1990

ANNUAL PROGRESS REPORT

concerning

BREEDING AND DEVELOPMENT OF ZOYSIAGRASS

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1990 ANNUAL RESEARCH REPORT
ZOYSIAGRASS BREEDING AND DEVELOPMENT

EXECUTIVE SUMMARY

1990 Annual Zoysiagrass Progress Report

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Research Period: 1 November 1989 to 1 November 1990

A major redirection within the zoysiagrass program occurred in 1989 and 1990 with the addition of Dr. Richard H. White, as Assistant Research Scientist specializing in turfgrass physiology, and Dr. Bridget Ruemmele in turfgrass breeding. The combined efforts of the group have been directed specifically to the assessment of germplasm relative to stress tolerance mechanisms and the specific hybridization of selected accessions in order to study the relative heritabilities of such traits and to combine multiple desirable traits into new varieties. Considerable progress has been made in the area of developing seeded zoysiagrasses.

Maintenance of the zoysiagrass germplasm nurseries will receive considerable attention these next few years due to the reduction in turfgrass research efforts on the part of the United States Department of Agriculture. Due to Federal budget problems, the Oriental zoysiagrass collection is being preserved vegetatively at TAES-Dallas, however no funds are available to complete the documentation, nor to develop the CORE collection for entry into the Plant Introduction (PI) System, nor for increase and distribution. Regardless, vegetative maintenance and production of these accessions, as well as newly developed cultivars has become streamlined and more expedient with the use of thin-layer sod production techniques developed here. Once entered into the PI system the CORE collection will be available to requesting agencies as prescribed by the rules and regulations of the USDA Plant Introduction system.

Numerous elite accessions of zoysiagrasses have been evaluated for water-use requirements under field conditions using the Linear Gradient Irrigation System (LGIS). Major separations have occurred for plant growth response and survival among zoysiagrass cultivars and accessions. Of the commercial cultivars, El Toro and Belair required less water than Meyer or FC13521. A number of the DALZ lines have remarkable potential to recover from drought stress. The Turfgrass Root Investigation Facility (TRIF) has provided considerable information on the rooting characters of many of the elite lines. The shade trials continue with marked separation of plant materials in their ability to persist and grow under limited light. The combined testing facilities suggest considerable genetic variability exist within the elite accessions (DALZ lines) as well as the Oriental collection. Of greatest promise is the variation noted for water-use, canopy temperature, growth response, growth habit, texture and turf quality. Regional trials suggest good variability exists among the lines under evaluation for cold hardiness, rate of spread, texture and turf quality.

Results from 11 regional field trials continue to provide excellent information on area of adaptation and potential utility of the elite accessions under development. Regional field trials are located in; Missouri, Illinois, Arizona, California, Oklahoma and Florida as well as several locations in Texas. Electrophoresis has been completed on 23 DALZ lines by Dr. Lin Wu, University of California - Davis. DNA finger printing has been completed by Dr. Lloyd Callahan, and Dr. Peter Gresshoff (University of Tennessee) on 5 elite lines in comparison to Meyer zoysiagrass.

The National Turf Evaluation Program will sponsor a Zoysiagrass trial to be planted in the spring of 1991. A total of 23 entries including 4 commercial varieties will likely be included, and that approximately 30 locations across the United States will participate. This project will enter approximately 10 elite accessions. Data from these National test are invaluable in defining adaptive characters as well as potential utilities of newly developed varieties. TAES-Dallas will assume the responsibility for increasing all of the germplasm of these trials, with distribution anticipated in mid-May 1991.

Numerous selections have been identified in the Oriental Collection for turf quality, color retention, greenup, drought hardiness, seed production potential, and numerous desirable agronomic traits. Approximately 1500 progeny are under field evaluation for turf performance and seed production potential. Heritability studies and parent-progeny populations are included for seed production, drought resistance, root characters and general turf performance.

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1990 ANNUAL ZOYSIAGRASS REPORT

M. C. Engelke, R. H. White, B. A. Ruemmele, and S. J. Morton

I. INTRODUCTION

The Zoysiagrass Breeding and Development program is in its seventh year of funding through the United States Golf Association. The cooperative effort between the Texas Agricultural Experiment Station and USGA to develop improved zoysiagrasses for the golf and turf industry was initiated in May 1984. To date $292,085 has been directed by the USGA/GCSAA research to the zoysiagrass breeding program. The present grant provides $45,000 annually. In order for the program to continue at the level it is presently operating, additional funding will be necessary in the near future. This report will address project activities especially for the period November 1, 1989 through November 1, 1990.

II. TECHNICAL SUPPORT PERSONNEL

Dr. Bridget Ruemmele was employed January 1989 as Post-Doctoral Research Associate on the Turfgrass Breeding Program. Funding for Dr. Ruemmele's position is provided in its entirety by Texas Agricultural Experiment Station. Approximately 60% of her time is directed to the zoysiagrass breeding program, with specific emphasis being directed to germplasm development.

Dr. Richard H. White joined the Turf Breeding Staff at TAES-Dallas effective 1 May 1989 as an Assistant Research Scientist. Dr. White's responsibilities center on the physiological development of zoysiagrass germplasm with special emphasis on drought resistance and water use characters. Approximately 80% of Dr. White's time is spent on the zoysiagrass breeding program.

Ms. Sharon Morton has joined the zoysiagrass breeding program effective 1 September 1989, under the supervision of Dr. White. Ms. Morton's position is funded from contracts with numerous chemical companies for product evaluation and the Texas Department of Transportation. Approximately 80% of her time is spent on the zoysia project.

Mr. Robert Cunningham provides part-time technical assistance for Dr. Ruemmele and is funded from contracts with numerous chemical companies for product evaluation and the Texas Department of Transportation. Approximately 60% of his time is spent on the zoysia program.

III. IMPLEMENTATION

A. GREENHOUSE AND LABORATORY PROGRESS

1. GERMPLASM MAINTENANCE

The *Zoysia* spp. germplasm of over 800 unique accessions continues to be maintained in Deepots in the greenhouse to insure individual integrity. Individual plants have been maintained in this high density arrangement under greenhouse conditions since 1983. Less than 1% cross pegging (contamination) occurs between pots. This high density arrangement increases space efficiency by approximately 50% over terra-cotta pots of similar size. This procedure simultaneously provides a fixed position for ease of cataloging and a significant reduction in risk of germplasm contamination. An intensive inventory, genetic purity check and repotting occurs every 3-4 years and was completed over the past year. This involved cross-checking labels and plant materials with historical records and relabeling each sample in triplicate as stolons are transferred to new pots and growth medium. The TAES-Dallas zoysia germplasm inventory was cross-checked with the zoysia inventory in Beltsville, Maryland. A list of non-duplicated material is in Beltsville at this time. Any available, non-duplicated material in Beltsville will be transferred to the Dallas collection prior to elimination of the Beltsville collection this year.

In October 1988, Mr. J. J. Murray, USDA, ARS, Beltsville, Maryland retired and, in February 1989, his position was officially closed. To date, none of the zoysiagrass germplasm collected in 1982 has been entered into the United States Department of Agriculture Plant Introduction (PI) System. A preproposal was submitted to the USDA Germplasm Crop Advisory Committee for Grasses to support a research project developing a CORE collection of zoysia from the Oriental Collection to be included in the PI system. Tentative approval of the proposal has been made. A full proposal was submitted in February 1990. In addition, a proposal was written in March, 1990 for a cooperative project between TAES-Dallas and the USDA PI Center - Griffin, Georgia for the short-term (3-5 years) maintenance of the germplasm collection until necessary facilities can be constructed at Griffin, Georgia where the CORE collection will ultimately be maintained within the USDA Plant Introduction System. This proposal remains pending.

2. ELECTROPHORESIS ANALYSES

Two students at Austin College in Sherman, TX, under the direction of Drs. George Diggs and Peggy Redshaw, conducted electrophoretic analyses of 4 experimental DALZ lines and 3 commercial zoysias during summer, 1990. Results have not been obtained to date.

3. RFLP ANALYSES

Dr. Lloyd Callahan, at the University of Tennessee, is using DNA fingerprinting analysis to assess 5 DALZ experimental lines for unique characters compared to selected commercial zoysias. Results have not been obtained to date.

B. FIELD EVALUATION AND PRODUCTION TRIALS:

1. DALLAS FIELD TRIAL - MANAGEMENT

INTRODUCTION: Zoysiagrass is one of the least utilized warm season turfgrasses in the United States. This is partially due to the limited number of available cultivars, slow establishment, and relatively high cost of production in comparison to other warm season grasses. In the recent past, interest in Zoysia spp. has increased as new cultivars have emerged and the potential of several experimental selections has become apparent. Acceptance and utilization of new cultivars of zoysia also depends on development of appropriate and efficient management strategies. Emphasis must be placed on determining minimum and optimum requirements for producing superior turf, with particular attention given to turf quality, persistence, and thatching tendency relative to fertilization and mowing.

OBJECTIVES: Develop and refine cultural strategies and practices that optimize turf quality and resource efficiency for existing and newly developed zoysiagrass cultivars for southern regions of the United States.

PROGRESS: During the winter of 1987 to 1988, plant material was increased under greenhouse conditions to provide a 1:36 (1 m^2 sod to 36 m^2 land surface) field expansion planting ratio. The field planting material consisted of 3.8 cm plugs planted on 0.3 m centers. The field plot design is a randomized complete block, consisting of three replications of 10 entries. Plot size is 5.79 m by 4.27 m. Cultivars in this management trial include Meyer, Emerald, El Toro, Belair, Cashmere and one proprietary lines, designated TAES3372. Experimentals include DALZ8501, DALZ8502, DALZ8508, and DALZ8516. These same materials are in Regional Field Trials.

