by gentle washing with water.

Radioactive $^{14}CO_2$ Exposure Chamber and Radioactive $^{14}CO_2$ Generator/Pumping Apparatus. A maximum of eight mini-root columns can be simultaneously placed in the 133-liter exposure chamber which has a removable top, lined with a foam rubber seal and fastened to the sides with ten latches. The plexiglass sides and bottom of the chamber are assembled with screws and silicon sealant. An electric fan mounted on the chamber top provides uniform mixing of air. The exposure chamber is placed in a growth chamber to provide uniform environmental conditions during labeling. The exposure chamber is connected to the radioactive $^{14}CO_2$ generator/pumping apparatus by polyethylene tubing which forms a continuous-flow, closed circuit. The $^{14}CO_2$ generator/pumping apparatus is a self-contained unit, built of wood, which houses a moisture trap, electric pump, reaction test tube, sodium hydroxide trap, valves, and polyethylene tubing. Sodium carbonate ^{14}C solution is placed into the reaction test tube and lactic acid is introduced by a syringe to initiate the release of radioactive $^{14}CO_2$. The temperature within the chamber is monitored with a CR5 digital recorder connected to thermocouples leading into the exposure chamber. Following the exposure period, the air flow is directed through the sodium hydroxide trap, a CO_2 scrubber, until three chamber volumes have been passed through. Following scrubbing, the levels of radioactive $^{14}CO_2$ in the exhausted air are essentially zero.



Root Hair Observation Facility



Radioactive $^{14}CO_2$ Exposure Chamber and
Radioactive $^{14}CO_2$ Generator/Pumping Apparatus

TURFGRASS RESEARCH PROJECT
ORGANIZATIONAL STRUCTURE

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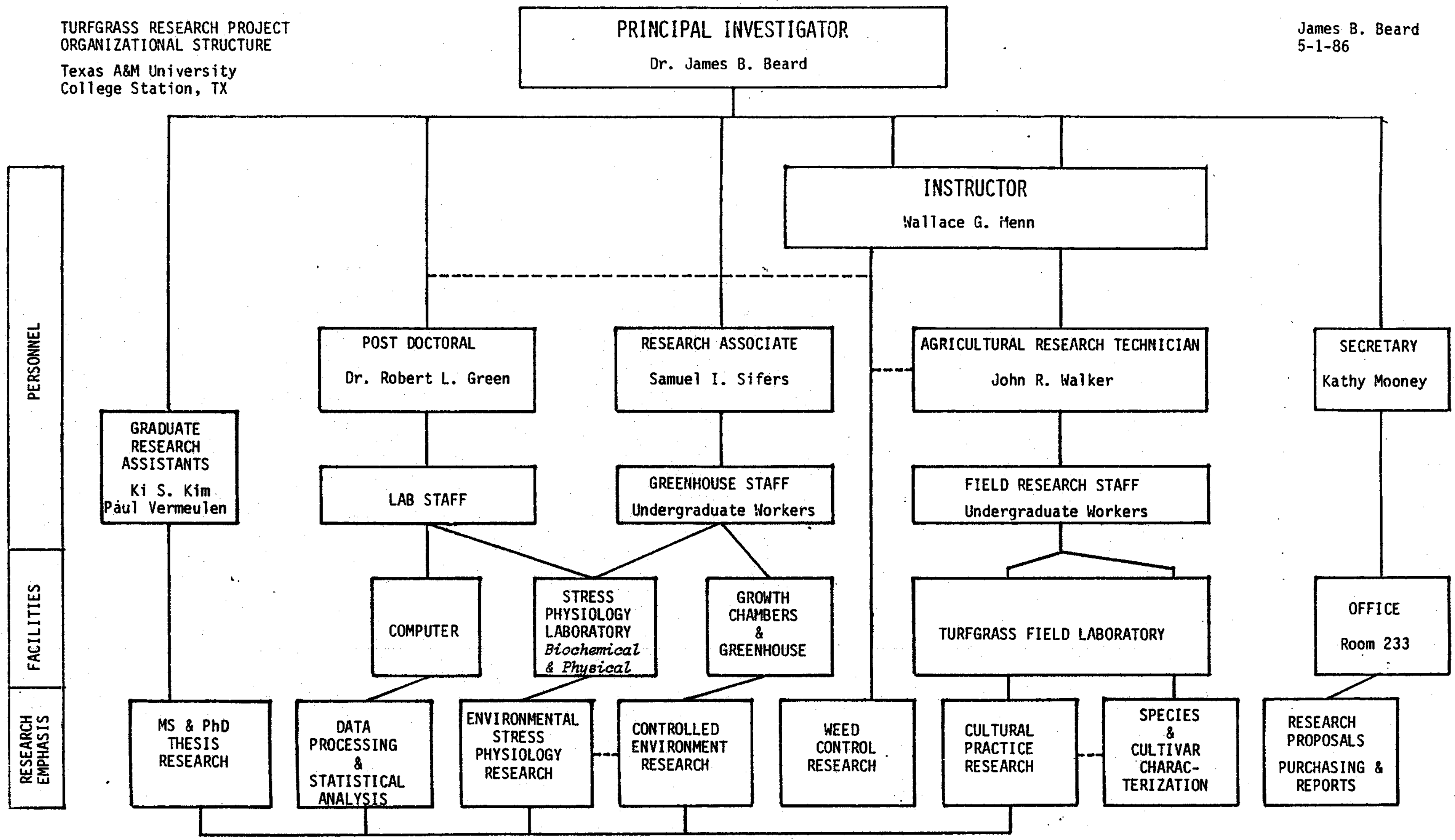