During 21 through 24 December 1989, TAES-Dallas experienced 90 hours of maximum air temperatures below freezing with an absolute low of -20 C. The extremely low temperatures experienced during that period were followed by unseasonably mild temperatures during January through April 1990. This combination of weather produced notable information concerning survival and green-up of the zoysiagrass entries. Although green-up of many entries was slow, all survived the low temperatures during late 1989.

Meyer and Belair greened more rapidly than other entries, followed by DALZ8516, then Emerald (Table 1). DALZ8501, DALZ8502, DALZ8508, TAES3372, and Cashmere greened slowly but survived the extremely low temperatures during December. Results of spring green-up evaluations during 1990 demonstrate that the utility of DALZ8501, DALZ8502, TAES3372, and Cashmere will be limited primarily to Gulf Coast States.

Management treatments consisting of mowing heights and nitrogen fertility levels were imposed during July 1990. Mowing treatments include heights of 1.6 and 3.2 cm. Nitrogen treatments consist of 0, 0.14, and 0.29 Kg N are^{-1} applied April, May, July, and September for total yearly amounts of 0, 1, and 2 Kg N are^{-1}, respectively. Data collected on the effects of management treatments are thus far preliminary and are not included in this report.

Belair, Emerald, El Toro, Meyer, and DALZ8508 had similar high coverage by 17 October 1990 (Table 2). Cashmere, DALZ8501, and DALZ8516 had intermediate coverage by mid-October. DALZ8502 had the lowest turf cover. DALZ8502 and TAES3372 apparently continue to suffer from winter injury and thus poor turf coverage.

Mean turf quality scores during summer 1990 were highest for Emerald, El Toro, Meyer, and DALZ8508 (Table 3). Belair was intermediate in turf quality. DALZ8501, DALZ8502, DALZ8516, and TAES3372 had the lowest mean turf quality primarily due to weak stands and subsequent weed invasion.

FUTURE WORK: Turf performance will continue to be monitored during 1991. Attention will focus more intently on the response of entries to differential mowing and nitrogen fertilization. Performance of entries will be based on turf quality parameters, including density, uniformity, and color, as well as fall color retention, spring greening, resistance to pests and environmental stresses, and thatching tendency.

2. LINEAR GRADIENT IRRIGATION SYSTEM

INTRODUCTION: Limitations on resources and societies' concern for the environment dictate that future turfgrass cultivars have high tolerance to pests and environmental stresses. They must produce acceptable to high aesthetic and functional turf quality with minimum cultural inputs. The development and utilization of turfgrass cultivars with superior drought resistance continues to be one of the greatest needs of the turfgrass industry and demands high priority. The linear gradient irrigation system (LGIS) at TAES-Dallas was developed specifically to evaluate water requirements of newly developed turfgrasses under field conditions.

OBJECTIVES: The objectives of this study are to 1) determine the amount of irrigation water required to: A) prevent drought stress B) maintain acceptable turf quality C) maintain a persistent turf cover which should stabilize and conserve soil, and 2) evaluate drought recovery for 26 zoysiagrass lines.

PROGRESS: A total of 26 different zoysiagrasses were planted to LGIS during 1987. A randomized complete block with four replications, two on either side of the line irrigation source, were used (Photograph RHWP1). Plots were 1.5 m wide by 20 m perpendicular to the line irrigation source and were planted as sprigs using a 1:35 planting ratio. The area received uniform fertilization and irrigation as needed in 1987 and 1988 to prevent stress. Full turf coverage was achieved by fall 1988. During 1989 and 1990 the experimental area received a yearly total of 0.98 kg N are^{-1} and was maintained at a 2.54 cm mowing height.

Gradient irrigation was imposed mid-July 1989 through 1 October 1990 to create a moisture stress gradient and to determine the volume of irrigation required to prevent drought stress, maintain acceptable turf quality, and maintain at least 50% green turf ground cover. Average annual rainfall for Dallas, Texas is about 71 cm, but was 124 and 110 cm for 1989 and 1990, respectively (Figures RHWF1 and RHWF2). Water distribution for the gradient was determined by measuring irrigation water collected in rain gauges positioned at 1.5 m increments from the line irrigation source. Least squares non-linear regression of irrigation volume against distance from the line source was used to predict irrigation distribution along the gradient (Figure RHWF3). Irrigation water volume in 1990 exceeded that of 1989 because the study period was extended and rainfall was lower in the summer of 1990. Turf wilt and green color loss, which are indicators of drought stress, and turf quality and percentage of green turf ground cover were visually determined at 1.5 m increments from the line source. The irrigation required to prevent stress, maintain acceptable turf quality, and maintain 50% green turf ground cover was determined from irrigation distribution and visual assessments (Table 4).

Of the 26 zoysiagrass lines tested, generally, coarse-textured types require less irrigation to prevent stress and maintain ground cover than other textural types, but require amounts similar to other textural classes to maintain acceptable turf quality (rank=5).

Components of turf quality include canopy density, wilt, color, uniformity, weed cover, percentages of green and total turf covers. Increasing amounts of irrigation are required to prevent stress as textural types become finer. Medium and fine textural classes had similar irrigation requirements for maintenance of acceptable turf quality and ground cover. Among commercial lines irrigation requirements to prevent stress ranged from 262 m^3 for Belair to 825 m^3 for FC13521.

During and after drought, mean green turf ground cover of textural classes decreased in the order of coarse > fine > medium in zones of intermediate and no irrigation (Table 5). Percent green turf ground cover doubled for all textural classes within 7 days after termination of stress. Notable recovery was observed for DALZ8507, DALZ8512, DALZ8514, Emerald, and El Toro (Table RHW?). Several of the DALZ lines have remarkable potential to recover from drought stress (Photographs RHWP2 and RHWP3).

FUTURE WORK: The information obtained from LGIS during 1989 and 1990 is invaluable to the objectives of the turfgrass breeding program at TAES-Dallas. These data demonstrate the utility of LGIS for determining water requirements of experimental and commercially available germplasm under field conditions. With long-term use, LGIS will allow identification of grasses that will persist and function acceptably with little or no supplemental irrigation. However, the information obtained is only a start toward developing grasses with superior drought resistance. Presently, a tremendous need exists to gain a definitive understanding of the mechanisms involved in turfgrass drought resistance. The 1989 results from LGIS allowed identification of germplasm with superior drought resistance. This material is being used to explore specific physiological and morphological characters contributing to drought resistance. Several accessions are being increased for follow-up studies on heritability of drought resistance characters. Such knowledge is vital to rapid breeding progress and cultivar development, while increasing overall basic understanding of drought survival.

3. SHADE TOLERANCE TRIALS

INTRODUCTION: Zoysiagrasses are considered intermediate among warm season grasses in their ability to persist under heavily shaded conditions. Determination of light requirements for newly-developed cultivars and experimental selections is essential to defining utilization guidelines.

OBJECTIVE: Identify the relative shade tolerance of commercial and elite experimental varieties of zoysiagrass.

PROGRESS: In cooperation with the City of Richardson, TX, Parks and Recreation Department, a zoysiagrass evaluation trial was established on 24 May 1990 at Cottonwood Park. The planting site was under low light conditions (only about 15% of full sunlight) caused by dense shade from live oaks and cedar elms. Twenty elite DALZ lines and commercial zoysiagrasses, including Meyer, Emerald, El Toro, FC13521, and Belair and two proprietary lines designated TAES3372, and Cashmere were planted as 10 cm plugs on 0.6 m centers in a randomized complete block design with four replications. Also included, were 26 St. Augustinegrasses, 7 buffalograsses, and 7 centipede grasses. Irrigation was provided as needed to prevent drought stress. Density was determined by visually scoring plants on a 1 to 9 scale with 9 equal best. Rate of spread was determined by measuring the longest stolon length beyond the perimeter of the original plug. Density estimates proved to be the most useful indicator of shade tolerance and were used to rank the zoysiagrass entries and other warm-season turfgrass species.

Spread, as indicated by longest stolon length (Table 6), was statistically similar for all zoysiagrass entries at each sampling date. However, mean spread values for DALZ8502, DALZ8508, DALZ8510, DALZ8513, and DALZ8522 were notably higher than for Emerald, Meyer, FC13521, Belair, and Korean common. Belair, DALZ8511, DALZ8515, and Korean common had mean longest stolon lengths of zero. Compared to other warm-season turfgrass species, the zoysiagrasses were similar to centipedegrass in longest stolon length overall. Buffalograss and St. Augustine produced longer stolons than the zoysiagrasses.

Turf density scores provide a good indication of turfgrass shade tolerance (Table 7). DALZ8501, DALZ8503, DALZ8506, DALZ8507, DALZ8524, and Emerald had similar high mean turf density scores. Whereas, DALZ8505, DALZ8508, DALZ8512, DALZ8513, DALZ8522, and TAES3372 had low mean turf density scores. The zoysiagrasses maintained higher mean turf density scores than the other warm-season turfgrass species overall.

FUTURE WORK: Future work will continue to explore the relative shade tolerance of zoysiagrasses. Shade tolerance trials of these same materials will be established again in mid-May 1991.

4. TURFGRASS ROOT INVESTIGATION

INTRODUCTION: Attention is being directed to developing turfgrasses with greater root extension. Such root systems are capable of mining the subsurface moisture supply to provide superior persistence during drought periods. The turfgrass root investigation facility (TRIF) was designed to permit field assessment of root characteristics. TRIF will allow a comparative assessment of relative root distribution within the soil profile, and to confirm greenhouse screening procedures for root distribution.

OBJECTIVES: Determine rooting characteristics of zoysiagrass germplasm and the relationship between root characters and drought resistance. Additionally, other characteristics contributing to drought resistance, such as dehydration tolerance and turgor maintenance, will be determined.