IV. ANNUAL STATUS REPORT OF ONGOING RESEARCH CONDUCTED DURING THE THIRD YEAR

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

A. Minimal Water Use Rates - Three studies are continuing two new studies have been initiated.

B. Enhanced Rooting/Water Absorption - Four studies are continuing, three new studies have been initiated, two studies are planned, and one study is on hold.

C. Improved Drought Resistance - Four studies are continuing, two new studies have been initiated, and one study is in the planning phase.

D. Mechanistic Basis of Minimum Maintenance Turfgrasses - One study is continuing, two studies have just been initiated, and one study is in the planning phase.

E. Improved Water Stress Hardiness - This is a new research thrust that was part of the overall master plan. The first study was initiated in 1986, and a second study is being developed.

A. OBJECTIVES FOR <u>MINIMAL WATER USE RATE</u>: 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-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.

<u>Status</u> - 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. (Breeding Markers)

<u>Results</u> - The experiments were conducted on field turf plots at the TAMU Turfgrass Field Research Laboratory which involved 24 bermudagrass and 11 zoysiagrass cultivars. The two species had been maintained at their

respective optimum cutting heights of 0.75 and 1.5 inches and received 0.5 kg nitrogen 100 m^{-2} (1 lb N 1,000 ft^{-2}) per growing month, as well as irrigation as needed to prevent visual wilt. The evapotranspiration measurements were accomplished using the water balance method with the mini-lysimeter technique. Three visual estimates of evapotranspiration rates were completed on both the mowed bermudagrasses and zoysiagrasses by the same four evaluators during the two years. These four evaluators, Drs. Beard, Engelke, and Horst and Mr. Sifers, made visual estimates of evapotranspiration rates based on the high canopy resistance - low leaf area concept. Indicators used were leaf canopy orientation, leaf extension rate, leaf width, and shoot density. Correlations between/with the visual estimate and actual evapotranspiration rates have been completed. There were differences in ratings among observers and between rating dates. The averages of all observations are reflected in Table A-9 by year. As can be seen, there was an overall improvement in the rating average as experience was gained in applying this visual technique.

Conclusions -

1. Visual assessment via the high canopy resistance - low leaf area concept offers a rapid, economical approach for screening large numbers of mowed bermudagrass or mowed zoysiagrass clonal plantings under field conditions for low water use rates.

2. Observer training and enhanced experience with this technique will ensure the best possible accuracy.

A-10 Determine the comparative potential evapotranspiration (PET) rates for 11 zoysiagrasses that have a diverse array of canopy densities, leaf orientations, and leaf extension rates. Initiated in 1985. S. Sifers, R. Green, and M. Engelke.

Status - The first year of a two-year study has been completed, and the initial results analyzed. The correlations among several parameters from 11 zoysiagrass cultivars included the actual evapotranspiration (ET) rates and leaf extension rates (LER) from both the field and those from the environment simulation chamber, and visual estimates of ET, LER, shoot density (SD), leaf width (LW) and leaf orientation (ORT), together with stomatal densities of abaxial and adaxial side of the leaf blades. (Intraspecies Comparison and Breeding Markers)

Results - There was a significant correlation between ET rates and LER in the environmental simulation chamber ($r = 0.166$, $P = 0.057$). However, no significant correlation was found between the above two in the field where other canopy resistance components were dominant. Overall, the ET rates from the chamber were higher than those from the field. There were good correlations among visually estimated parameters, such as ET, LER, SD, LW, and ORT. In the environmental simulation chamber study, there was a relationship between the leaf extension rate and the stomatal densities on the abaxial and adaxial sides of leaf blades ($r = 0.65$, $P = 0.0002$; and $r = 0.54$, $P = 0.0014$; respectively). There were

Table A-9. Average accuracy in visual ranking of evapotranspiration rates of mowed bermudagrass and zoysiagrass cultivars within years for four observers (Drs. Beard, Engelke, and Horst and Mr. Sifers) versus the actual evapotranspiration rates over a two-year period at College Station, Texas.

Year of Visual Estimation of Water Use Rates	Percent Accuracy by Four Observers vs Actual ET	Range
	24 Bermudagrass Cultivars	
1984	75%	62% - 83%
1985	77%	67% - 83%
	11 Zoysiagrass Cultivars	
1985	77%	64% - 81%
1986	82%	73% - 91%

some shifts between potential ET rates monitored in the simulation chamber and the actual ET rates observed from the field in terms of relative ranking of each cultivar. This study must be repeated for a second year under more controlled conditions before valid conclusions can be drawn.

A-11 Investigate more critically the influences of cutting heights and nitrogen/potassium nutritional levels on turfgrass evapotranspiration rates. Initiated in 1984. W. Menn, J. Walker, and S. Sifers.

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, and three potassium levels of 0.5, 1.0, and 1.5 pounds per 1,000 square feet. These cutlural treatments are combined in all possible combinations in three replications. The experimental site is a modified sand root zone with a subsurface drainage system. It is hoped that specific water use rate measurements using the water balance method with mini-lysimeters can be implemented in late 1987. (Improved Cultural Systems)

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 - One preliminary greenhouse study was completed assessing 24 unmowed bermudagrass cultivars grown in mini-lysimeters. Three evaluators, Drs. Beard, Engelke, and Horst, estimated the evapotranspiration rates across three replications of each turf cultivar. These assessments were compared to the actual evapotranspiration rate.

Results - The three evaluators achieved an average accuracy of 85% in identifying the 24 cultivars as having a high, medium, or low water use rate. A follow-up field study, using different observers to verify this technique, is planned for late 1986.

Conclusion - Visual assessment via the high canopy resistance - low leaf area concept offers a rapid, economical approach for screening large numbers of unmowed bermudagrass clonal plantings for low evapotranspiration rates under field conditions.

A-13 Determine the comparative evapotranspiration (ET) rates for 6 centipedegrass cultivars. Initiated in 1986. S. Sifers and J. Walker.

Status - The first year of field studies has been completed. A detailed analysis of the data is now underway. It is anticipated that final results will be published after the second year's results are completed in 1987. (Intraspecies Comparisons)

Result - Results of the initial year's study reveal significant differentials in evapotranspiration rates among the commercially available centipedegrass cultivars.