PROGRESS: On 18 May 1989, commercial cultivars and experimental selections of zoysiagrass, buffalograss, centipedegrass, and St. Augustinegrass were planted in separate randomized complete block designs. All entries were replicated four times, except centipedegrass, which was replicated three times. All material was planted as 10 cm2 plugs. The plants were uniformly fertilized with 0.5 kg N are-1 with a slow release (24-4-11: N, P_2O_5, K_2O) fertilizer every 2 weeks.

Soil core samples (5 cm by 76 cm deep) from individual entries were obtained by replication during December 1989 and January 1990 and stored at 5 C. Components of root distribution densities were analyzed, and included root length, and root number and volume at 10 cm increments of each root system. The largest root systems were observed for TAES3347, DALZ8523, and DALZ8508 (Tables 8, 9, and 10). Even though DALZ8523 had only three root sections, it had higher mean number of roots at 10 and 20 cm soil depths than all other entries. Only TAES3347, which had the highest total root mass, was consistently highly ranked for the three variables measured, and would be expected to have good drought avoidance. The poorest root development was observed in TAES3357, TAES3358, TAES3362, and TAES3364.

In fall 1989, all entries included on TRIF were propagated for inclusion in Greenhouse Flexible Tube evaluations for rooting potential as described by Engelke and Lehman (USGA Bentgrass Progress Report, 1988). Previously propagated entries were planted as 4.0 cm cores to individual flexible tubes and watered to saturation. Irrigation was applied four times daily until termination of the study. A complete fertilizer (20-20-20: N, P_2O_5, K_2O) was applied once to supply 0.30 kg N are^{-1}. The tubes were arranged in a randomized complete block design with six replications.

Root extension was determined weekly by marking maximum root depth on the flexible tube face. Root systems of entries were harvested by replication when one entry reached the bottom of the flexible tubes. Root systems of the entries were assessed for maximum root length, and root number and mass at 10 cm increments. The largest root systems were observed for TAES3366, TAES3362, and DALZ8513 (Tables 11, 12, and 13), of which TAES3366 had the greatest total root mass. All three had similar root numbers in the upper three 10 cm sections. DALZ8522 had the longest maximum root, but had only moderate total root mass and numbers of roots. The poorest root development was observed for DALZ8502, DALZ8507, and DALZ8517.

Other parameters were more easily determined from flexible tubes than from TRIF, such as total leaf area per plant. Generally, those zoysiagrasses which had the smallest root systems (DALZ8517, DALZ8502, and DALZ8507) also had the smallest total leaf area per plant. Yet, TAES3362, which had one of the largest root systems, was only intermediate in total leaf area (Table 11).

Analysis of genera planted to TRIF indicated that centipedegrass had larger roots in the top 10 cm section than the other three genera evaluated (Tables 14, 15, and 16). Other variables considered were similar across genera. Differences among genera were more pronounced for plants grown in flexible tubes. Of these differences, it is interesting to note that most zoysiagrass root production characteristics were similar to those of drought resistant buffalograsses, such as "Prairie" (Tables 17, 18, and 19).

Overall there was no positive correlation between parameters evaluated in flexible tube experiments with root development on TRIF. This may be a function of field sampling techniques. New methods are currently being developed for 1991 sampling from TRIF. It should also be noted that nematode damage was observed on some roots harvested from TRIF, but none was observed on the roots of plants in the flexible tubes. This damage may have contributed to some of the variation among reps for the root attributes measured.

FUTURE WORK: Due to nearly 100% winterkill of all entries, plots were reestablished July 1990. Root distribution will be periodically monitored on TRIF during subsequent years of this study. Moisture stress will be imposed during the second and third years of the study to determine moisture stress tolerance of the entries and the relationship of root density distribution to drought resistance. Other characteristics, such as leaf firing, turgor maintenance, and tissue dehydration tolerance, will also be ascertained. We should also be able to determine which species can be accurately evaluated in this environment.

5. REGIONAL FIELD TRIALS

INTRODUCTION: Regional field trials are used to define the area of adaptation and utility of improved zoysiagrasses in comparison to commercially available cultivars.

OBJECTIVE: Develop a base of information on performance of these varieties under different environmental conditions and under various management practices.

PROGRESS: During the fall/spring of 1986/87, four elite experimental selections (DALZ8501, DALZ8502, DALZ8508, and DALZ8516) and four commercially available varieties (Meyer, Emerald, El Toro, and Belair) were provided to numerous research programs throughout the United States for extensive REGIONAL FIELD

TRIALS. A list of cooperators, site locations, and trial types is specified in the 1987 annual report.

Additional data from these sites were included in prior 1988-90 reports. Additional sites were added in 1988-90 as noted.

Specific locations cooperating in the Regional Zoysia Trial since 1986/1987 include:

1) University of Missouri in cooperation with Drs. John Dunn and Dave Miner;

2) Southern Illinois University - Carbondale in cooperation with Dr. Ken Diesberg (previously with Dr. Anna Marie Pennucci (this study has been discontinued);

3) Oklahoma State University in cooperation with Drs. Mike Kenna and Joel Barber (Dr. Kenna sent notice in April, 1990 that these plots were discontinued effective fall, 1989);

4) University of Arizona in cooperation with Drs. Charles Mancino and Dave Kopec;

5) University of California - Davis in cooperation with Mr. Ali Harivandi with field plantings and Dr. Lin Wu, with electrophoresis studies.

Two additional sites were established between November 1988 and May 1989:

6) Banyan Golf Course, FL, under the direction of Dan Jones; and

7) Palmetto Golf Club, FL, under the direction of Alan Wietzel (see May, 1989 Appendix).

Both provided space for management studies involving mowing and fertilization practices. These Regional Field Study site accessions were amended and abbreviated for the specific nature of the study. They included DALZ8501, DALZ8502, DALZ8508, DALZ8701, Cashmere and Emerald.

8) Dr. Victor Gibeault, from the University of California - Riverside was added as a cooperator in May, 1989.

In addition to the same set of grasses distributed earlier, Drs. Gibeault and Dunn also received the additional DALZ accessions 8507, 8512, 8514, and 8701 during the same time period.

Two other sites with DALZ and commercial accessions were:

9) Quality Turf sod producers (Ferris, TX) under the direction of Dr. David Huff, received the same samples as the original regional trial in 1988; and

10) Sunset Hills Country Club, IL, which received 36 experimental Dallas lines and 7 commercial varieties in May, 1989.

One regional evaluation site was planted in August, 1990:

11) Crenshaw-Doguet Turfgrass Co. under the direction of Mr. David Doguett in Bastrop, Texas. This trial includes 8 varieties and 42 experimental lines from the TAES-Dallas zoysiagrass breeding program. Five of the experimental lines were selected for seed production potential and will be evaluated as such in that particular environment.

Regional trial results have recently been received from Drs. Charles Mancino, U of AZ; Ali Harivandi, UC-Santa Clara Field Station; Victor Gibeault, UC-Riverside; and John Dunn, U of MO, Notes were also collected by visitors at the Banyan golf site.

Dr. Mancino's report from the U of AZ is included in Table 20. Color ratings for DALZ8516 were in the superior group for April through June, while DALZ8501 color ratings were in the highest group from July through October. DALZ8502 color rated in the highest group during August through October. For overall quality, DALZ8501 performed best of the DALZ experimental clones. The highest ratings for DALZ8501 occurred from July through October. Although ground coverage ratings for DALZ8502 were lower than those for El Toro, Emerald, and Meyer, the differences were not statistically significant. Ratings for chlorosis placed DALZ8501 and DALZ8502 in the highest group along with El Toro and Emerald. DALZ8508 was in the top group for one chlorosis rating, while scoring just below the highest group for the second chlorosis rating.

The zoysiagrass regional trial at the University of Arizona is planted on a soil containing a sand:peat mixture, either 90:10 or 80:20. Soil pH averages 8.1 across the entire site. Nitrogen was applied at a rate of 1 lb N/1000 ft^2 (21-7-14) in April, June, July and at 0.5 lb N/1000 ft^2 in August. Iron was applied to foliage at 2 oz/1000 ft^2 in May and 3 times in July. In September, granular iron was applied as ferresulfate (31% Fe).

Average monthly temperature for 1990 included:

Month	Mean Maximum	Mean Minimum	Average Daily
April	83.7	52.9	69.4
May	88.8	56.3	74.4
June	101.3	66.6	86.0
July	96.6	71.9	83.7
August	95.2	68.7	81.0
September	94.6	68.8	80.4

Results from Dr. Gibeault are summarized in Table 21. Dr. Gibeault's description of the plots and ratings follow. "The 24 ft^2 plots were established on July 18, 1989, by hand planting six plugs into each plot. Treatments were replicated three times. Recently, the area has been mowed regularly at 3/4 inch with a reel mower, fertilized at the equivalent of 1/2 lb. N/1000 ft^2 per month and irrigated according to reference ET X 0.6 adjusted for coefficient of uniformity.

"Cover ratings were taken from March to July. DALZ8507, 8512, and 8514 are faster establishing grasses than 8501, 8502, or 8701. They are somewhat faster than El Toro, but not significantly so.

"Color ratings were taken in January, March, May, and June. This information should be viewed in the context of an establishing grass cover that is not mature. there are indications that 8501, 8502, 8507, and 8701 will have better winter color than 8512 and 8514. DALZ8502 appears to have the deepest green color of (the DALZ experimental lines). It was also the finest textured grass.

"Because the grasses are now approaching full cover, turf score ratings will be taken on a monthly basis. The scores for July 1990, the first month of rating, are presented (Table __). Richard Autio is conducting this study."

Dr. Harivandi's report is summarized in Table 22. DALZ8508 and DALZ8516 scored in the top rating group for breaking dormancy in March, along with BK-7, Emerald, and Korean Common seeded at 2 lb/1000 ft^2. By April, all zoysia entries were fully recovered from dormancy. Quality ratings in March, August, and September placed DALZ8516 in the highest rating group each time. Emerald was the only commercial variety to also receive high quality rankings all three times. Scalping by rotary mowing was detrimental on all DALZ experimental clones compared to Belair, which had the least scalping compared with other commercial varieties.

Weather data from the Santa Clara, CA location follows:

Month	Air Temperature degrees F			Soil Temperature degrees F			Pan Evap. Inches	Precip. Inches	Net Evap. Inches
	Avg. Max.	Avg. Min.	Mean	Max.	Min.	Mean	Total	Total	Total
Jan.	57.96	39.87	48.9	50	46	48.0	2.077	1.868	0.209
Feb.	56.39	40.14	48.3	53	48	50.5	2.349	2.06	0.289
Mar.	64.81	46.23	55.5	60	51	55.5	4.504	0.91	3.594
Apr.	71.6	51.83	61.7	64	58	61.0	6.248	0.21	6.038
May	73.6	55.5	64.6	66	60	63.0	8.599	2.19	6.409
June	78.6	58.3	68.5	70	62	66.0	8.579	----	8.579
July	82.7	62.8	72.8	74	68	71.0	8.307	----	8.307
Aug.	82.0	65.1	73.6	80	70	75.0	7.406	----	7.406
Total							48.069	7.238	40.831

The report from Dr. Dunn is included in the form received (Appendix A).

At Banyan Golf Club, quality ratings were recorded September 12 and 13, 1990 (Table 23a). DALZ8502 consistently received the highest rating, although the difference was not statistically significant from ratings for Emerald and DALZ8701 for either the individual ratings or mean of the two ratings. J. Murray noted that one plot each of DALZ8501 and DALZ8502 were influenced by location effect. Elimination of these two plots from ratings decreased their mean quality score and affected significant differences among rankings (Table 23b). Murray also noted sedge on one plot each of Emerald and DALZ8501. Algae was observed on one plot of DALZ8508. Thinning turf was noted on two plots of DALZ8501 and one plot of DALZ8508. P. Busey noted sedge on one plot each of Emerald and DALZ8508, algae on two plots of DALZ8508 and one plot of DALZ8501. Broadleaved weeds were observed on one plot of Emerald.

Busey also described one plot of DALZ8502 having extremely fine texture. DALZ8701 plot comments included "bright green" and "going strong", while one plot of TAES3477 was described as "blue".

6. ORIENTAL COLLECTION - FIELD PERFORMANCE

INTRODUCTION: Oriental zoysiagrass accessions have been maintained in replicated field trials since 1984. These plants have been evaluated for leaf type, growth rate, plant color, anthesis, onset and rate of spring green-up, canopy temperature, and sod regrowth potential. Field evaluation studies will continue to broaden the base of information available on these germplasm resources.

OBJECTIVE: Evaluate for spring green-up, flowering habit, and seed production potential. Following seed harvest, assess traffic tolerance.

PROGRESS: As in 1989, spring and early summer evaluations include green-up assessment, stage of floral development, degree of flowering, height of inflorescence, and anther and stigma color. Most evaluations were completed, with similar results have been observed as in 1989. Analyses have yet to be completed on this data. Seed was collected from selected plants with high seed production and/or desirable turf traits. This seed was germinated with and without KOH treatment to assess fresh harvest viability (see section C1). Progeny from several of these plots are currently in isolation nurseries for seed production in several locations (see section C1). No effect on traffic wear has been observed. The traffic machine was not used as frequently as planned due to equipment design difficulties.

FUTURE WORK: Traffic studies will commence as soon as equipment is ready. Progeny from entries identified for high seed production and/or turf-type qualities will continue to be produced for field and greenhouse evaluations (see next section).

7. INCREASE PLANTINGS AT TAES - DALLAS

Four of the best elite DALZ lines were established on 3600 ft^2 plots by several vegetative methods during the summer of 1990. DALZ8502, DALZ8507, and DALZ8512 were planted with each including 5 methods of establishment. DALZ8701 was established with 4 planting methods. These plots are monitored for rate of establishment at the present time. Once established, they will be used to evaluate management practices for optimal and acceptable turf quality. DALZ8508 will be established in a similar planting in 1991.

C. ZOYSIAGRASS HYBRIDIZATION

INTRODUCTION: Morphological, floral, and seed production characters have been recorded on accessions from China, Japan, Korea, and the Philippines. Cultivar development to this stage, relative to the Oriental collection, has emphasized selection from these original accessions. Seed has been harvested from open pollinations and germinated to yield several progeny populations. Continued hybridization and progeny evaluations are necessary to enhance cultivar development and to combine desirable morphological and agronomic characters identified in selected parents.

1. DEVELOPING A SEEDED ZOYSIAGRASS

JUSTIFICATION: Zoysiagrass cultivars are predominantly distributed vegetatively due to their relatively poor seed production and strong seed dormancy. Earlier studies on zoysiagrass seed germination indicated that factors promoting dormancy increased during seed development and maturation. Seed harvested for germination prior to full maturation may be a viable means of avoiding seed dormancy complications. Simplification of seed germination and selection for enhanced seed production capabilities would increase the potential for developing a seed-produced cultivar. Hybridizations attempting to combine desirable turf characteristics are also needed. The present population includes genotypes with fine leaf texture, dark green color, vigorous growth habit, and disease resistance/tolerance.

OBJECTIVES:

1. Identify plants within the zoysiagrass germplasm introduction nursery which have high seed production potential.

2. Use single-cross and polycross matings to combine zoysiagrasses with high seed production potential and desirable turf quality.

3. Advance progeny through multiple cycles of selection to combine superior turf performance characters with high seed production potential.

4. Assess seed germination potential at increasing intervals between harvest and germination to determine onset of dormancy.

PROGRESS: Several accessions have been identified for high seed production capability and/or desirable turf traits. Data relating to morphological characters have been analyzed and summarized.

Seventy-five to 250 one-inch plugs of two experimental entries and Meyer established June 7, 1990 in a seed production trial in Amarillo, Texas. Seed production will be assessed beginning in 1991.

Additional seed production testing was initiated in Dallas and Utley, Tx; and in Oregon. Two isolation nurseries were established at the Dallas site. One planting includes 5 progeny each from 10 parents selected for vigorous seed production, elongated flowering culms, similar anthesis dates, and acceptable turf quality. The second planting contains 5 progeny each from 20 parents selected as above. The smaller planting includes the top 10 rated parents, while the second planting includes the top 20 rated parents.

The Utley, TX planting includes 5 clonally propagated parents selected from the oriental zoysiagrass field collection for seed production potential. These plants were established by thin-layer sod production and are included in a larger planting (50 entries) containing commercial varieties and elite Dallas lines. Any seed production from these plants may include outcrossing with parents not specifically selected for seed production, but having desirable turf qualities.

Deepots from the zoysiagrass germplasm collection were shipped to Oregon for seed production testing in fall of 1990. While the weather may be too severe for survival of all germplasm, it may be possible that some of the hardier zoysiagrasses may be able to produce adequate seed in this environment.

An experiment to test germination of freshly harvested seed was conducted. Weekly samples were tested over a period of 6 weeks to determine onset of dormancy. This testing will be continued again during the flowering period next spring. Results will be summarized upon completion of the testing next spring.

FUTURE WORK: When flowering, accessions selected for seed production and/or desirable turf characteristics will continue to be isolated for self and/or cross pollinations. Floral induction attempts during then late 1989 through early 1990 were of limited success, but will used whenever natural flowering diminishes. Progeny will continue to be assessed throughout 1990 for flowering habit, seed production potential, and obvious agronomic attributes.

2. PROGENY DEVELOPMENT

JUSTIFICATION: Although seed production capacity is a key goal, general plant improvement is also desirable, with the potential to also develop vegetatively propagated varieties. Hybridizations attempting to combine desirable turf characteristics are also needed. The present population includes genotypes with fine leaf texture, dark green color, vigorous growth habit, and disease resistance/tolerance.

OBJECTIVES:

1. Use self, cross, and open pollinations to obtain seed for progeny evaluations of zoysiagrasses with desirable turf morphological and physiological attributes.

2. Advance progeny through multiple cycles of selection to combine superior turf performance characters with or without high seed production potential.

PROGRESS: Progeny evaluation is underway for selected accessions. A space planting was established 1 August, 1989 by placing 822 1-inch plugs on 3 foot centers. Plants were generated from three seed sources of _Zoysia_ _sinica_ acquired from China, as well as seed produced by the Texas A&M - Dallas breeding program. The latter group included progeny which were generated from 9 high seed-producing genotypes and 4 elite DALZ selections. Although the _Z_. _sinica_ seed lots resulted in most plants with a medium-coarse texture and light green color, extremes in variability were noted. Survival, spread, color, and texture ratings have been recorded to date. The most desirable plants were selected in 1990 for advanced testing.

More than 1500 progeny were generated for a second space planting. Of these progeny, 976 were planted on 3 ft. centers from July through September, 1990. These progeny were produced from open, self, and cross pollinations of advanced TAES lines and commercial varieties. Any plants produced from seed collected this spring will be added to this planting in 1991. Included in this planting is a parent-progeny space planting to compare phenotypic and growth factors in a replicated trial. Eleven parents were selected based on available progeny. Each of 4 replications contained 1 parent planted among 4 progeny in the same row. For each parent, there are 16 progeny included for evaluation.