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

Developing 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 is "on hold" due to a lack of a functional rhizotron facility. Although specific funds have not been identified for the construction of a rhizotron/lysimeter/rainout shelter facility, a proposal is being prepared with the assistance of Dr. Wayne Jordan of the Water Resources Institute for submittal to a new University Research Agency which has set aside $18 million for short-term enrichment funds to develop facilities that will allow researchers to compete for grant funds from around the country. We are hopeful that it will be funded. 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 - A new series of studies were initiated in 1986: one each at 65°F (18°C), 75°F (24°C), 85°F (30°C), and 95°F (35°C) using pre-established sod plugs of 1 dm^2 grown in mini-root columns. The 1986 study is completed and the results are being analyzed. Iron, a seaweed extract, and oxamide are showing promise. Further studies are planned for 1987 based on the findings of these data. (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 experiments involved the development and testing of a procedure to monitor carbohydrate partitioning by radioactive ^{14}C assay. Studies to refine the radioactive labeling procedure are in progress. Replicated studies to determine if carbohydrate partitioning is involved in spring root decline in St. Augustinegrass and bermudagrass have been initiated and will be completed by April of 1987. Additional studies are planned to confirm and refine the results will follow later in 1987.

Results - The ^{14}C isotope technique developed for this spring root decline study, that also will be used in future drought mechanism studies, can be described as follows. Tifway bermudagrass and Texas Common St. Augustinegrass were planted in PVC root columns containing fritted clay. The columns are 10 cm in diameter and 30 cm long with a PVC cap on the bottom and a 5-cm wide glass observation window extending the full length of the column. The turfgrasses are grown under standard greenhouse conditions until uniform turf coverage of the soil surface is complete (about 6 weeks). The turfed columns are then placed in a high light, 5°C growth chamber until low-temperature shoot dormancy occurs. Next, one-half the dormant turfs are placed in a 35°C growth chamber to stimulate shoot greenup with SRD (SRD+); while the second half are removed to a 25°C growth chamber to stimulate shoot greenup without SRD (SRD-). Eight turfed columns are simultaneously placed in a 133-liter plexiglass chamber and exposed to $^{14}CO_2$ prior to the onset of shoot dormancy (before conditioning) and immediately following shoot greenup (during conditioning). The chamber is connected to a $^{14}CO_2$ gas generator/pump unit to provide a continuous flowing, closed circuit system. The exposure period is 45 minutes, during which 18.5 x 10^5 Bq (from sodium carbonate) ^{14}C is injected per column. Harvesting of the SRD+ and SRD- turfs occurs during (a) maximum root dieback, (b) early root regeneration, and (c) late root regeneration, as determined by visual observations of the SRD+ turfed columns. The turfs are separated into shoot and consecutive root sections, washed, dried, ground, and subsamples combusted in a Packard oxidizer. The resulting $^{14}CO_2$ in each sample is trapped in a scintillation vial containing Carbosorb. The trap solution is counted for radioactivity via a liquid scintillation counter. Data from the preliminary studies indicate the following.

1. It is possible to successfully incorporate an adequate amount of $^{14}CO_2$ into the plant tissue for radioactive assay.

2. Radioactive carbon is rapidly transferred throughout the entire shoot and root systems of bermudagrass.

3. The exposure time during radioactive labeling needs to be reduced to insure that the CO_2 concentrations do not limit photosynthesis or affect carbohydrate partitioning.

4. Difficulties have been encountered with the induction of shoot dormancy of bermudagrass. Experiments indicate that a fairly wide thermoperiodicity of at least 25°F is required to induce chilling-related low temperature discoloration.

Conclusions - A procedure for incorporating radioactive $^{14}CO_2$ into turfs and then assaying shoot and root sections for radioactivity has been successfully developed and tested for use in rooting studies.

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

Status - The initial study did not give statistically reasonable separations at the interspecies level for the cool-season turfgrasses. A combination of circumstances may have contributed to this, which required some modifications in procedures. Thus, our plans are for the study to be repeated during the fall and winter of 1986. The newly constructed root-column research facility will be utilized in these studies. (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 and J. Walker.