Ratings on these plots included texture, color, spread, density, stoloniferous vs. rhizomatous habit, stolon/rhizome counts, internode length, stolon/rhizome lengths, stolon color, and growth habit (upright vs. prostrate) (Tables 24-29). DALZ8516 and Cashmere progeny texture ratings extended beyond the parental extremes on both ends of the spectrum (Table 24). Several progeny had markedly finer or coarser textures than their maternal parents. Although progeny color ratings for September averaged lower than parental ratings, this may have been due to the greater growth of progeny compared to parents (Table 25). Otherwise, color rating comparisons between parents and progeny were similar, again with some individual striking differences.

Major increases in spread ratings of progeny compared to parents occurred for several accessions (Table 26). This group included DALZ8501, DALZ8511, DALZ8512, DALZ8514, Belair, and El Toro. Density ratings (Table 26) were similar between parents and their progeny, with exceptions in several cases. Stolon counts and stolon lengths were usually greater for progeny than parents (Table 27). In the case of stolon lengths, progeny exhibited faster growth than parents for all parents except DALZ8512, DALZ8514, and El Toro, the three most aggressive parents. Internode length ratings (Table 28) varied little between parents and their progeny, except for DALZ8501 and DALZ8516 which had progeny with increased internode lengths. Internode colors differed between parents and progeny in several instances (Table 28). These differences may be useful in heritability studies. Growth habits from upright to prostrate were variable among progeny for certain parents (Table 29). Belair is notable in that the parent had a prostrate growth compared to progeny with more upright growth patterns. In comparing rhizomatous versus stoloniferous growth habits, there were few differences between progeny and their parents (Table 29).

A third planting in September 1990 included 88 accessions from the zoysiagrass collection in Beltsville, MD; 3 elite DALZ lines; 14 advanced DALZ lines; 5 commercial varieties; and 13 other experimental lines from outside sources. Each accession was replicated 3 times, with each 36 ft^2 plot started from a 9 in^2 plug. Plants will be evaluated for growth habit, rate of spread, morphological attributes, and seed production potential.

Additional selected cross- and self-pollinations have been attempted during 1990. Mr. Robert Cunningham is currently conducting an internship project to evaluate the effects of sucrose and 8HQC on zoysiagrass flowering on excised culms. Zoysiagrass culms do not continue opening as readily in water alone as has been reported for other grass species. Seed from these isolation attempts will be germinated to produce progeny for field evaluation in 1991. An interesting phenomenon noted on some progeny produced in 1990 was the ability to flower after 2-3 months growth from seed. If this rate of cycling from seed to seed of approximately 3-4 months could be sustained, there is the potential to advance through 3-4 generations per year in at least some accessions.

FUTURE WORK: When flowering, accesstions selected for desirable turf characteristics will continue to be isolated for self and/or cross pollinations. Floral induction attempts during then late 1989 through early 1990 were of limited success, but will used whenever natural flowering diminishes. Progeny will continue to be assessed throughout 1990 for flowering habit, obvious agronomic attributes. Heritability studies will continue, with results from the 1990 parent-progeny space planting to be evaluated this winter.

3. STRESS TOLERANCE IN ZOYSIAGRASS HYBRIDIZATION PROGRAM *

JUSTIFICATION: Major progress is being made at Dallas in defining minimum levels of supplemental irrigation required for turfgrass maintenance utilizing a line source irrigation system (LGIS). Meteorological data and plant responses are being used to determine minimum irrigation levels required by major turfgrass species and elite zoysiagrass experimentals in an attempt to substantially reduce supplemental irrigation requirements.

Although significant progress has been made in understanding turfgrass water use and irrigation requirements, less attention has been given to understanding the heritability of biological characters associated with drought resistance in grasses used for turf purposes. The degree to which turfgrasses adapt physiologically to water deficits and high temperatures has received almost no attention in published technical literature.

Numerous accessions of zoysiagrass designated as DALZ lines are being evaluated for water requirements and tolerance to stress in general. Considerable variability exists among these lines for: 1) quantity of supplemental irrigation needed to sustain active growing turf, 2) leaf texture, 3) leaf orientation, 4) density of stand, and 5) general turf quality. Information on the heritability of such traits and the role of these traits in adaptation and performance under stress is not available.

OBJECTIVES:

1. Determine the relationship of specific water relations characters to morphological characters and to drought resistance to ascertain the feasibility of utilizing morphological characters as stable genetic markers to rapidly select for drought resistant germplasm.

2. Determine the heritability of such characters for utilization in a turfgrass breeding program emphasizing superior drought resistance and water use efficiency.

PROGRESS: Linear Gradient Irrigation System (LGIS) field facilities at Dallas permit a gradient application of water onto established, replicated turf plots. LGIS was utilized during 1989 to determine drought resistance and water use characteristics of elite zoysiagrasses and commercial varieties. Superior experimental zoysiagrasses were identified and selected for an intensive hybridization program. Plants have been established for diallel crossing to assess heritability of stress tolerance. Additionally, zoysiagrass entries from LGIS representing the extremes in drought resistance among morphological zoysiagrass types are currently being evaluated under greenhouse conditions for drought tolerance. A technique is currently being applied to these entries to determine whether differences in drought tolerance can be quantified. Preliminary results from this Competitive Soil Moisture Extraction Technique (CSMET) indicate that substantial differences in basal osmotic potential occur among these entries. We will also determine whether osmoregulation occurs for entries and how this mechanism relates to turgor and tissue hydration maintenance, growth, and field performance.

FUTURE: The Turfgrass Root Investigation Facility established at Dallas was planted during May 1989 to replicated plots of zoysiagrasses common to LGIS. This will allow determination of subsurface plant characteristics such as root mass, root distribution, root number, and root extension rate, that may contribute to superior drought resistance. Greenhouse studies are also in progress to determine the feasibility of screening for specific physiological drought tolerance characters.

Specific water relations characteristics will be measured for grasses planted to TRIF and LGIS to quantify drought resistance of selected genotypes. Parameters to be measured include osmotic potential, water potential, and relative water content. Correlations among these characters and performance under moisture deficits will be used to ascertain mechanisms of drought resistance such as osmotic adjustment, tissue elasticity regulation, and apoplastic water fraction adaptation. The relationship of water relations characteristics to morphological characters and drought stress symptoms will be ascertained from data collected to determine morphological markers that will allow rapid selection of superior germplasm.

The aerial morphological characteristics of these grasses, such as leaf width, leaf extension rate, leaf surface characteristics, and leaf rolling and leaf firing during moisture deficits, will be determined. A knowledge of the drought resistance, morphological characters, and physiological adaptation of these grasses to moisture deficits will allow the identification of mechanisms which favor excellent performance under adverse environments and identification of stable genetic markers easily utilized in the selection process.

Diallel seed production and progeny evaluation will be utilized to determine heritability of desirable characteristics and a breeding scheme which will make optimal progress toward species improvement. Development and implementation of greenhouse techniques to rapidly identify stress tolerant germplasm will accelerate development and release of drought resistant turfgrass cultivars.

Table 1. 1990 spring greening of zoysiagrass cultivars and experimental selections planted 21 June 1988 at TAES-Dallas.

	Percentage of green plot area						
Entry	15 Jan.	31 Jan.	08 Feb.	27 Feb.	13 Mar.	28 Mar.	16 Apr.
Belair	1.0	2.3	4.0	6.7	35	45	72
Cashmere	0.0	0.7	0.7	0.7	1	1	1
El Toro	0.3	1.0	1.0	2.3	5	10	18
Emerald	0.7	1.0	1.0	5.0	5	13	33
Meyer	0.7	3.7	7.0	8.3	33	43	72
DALZ8501	0.0	0.0	0.0	0.0	1	1	1
DALZ8502	0.0	0.0	0.0	0.0	1	1	5
DALZ8508	0.0	1.0	1.0	2.3	5	10	18
DALZ8516	0.7	2.3	7.0	8.3	27	33	48
TAES3372	0.0	0.3	0.3	0.3	1	1	1
MSD[1]	0.6	2.5	5.0	2.7	7	7	10

[1] MSD = minimum significant difference for comparison of means within columns based on Waller-Duncan K-ratio t test (K-ratio = 100).

Table 2. Percent green ground cover of zoysiagrasses planted 21 June 1988 at TAES-Dallas.

	Percent green ground cover						
Entry	17 May	27 June	10 July	08 Aug.	12 Sept.	17 Oct.	Mean
Belair	87	88	92	92	92	93	91
Cashmere	77	77	85	88	85	87	83
El Toro	85	88	94	94	90	93	91
Emerald	88	87	94	93	90	94	91
Meyer	88	88	93	96	93	97	93
DALZ8501	67	73	83	77	75	78	76
DALZ8502	47	48	58	58	50	57	53
DALZ8508	83	85	93	91	83	92	88
DALZ8516	75	75	82	85	80	83	80
TAES3372	53	57	67	67	63	68	63
MSD[1]	20	17	17	21	18	17	6

[1] MSD = minimum significant difference for comparison of means within columns based on Waller-Duncan K-ratio t test (K-ratio = 100).

Table 3. Turf quality of zoysiagrasses planted 21 June 1988 at TAES-Dallas during 1990.

	Turf quality 1990						
Entry	17 May	27 June	10 July	08 Aug.	12 Sept.	17 Oct.	Mean
Belair	4.3	4.7	4.3	5.7	6.0	5.3	5.1
Cashmere	3.7	3.7	3.7	4.3	5.0	4.3	4.1
El Toro	5.0	4.7	5.7	6.7	6.0	5.7	5.6
Emerald	5.3	5.0	5.3	7.3	7.0	6.3	6.1
Meyer	5.0	5.3	6.0	7.0	6.3	6.7	6.1
DALZ8501	2.7	2.7	3.0	4.0	4.0	3.7	3.3
DALZ8502	1.7	1.3	2.0	3.3	3.0	2.3	2.3
DALZ8508	5.3	4.7	5.3	6.0	6.0	6.0	5.6
DALZ8516	2.7	3.0	2.7	3.3	3.7	3.3	3.1
TAES3372	1.7	2.0	2.0	4.0	3.7	3.0	2.7
MSD[1]	1.0	1.1	1.2	1.4	1.6	0.9	0.5

[1] MSD = minimum significant difference for comparison of means within columns based on Waller-Duncan K-ratio t test (K-ratio = 100).

Table 4. Supplemental irrigation required to prevent stress, maintain a minimum turf quality (TQ) of five, and to maintain 50% green ground cover (GGC) at the termination of stress during September 1989 and 1990 for zoysiagrasses planted to LGIS at TAES-Dallas, Texas.

		1989-1990 Mean		
Textural Class	Entry	Prevent stress	Minimum TQ of 5	Minimum 50% GGC
		m^3 irrigation		
Fine	Cashmere	849	2027	829
Fine	Emerald	715	1282	377
Fine	FC13521	825	1049	345
Fine	DALZ8501	868	1664	568
Fine	DALZ8502	750	1057	509
Fine	DALZ8506	699	1221	568
Fine	DALZ8507	505	715	246
Fine	DALZ8508	697	1084	405
Fine	DALZ8510	596	740	342
Fine	DALZ8515	747	1265	639
Fine	DALZ8516	724	2068	365
Fine	DALZ8517	743	1294	548
Fine	DALZ8524	942	2585	519
Mean		743	1389	482
Medium	Meyer	603	1312	418
Medium	DALZ8503	560	1084	576
Medium	DALZ8504	724	1605	884
Medium	DALZ8505	500	1200	553
Medium	DALZ8511	557	1336	507
Medium	DALZ8513	379	1665	261
Medium	DALZ8522	1974	2585	2507
Medium	DALZ8523	803	1831	1375
Mean		762	1577	885
Coarse	Belair	262	1084	186
Coarse	El Toro	276	1049	205
Coarse	Korean Common	497	1490	496
Coarse	DALZ8512	118	995	124
Coarse	DALZ8514	144	810	198
Mean		259	1085	242
MSD class[1]		124	276	174
MSD entry[2]		192	557	317

[1] MSD = minimum significant difference for comparison of textural class means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).
[2] MSD = minimum significant difference for comparison of entry means within columns based on the Waller-Duncan K-ratio t test where K=100.

Table 5. Mean percentage green turf cover during stress (5 Sept.) and 7 days after termination of stress (15 Sept.) by rainfall for three levels of irrigation on LGIS zoysiagrasses at TAES-Dallas, Texas in 1990.

Textural class	Entry	5 Sept.			15 Sept.		
		High[1]	Inter.	None	High	Inter.	None
Fine	Cashmere	78	48	8	83	52	10
Fine	Emerald	95	82	20	95	84	66
Fine	FC13521	95	78	16	93	81	52
Fine	DALZ8501	89	64	16	89	64	19
Fine	DALZ8502	90	74	20	90	81	41
Fine	DALZ8506	94	67	18	95	74	33
Fine	DALZ8507	96	82	25	97	87	67
Fine	DALZ8508	95	76	17	96	80	35
Fine	DALZ8510	96	76	21	95	81	58
Fine	DALZ8515	94	65	9	94	68	13
Fine	DALZ8516	90	73	22	91	76	41
Fine	DALZ8517	94	70	10	95	80	30
Fine	DALZ8524	84	68	23	85	74	29
Mean[2]		92	71	17	92	76	38
Medium	Meyer	96	73	13	95	80	40
Medium	DALZ8503	96	67	8	96	69	14
Medium	DALZ8504	91	54	7	94	64	17
Medium	DALZ8505	89	66	5	94	66	13
Medium	DALZ8511	96	68	15	93	72	27
Medium	DALZ8513	83	67	21	82	70	45
Medium	DALZ8522	25	6	1	25	13	2
Medium	DALZ8523	56	31	11	49	34	18
Mean		79	54	10	79	59	22
Coarse	Belair	93	87	36	93	85	70
Coarse	El Toro	93	90	35	95	90	77
Coarse	K. common	96	76	13	96	78	39
Coarse	DALZ8512	92	89	45	94	93	80
Coarse	DALZ8514	94	88	35	94	92	78
Mean		94	86	33	94	88	69
MSD class[3]		3	8	3	4	8	4
MSD entry[4]		6	15	5	6	14	7

[1] Irrigation levels of high, intermediate, and none are equivalent to 87, 29, and 0% of the irrigation volume applied at the line source, respectively.
[2] Class means calculated from observations for all class entries.
[3] MSD = minimum significant difference for comparison of textural class means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).
[4] MSD = minimum significant difference for comparison of entry means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 6. Spread of zoysiagrass entries and warm-season grass species planted at Cottonwood Park Richardson, TX in cooperation with TAES-Dallas. Planted May 1990.

		Longest stolon length							
Species	Entry	14 June	27 June	18 July	01 Aug.	21 Aug.	06 Sept.	21 Sept.	Mean
		cm							
Zoysia	Belair	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zoysia	Cashmere	1.3	2.2	0.0	1.9	0.0	0.0	0.0	0.8
Zoysia	El Toro	3.8	2.9	0.0	0.0	0.0	0.0	0.0	0.8
Zoysia	Emerald	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Zoysia	FC13521	0.6	2.2	1.0	1.0	0.0	0.0	0.0	0.7
Zoysia	K. Common	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zoysia	Meyer	0.0	1.3	0.6	1.3	0.0	0.0	0.0	0.4
Zoysia	DALZ8501	3.0	2.9	0.0	1.0	0.0	0.0	0.0	0.9
Zoysia	DALZ8502	2.5	3.2	2.2	1.3	0.0	0.0	4.5	2.0
Zoysia	DALZ8503	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Zoysia	DALZ8504	3.0	3.2	2.5	1.0	0.0	0.0	1.9	1.7
Zoysia	DALZ8505	1.3	1.3	0.0	0.0	0.0	0.0	0.0	0.4
Zoysia	DALZ8506	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Zoysia	DALZ8507	3.0	2.9	1.6	2.2	0.0	0.0	0.0	1.3
Zoysia	DALZ8508	0.6	4.1	3.2	5.7	3.5	3.2	3.5	3.2
Zoysia	DALZ8510	3.6	4.8	2.2	3.2	2.2	0.0	0.0	2.3
Zoysia	DALZ8511	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zoysia	DALZ8512	2.1	1.9	0.0	0.0	0.0	0.0	0.0	0.5
Zoysia	DALZ8513	4.8	7.0	6.7	4.8	0.0	1.9	0.0	3.6
Zoysia	DALZ8514	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Zoysia	DALZ8515	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zoysia	DALZ8516	0.6	1.3	0.0	0.0	0.0	0.0	0.0	0.3
Zoysia	DALZ8517	2.9	1.3	1.3	1.3	0.0	0.0	0.0	0.9
Zoysia	DALZ8522	4.3	2.9	4.1	5.1	0.0	0.0	0.0	2.4
Zoysia	DALZ8523	2.9	2.5	0.6	0.0	0.0	0.0	0.0	0.9
Zoysia	DALZ8524	2.0	1.3	1.0	1.0	1.3	0.0	0.0	1.0
Zoysia	DALZ8701	2.9	-	-	-	-	-	-	0.5
Zoysia	TAES3372	2.5	1.9	1.0	1.9	0.6	0.6	0.0	1.2
MSD entry[1]		NS	NS	NS	NS	NS	NS	NS	1.2
Zoysia		1.8	1.8	1.0	1.1	0.3	0.2	0.4	0.9
St. Augustine		0.1	7.1	10.4	12.8	16.8	23.1	24.9	14.8
Centipede		1.4	0.8	0.8	0.7	1.2	2.3	2.5	1.4
Buffalograss		0.7	1.1	0.9	2.1	4.4	3.9	7.7	2.9
MSD species[2]		1.3	1.7	2.7	3.8	4.7	6.4	6.9	1.8

[1] MSD = minimum significant difference for comparison of entry means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).
[2] MSD = minimum significant difference for comparison of species means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 7. Turf density of zoysiagrass entries and warm-season grass species planted at Cottonwood Park in Richardson, TX in cooperation with TAES-Dallas. Planted May 1990.