Status - The initial study of rooting capability under heat stress, was conducted during the mid-summer period in Texas. Minimal differentials in rooting capability were found among the twelve major cool-season turfgasses (see 1985 report). The only exceptions were crested wheatgrass and tall fescue. It is planned for the study to be repeated in the fall of 1986 under less severe heat stress conditions to observe if any additional rooting differentials will occur that would provide a more complete understanding of genetic rooting potentials under varying degrees of heat stress. (Interspecies Comparisons)

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.

Status - Root Hair Study I and Root Hair Study II are completed and were used to develop, test, and refine the growth assembly, cultural and propagation system, and the sampling, fixing, and microscopic root hair observation techniques. Data have been collected and analyzed from Root Hair Study II. Root Hair Study III and Root Hair Study IV, which are duplicates of Root Hair Study II, are scheduled for harvest when the longest adventitious root nears the bottom of the tube.

Results - The 13 C-4 perennial turfgrasses were grown under greenhouse conditions in PVC columns, 5 cm diameter by 122 cm long, which housed flexible plastic tubings, 5 cm diameter by 121 cm long, containing washed, screened masonry sand. Pre-rooted, uniform propagules are transplanted, watered via automatic drip irrigation, and fertilized semi-weekly. Each species is harvested when the deepest adventitious root nears the bottom of the flexible clear plastic tube, which is removed from the PVC column and then cut away from the soil core. The entire root system is separated from the soil core by gentle washing with water. Sections of adventitious roots, 2.54 cm long, along with their branches, are sampled at 15-cm intervals, starting from the root cap. Each root section is placed in a vial and sequentially submerged in a paraformaldehyde solution, 25% ethanol, and 50% ethanol and then stored in 70% ethanol for future microscopic determinations of root hair size, number, and distribution. In Root Hair Study I, we developed and tested the growth assembly, cultural and propagation system, and the sampling, fixing, and microscopic root hair observation techniques. In Root Hair Study II, we refined our cultural and propagation systems and further tested the sampling and microscopic root hair observation techniques. Root Hair Study II was harvested after 76 days growth. Results from Root Hair Study III and IV are needed to verify our findings. Findings from Root Hair Study II are listed below.

1. The warm-season turfgrass species are significantly different for the number of primary roots arising from adventitious roots. However, number of primary roots is not significantly influenced by depth (distance from the root cap).

2. The warm-season turfgrass species are significantly different for the number and length of root hairs arising from adventitious roots. The number is highly sensitive to depth, unlike length. This indicates root hairs rapidly attain maximum length, and their number

increases with root maturity.

3. The warm-season turfgrass species are significantly differnt for the number and length of root hairs arising from primary and secondary roots. Number and length of root hairs is not influenced by depth. This may indicate primary and secondary roots mature and produce root hairs in a more localized fashion, unrelated to the maturity status of the adventitious root. More data is needed to clarify this point.

Conclusions -

1. A system for growing turf, enabling the harvest of the entire root system with undamaged root hairs has been successfully developed and tested.

2. Substantial differences in terms of root hair distribution and length are evident among 13 warm-season turfgrass species.

B-9 Develop a reliable, practical model for determining the cumulative length of all roots on a soil volume basis. Initiated in 1986. R. Green.

Status - This objective and objective B-8 comprise the original objective B-1. Not only do we need to know the distribution and length of functional root hairs in estimating the total functional root hair zone, but we need to know the total length of functional roots. These plant parameters will address questions of enhanced rooting/water absorption more directly than measuring only root mass (weight) and root depth. Objective B-9 is in cooperation with Dr. Mark Hussey, TAMU forage breeder. (Mechanistic Study)

Approach - Two turf-type bermudagrasses, Tifgreen and FB119, and two forage-type bermudagrasses, Brazos and Coastal, are being grown under greenhouse conditions in PVC columns (10 cm diameter by 210 cm long) that are cut and rejoined forming 7 consecutive, 30-cm sections. Columns are filled with washed, screened masonry sand and connected to an automatic drip irrigation system to supply water and nutrients. This first project is scheduled for harvest in December, after 5 months growth. We are considering measurements of total shoot weight and total root weight (mass); plus root weight, area, volume, and length (subsamples) from each section. The objective is to determine the number of subsamples required to confidently estimate total root length when combined with total sample measurements, either root weight, area, or volume. We want to determine and test the confidence level of our subsampling procedure over a wide range of textures among bermudagrass (*Cynodon* spp.). A second study will probably be initiated, either duplicating the first or including additional species to further test and refine our procedure for estimating total root length.

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

Status - A root-column facility has been constructed. Turfs were planted during July of 1986. The study is progressing quite well. Sectional root harvests are planned for the late fall of 1986. (Intraspecies Comparison)

B-11 Assess the intraspecific rooting potentials of 11 zoysiagrass cultivars under non-limiting moisture conditions. To be initiated in late 1986. S. Sifers.

Status - A root-column facility has been constructed. The 11 zoysiagrass cultivars will be planted as space becomes available in the facility in late fall of 1986. (Intraspecies Comparisons)

B-12 Assess the intraspecific rooting potentials of 10 St. Augustinegrass cultivars under non-limiting moisture conditions. To be initiated in late 1986. S. Sifers.

Status - A root-column facility has been constructed. The St. Augustinegrasses will be planted as space becomes available in the facility in late fall of 1986. (Intraspecies Comparisons)

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 drought 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 the dimensions of drought avoidance. This is the reason we initiated Objectives A and B first, rather than the drought resistance studies of Objective C.

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

Status - A two-year field study and a greenhouse study using mini-lysimeter pots, plus a two-year field study on the newly constructed modified sand root zone have been completed. Data collected includes leaf firing, leaf folding, leaf water potential, stomatal density and opening, wax accumulation on leaf, leaf proline content, and shoot recovery rate. Rooting potentials were measured in the greenhouse utilizing 210-cm long PVC root-columns. A greenhouse study utilizing a hydroponic culture system containing polyethylene glycol (PEG) was completed during the summer of 1986, and is now being repeated. Leaf proline contents during water stress were assessed on turfs grown in 4-cm diameter containers in the greenhouse. In the controlled environment growth chamber, St. Augustinegrass, bahiagrass, and Common bermudagrass were evaluated as to on their responses and physiological changes, such as leaf proline and absisic acid (ABA) contents, along with ultrastructure characterization via a scanning electron microscope. The data have been analyzed. (Species Comparisons)

Results - Drought resistance was determined according to the survival or recovery of the plant after severe water stress (Table C-1). Zoysiagrass, three bermudagrass cultivars, and centipedegrass exhibited high drought resistance; whereas St. Augustinegrass, seashore paspalum, and Tifway bermudagrass showed poor drought resistance.

Drought avoidance was determined by the degree of leaf firing during progressive water stress in the field, on the assumption that drought avoiding species maintain high leaf water potentials and the resultant high turgor and less leaf firing. Bermudagrasses, centipedegrass, and zoysiagrass had good drought avoidance; while St. Augustinegrass, seashore paspalum, and Tifway bermudagrass showed poor drought avoidance.

Assuming that drought resistance can be attributed to the combined effects of drought avoidance and drought tolerance, the drought tolerance was determined from the relative drought avoidance and drought resistance responses. A uniform water stress imposed by polyethylene glycol (PEG) could eliminate the water uptake/transpiration factors, and, thereby aid in the assessment of drought tolerance. For example, zoysiagrass does not possess a better rooting potential than centipedegrass, and had less leaf firing in the PEG solution. This suggests that zoysiagrass has a better drought tolerance capability than centipedegrass. Based on field study, buffalograss and bahiagrass showed similar drought resistance under water stress. However, based on the better survival of buffalograss in the PEG study and since buffalograss possessed a less extensive root system, it suggests that buffalograss has a better drought tolerance capability than bahiagrass. Additional experiments are needed to explain the ambiguous phenomena among certain species or cultivars.