		Turf density							
Species	Entry	14 June	27 June	18 July	01 Aug.	21 Aug.	06 Sept.	21 Sept.	Mean
Zoysia	Belair	6.3	5.5	4.3	4.5	3.3	4.3	5.3	4.8
Zoysia	Cashmere	6.0	5.0	4.5	4.8	3.3	4.3	4.5	4.6
Zoysia	El Toro	6.0	6.3	4.5	4.8	3.5	4.0	4.5	4.7
Zoysia	Emerald	7.6	7.5	6.0	6.3	4.5	6.5	6.3	6.4
Zoysia	FC13521	5.8	6.0	4.3	5.0	3.8	5.0	4.5	4.9
Zoysia	K. Common	5.0	6.3	4.8	4.8	3.0	4.3	3.5	4.5
Zoysia	Meyer	7.0	6.5	5.0	4.8	3.3	4.3	4.0	5.0
Zoysia	DALZ8501	7.3	7.5	5.5	6.8	4.5	6.5	6.0	6.3
Zoysia	DALZ8502	6.6	7.3	5.0	5.0	4.3	6.5	5.0	5.7
Zoysia	DALZ8503	7.3	7.5	6.3	6.5	4.0	6.3	5.5	6.2
Zoysia	DALZ8504	7.3	7.3	5.8	6.0	3.7	4.5	4.5	5.6
Zoysia	DALZ8505	5.0	5.8	4.3	4.5	2.8	4.0	3.5	4.3
Zoysia	DALZ8506	6.8	7.5	5.5	6.3	4.5	6.0	6.0	6.1
Zoysia	DALZ8507	7.0	7.3	5.3	6.5	4.5	6.5	5.5	6.0
Zoysia	DALZ8508	4.0	3.8	4.7	6.5	4.0	3.5	6.5	4.4
Zoysia	DALZ8510	6.2	6.8	5.0	5.5	4.3	5.0	4.8	5.4
Zoysia	DALZ8511	5.8	6.3	4.5	5.0	4.0	4.8	4.3	4.9
Zoysia	DALZ8512	5.3	4.3	3.8	4.0	3.2	4.3	4.5	4.1
Zoysia	DALZ8513	4.5	4.0	3.5	4.3	3.0	4.0	4.5	4.0
Zoysia	DALZ8514	5.3	5.5	5.0	5.7	4.0	4.8	5.3	5.1
Zoysia	DALZ8515	7.3	7.5	5.5	5.5	3.5	5.5	5.0	5.7
Zoysia	DALZ8516	7.0	6.0	4.8	5.3	3.0	5.8	4.5	5.2
Zoysia	DALZ8517	7.3	7.3	5.0	5.8	4.6	6.5	4.5	5.8
Zoysia	DALZ8522	3.8	2.8	3.3	3.3	2.3	2.5	2.8	3.0
Zoysia	DALZ8523	6.0	5.3	4.3	4.5	3.5	4.8	4.5	4.7
Zoysia	DALZ8524	7.4	7.0	5.8	5.8	4.5	6.3	5.3	6.1
Zoysia	DALZ8701	2.0	-	-	-	-	-	-	0.6
Zoysia	TAES3372	3.8	4.0	3.5	4.0	3.0	4.8	4.0	3.9
MSD entry[1]	3.2	1.8	2.0	1.2	1.2	1.6	1.5	0.7	
Zoysia		5.9	5.8	4.8	5.2	3.7	4.8	4.7	5.0
St. Augustine		2.6	2.6	3.2	3.6	3.5	4.2	3.8	3.4
Centipede		2.4	2.2	3.1	3.2	2.8	3.0	2.7	2.8
Buffalo		4.0	4.0	4.8	4.0	4.1	4.2	3.5	4.0
MSD species[2]		0.6	0.6	0.4	0.5	0.4	0.6	0.4	0.2

[1] MSD = minimum significant difference for comparison of entry means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

[2] MSD = minimum significant difference for comparison of species means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 8. Mean maximum and mean third maximum roots of zoysiagrasses planted to TRIF.

Entry	Root lengths, mm Maximum	Third maximum
Belair	165	228
Cashmere	316	337
El Toro	176	245
Emerald	110	149
FC13521	190	209
Meyer	112	179
DALZ8501	183	219
DALZ8502	137	184
DALZ8503	162	161
DALZ8504	113	138
DALZ8505	170	220
DALZ8506	179	214
DALZ8507	244	256
DALZ8508	257	349
DALZ8510	339	344
DALZ8511	214	271
DALZ8512	231	264
DALZ8513	183	214
DALZ8514	242	262
DALZ8515	260	265
DALZ8516	294	318
DALZ8517	168	205
DALZ8522	238	260
DALZ8523	234	286
DALZ8524	211	244
DALZ8701	166	195
TAES3356	176	228
TAES3357	125	157
TAES3358	140	157
TAES3359	98	116
TAES3360	125	236
TAES3361	271	303
TAES3362	155	296
TAES3363	239	285
TAES3364	92	194
TAES3365	244	342
TAES3366	285	322
TAES3367	262	343
TAES3372	190	187
MSD entry[1]	152	165

[1] MSD = minimum significance difference for comparison of entry means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 9. Mean root mass (mg) per 10 cm vertical root section for zoysiagrasses planted to TRIF.

Entry	Root mass (mg) per 10 cm section 0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm	Total Mass
Belair	675	100	25	0	0	800
Cashmere	1025	450	350	100	0	1925
El Toro	475	75	50	0	0	600
Emerald	700	267	0	0	0	967
FC13521	350	225	0	0	0	575
Meyer	400	225	25	0	0	650
DALZ8501	450	200	0	0	0	650
DALZ8502	425	100	25	0	0	550
DALZ8503	300	100	25	0	0	425
DALZ8504	375	75	0	0	0	450
DALZ8505	450	200	75	0	0	725
DALZ8506	200	75	75	0	0	350
DALZ8507	280	220	140	0	0	640
DALZ8508	550	375	150	25	0	1100
DALZ8510	400	275	350	100	0	1125
DALZ8511	300	150	50	425	0	925
DALZ8512	375	200	225	0	0	800
DALZ8513	500	100	50	25	0	675
DALZ8514	475	225	50	0	0	750
DALZ8515	375	125	50	0	0	550
DALZ8516	450	200	225	275	0	1150
DALZ8517	300	125	50	0	0	475
DALZ8522	525	150	125	100	0	900
DALZ8523	400	325	225	0	0	950
DALZ8524	1025	250	50	25	0	1350
DALZ8701	1025	200	50	0	0	1275
TAES3356	425	125	50	0	0	600
TAES3357	250	25	50	0	0	325
TAES3358	500	125	0	0	0	625
TAES3359	300	33	67	0	0	400
TAES3360	400	100	0	0	25	525
TAES3361	125	275	200	100	25	1125
TAES3362	350	75	75	25	0	525
TAES3363	300	100	50	0	0	450
TAES3364	650	25	25	0	0	700
TAES3365	250	400	375	225	25	1275
TAES3366	420	100	40	60	40	660
TAES3367	275	125	150	25	0	575
TAES3372	250	125	25	0	0	400
MSD entry[1]	944	405	210	391	45	1061

[1] MSD = minimum significant difference for comparison of entry means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 10. Mean numbers of roots per 10 cm vertical root section for zoysiagrasses planted to TRIF.

Entry	Number of roots				
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm
Belair	10	7	2	0	0
Cashmere	24	15	11	3	0
El Toro	16	6	4	1	0
Emerald	9	4	0	0	0
FC13521	17	6	2	0	0
Meyer	18	3	2	0	0
DALZ8501	11	8	2	3	0
DALZ8502	19	6	1	0	0
DALZ8503	17	11	2	0	0
DALZ8504	13	3	1	0	0
DALZ8505	12	12	6	0	0
DALZ8506	6	3	5	1	0
DALZ8507	11	16	7	2	0
DALZ8508	21	11	11	2	0
DALZ8510	11	15	11	3	0
DALZ8511	15	9	3	1	0
DALZ8512	10	11	5	1	0
DALZ8513	10	5	4	2	0
DALZ8514	15	14	5	1	0
DALZ8515	14	6	4	0	0
DALZ8516	17	14	11	8	1
DALZ8517	13	5	1	0	0
DALZ8522	20	13	7	2	0
DALZ8523	29	19	9	0	0
DALZ8524	11	8	4	1	0
DALZ8701	11	6	1	0	0
TAES3356	14	8	4	0	0
TAES3357	7	2	1	0	0
TAES3358	10	3	1	0	0
TAES3359	12	4	1	0	0
TAES3360	13	4	0	0	1
TAES3361	22	15	10	8	2
TAES3362	10	3	2	2	0
TAES3363	17	10	5	0	0
TAES3364	9	2	0	0	0
TAES3365	20	14	9	6	0
TAES3366	20	12	7	3	1
TAES3367	9	8	11	3	0
TAES3372	19	9	4	0	0
MSD entry[1]	19	16	8	5	1

[1] MSD = minimum significant difference for comparison of entry means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 11. Mean maximum and third maximum root lengths, mean extension rates, and mean total leaf areas for zoysiagrasses planted in flexible tubes.

	Root length, mm			
Entry	Maximum	Third maximum	Extension rate	Total leaf area
	- mm -	- mm -	- mm/day -	-- cm2 --
Belair	230	53	6.4	9.2
Cashmere	307	165	7.8	12.0
El Toro	425	195	12.9	19.8
Emerald	491	127	13.3	12.0
FC13521	446	169	8.5	13.3
Meyer	453	230	13.0	20.5
DALZ8501	264	87	6.4	10.6
DALZ8502	253	123	6.6	4.6
DALZ8503	128	84	2.8	21.4
DALZ8504	469	218	14.4	22.7
DALZ8505	433	266	12.2	34.8
DALZ8506	323	200	6.3	10.5
DALZ8507	276	66	6.3	8.7
DALZ8508	423	76	10.8	5.2
DALZ8510	358	136	7.8	13.6
DALZ8511	489	289	15.2	26.5
DALZ8512	473	267	13.3	42.0
DALZ8513	277	162	7.8	20.5
DALZ8514	410	189	8.0	29.5
DALZ8515	384	114	7.7	11.6
DALZ8516	359	121	9.6	14.5
DALZ8517	93	44	3.0	7.3
DALZ8522	556	247	13.7	13.7
DALZ8523	441	172	12.0	10.2
DALZ8524	246	162	4.5	5.8
DALZ8701	372	162	10.4	8.9
TAES3356	481	232	14.6	28.4
TAES3357	532	236	15.8	32.2
TAES3358	494	234	11.9	28.9
TAES3359	302	125	8.3	12.5
TAES3360	323	123	7.6	13.1
TAES3361	291	102	6.8	9.7
TAES3362	458	275	10.8	25.4
TAES3363	516	264	13.7	9.5
TAES3364	464	174	9.8	33.5
TAES3365	449	160	11.6	13.4
TAES3366	530	440	13.1	35.4
TAES3367	331	155	9.4	17.0
TAES3372	486	185	12.6	15.3
MSD entry[1]	273	180	8.3	14.5

[1] MSD = minimum significant difference for comparison of entry means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 12. Mean root mass per section and mean total root mass for zoysiagrasses planted in root tube study.

Entry	Root mass(mg) per 10 cm section							Total mass
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm	50-60 cm	60-70 cm	
Belair	160	20	20	0	0	0	0	200
Cashmere	233	33	0	0	0	0	0	267
El Toro	300	117	500	50	33	17	0	1017
Emerald	167	33	33	0	0	17	0	250
FC13521	150	50	0	0	0	0	0	200
Meyer	183	0	17	0	17	17	0	233
DALZ8501	160	0	20	0	0	0	0	180
DALZ8502	100	0	0	0	0	0	0	100
DALZ8503	250	25	0	0	0	0	0	275
DALZ8504	233	33	33	17	0	0	0	317
DALZ8505	529	143	86	86	57	0	0	900
DALZ8506	117	50	17	0	0	0	0	183
DALZ8507	100	0	0	0	0	0	0	100
DALZ8508	83	17	0	0	0	0	0	100
DALZ8510	117	17	0	0	0	0	0	133
DALZ8511	214	71	43	14	14	14	0	371
DALZ8512	400	150	83	50	17	17	0	717
DALZ8513	300	60	40	20	20	20	0	460
DALZ8514	260	100	100	40	0	20	0	520
DALZ8515	133	17	0	17	0	0	0	167
DALZ8516	150	17	17	0	0	0	0	183
DALZ8517	83	0	0	0	0	0	0	83
DALZ8522	140	20	40	40	20	20	0	280
DALZ8523	150	33	33	33	17	0	0	267
DALZ8524	100	17	17	17	0	0	0	150
DALZ8701	167	33	0	0	0	0	0	200
TAES3356	383	83	50	67	50	33	0	667
TAES3357	267	117	83	67	50	17	0	600
TAES3358	340	80	80	40	20	60	0	620
TAES3359	200	50	33	0	17	17	0	317
TAES3360	220	20	20	20	20	0	0	300
TAES3361	100	17	17	0	0	0	0	133
TAES3362	580	120	120	60	40	40	0	960
TAES3363	100	60	40	40	20	20	0	280
TAES3364	283	67	50	17	17	0	0	433
TAES3365	150	50	17	33	0	0	0	250
TAES3366	883	217	233	150	83	17	0	1583
TAES3367	150	50	17	17	0	0	0	233
TAES3372	183	67	33	17	0	0	0	300
MSD entry[1]	301	74	471	61	60	68	NS	539

[1] MSD = minimum significant difference for comparison of entry means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 13. Mean numbers of roots per 10 cm vertical root section for zoysiagrasses planted in flexible tubes.

Entry	Root numbers per 10cm section						
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm	50-60 cm	60-70 cm
Belair	3.20	2.67	2.67	2.00	1.50	2.00	0.0
Cashmere	4.00	3.00	1.80	1.33	1.00	0.00	0.0
El Toro	4.17	3.20	2.20	1.75	1.75	1.50	0.0
Emerald	5.57	3.29	1.83	1.50	1.33	1.50	0.0
FC13521	5.00	3.33	2.67	1.33	1.00	0.00	0.0
Meyer	3.67	2.80	2.20	2.50	1.75	1.50	0.0
DALZ8501	3.50	2.75	1.50	1.00	1.00	1.00	0.0
DALZ8502	3.00	2.50	1.50	1.00	0.00	0.00	0.0
DALZ8503	4.00	5.00	3.50	4.00	2.00	2.00	0.0
DALZ8504	5.67	3.17	2.00	1.60	1.33	1.50	0.0
DALZ8505	7.17	5.00	3.20	2.25	1.25	1.00	0.0
DALZ8506	4.00	2.33	1.50	1.50	1.00	1.00	0.0
DALZ8507	2.60	1.75	1.00	1.00	1.00	0.00	0.0
DALZ8508	2.50	1.67	1.20	1.00	1.33	1.00	0.0
DALZ8510	3.80	2.25	1.25	1.33	1.00	0.00	0.0
DALZ8511	5.83	3.67	3.40	2.20	2.33	2.50	0.0
DALZ8512	4.60	3.75	3.00	2.25	1.67	1.33	0.0
DALZ8513	5.33	5.67	4.67	2.67	1.33	1.33	0.0
DALZ8514	4.80	3.25	3.00	2.25	1.67	1.50	0.0
DALZ8515	4.00	1.75	1.25	1.33	0.00	0.00	0.0
DALZ8516	4.50	2.40	1.75	2.00	1.50	1.00	0.0
DALZ8517	2.86	2.00	1.00	1.00	1.00	1.00	0.0
DALZ8522	5.17	3.67	2.50	2.20	1.60	1.20	0.0
DALZ8523	2.83	2.20	2.00	1.60	1.25	1.50	0.0
DALZ8524	3.00	2.50	2.00	1.00	0.00	0.00	0.0
DALZ8701	4.17	2.40	1.60	1.00	1.00	1.00	0.0
TAES3356	5.67	3.00	2.60	2.00	1.75	2.00	0.0
TAES3357	5.83	4.17	3.50	2.80	2.60	1.75	0.0
TAES3358	5.60	4.20	3.60	2.60	2.20	2.20	0.0
TAES3359	3.17	3.00	2.33	1.33	1.00	0.00	0.0
TAES3360	4.00	2.83	1.75	1.50	1.00	1.00	0.0
TAES3361	3.40	2.00	1.67	2.00	2.00	1.00	0.0
TAES3362	9.17	5.67	3.60	2.50	1.50	1.25	0.0
TAES3363	3.00	3.20	2.40	2.00	1.60	1.40	0.0
TAES3364	3.83	2.80	2.00	1.75	1.25	1.33	0.0
TAES3365	3.67	2.60	1.60	1.33	1.00	0.00	0.0
TAES3366	6.33	4.67	3.67	3.33	2.60	2.00	0.0
TAES3367	4.00	3.50	2.50	1.33	1.00	1.00	0.0
TAES3372	5.33	3.17	1.83	1.40	1.00	1.00	0.0
MSD entry[1]	3.69	4.96	2.37	2.54	2.20	2.70	NS

[1] MSD = minimum significant difference for comparison of entry means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 14. Mean maximum and mean third maximum roots of warm season turfgrasses planted to TRIF.

Genus	Root length, mm Maximum	Third maximum
Zoysia	204	239
St. Augustine	212	220
Centipede	174	219
Buffalo	170	195
MSD genus[1]	NS	NS

[1] MSD = minimum significant difference for comparison of genus means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 15. Mean root mass (mg) per 10 cm vertical root section for warm season turfgrasses planted to TRIF.

Genus	Root mass (mg)					Total
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm	mass
Zoysia	452	171	92	39	3	756
St.Augustine	533	260	53	0	13	860
Centipede	820	170	45	10	0	1045
Buffalo	369	213	88	31	0	700
MSD genus[1]	217	NS	NS	NS	NS	NS

[1] MSD = Minimum significant difference for comparison of genus means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 16. Mean numbers of roots per 10 cm vertical root section for warm season turfgrasses planted to TRIF.

Genus	Numbers of roots				
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm
Zoysia	14	8	4	1	0
St.Augustine	19	10	2	0	0
Centipede	18	9	3	1	0
Buffalo	16	9	2	1	0
MSD genus[1]	NS	NS	4	NS	NS

[1] MSD = minimum significant difference for comparison of genus means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 17. Mean root mass per section and mean total root mass for warm season turfgrasses planted in flexible tubes.

Genus	Root mass (mg) per 10 cm section							Total
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm	50-60 cm	60-70 cm	mass
Zoysia	226	53	49	24	13	8	0	374
St. Augustine	996	350	188	167	142	158	0	2000
Centipede	328	191	172	153	144	116	0	1103
Buffalo	157	91	61	35	48	35	0	426
MSD genus[1]	120	45	85	37	34	40	0	259

[1] MSD = minimum significant difference for comparison of generic means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 18. Mean numbers of roots per 10 cm vertical root section for warm season turfgrasses planted in flexible tubes.

Genus	Root numbers per 10 cm section						
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm	50-60 cm	60-70 cm
Zoysia	4.43	3.17	2.30	1.90	1.56	1.47	0.0
St. Augustine	6.21	4.58	3.36	2.57	1.90	1.70	1.5
Centipede	8.55	7.37	5.90	5.33	4.48	3.83	0.0
Buffalo	4.26	3.04	2.32	2.16	1.69	1.70	2.0
MSD genus[1]	1.31	1.03	0.81	0.79	0.83	0.83	NS

[1] MSD = minimum significant difference for comparison of generic means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 19. Mean maximum and third maximum root lengths, mean extension rates, and mean total leaf areas for warm season turfgrasses planted in flexible tubes.

Genus	Maximum root length	Third max. root	Extension rate	Total leaf area
	--- mm ---	-- mm --	- mm/day -	-- cm^2 --
Zoysia	387	174	10.0	17.4
St. Augustine	552	255	22.5	82.2
Centipede	554	455	11.9	30.8
Buffalo	498	190	18.1	16.8
MSD genus[1]	82	62	2.9	8.8

[1] MSD = minimum significant difference for comparison of entry means within columns based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 20. April through October 1990 color, quality, ground cover, and chlorosis ratings for the University of Arizona zoysiagrass regional trial established summer, 1987.

Entry	Color 1-9, 9=best							
	April	May	June	July	August	September	October	PS[1]
DALZ8501	2.0	2.8	4.7	6.5a[2]	7.8a	7.8a	8.0a	4
DALZ8502	1.7	3.8	6.0a	6.2	7.7a	7.7a	8.0a	4
DALZ8508	2.2	4.5a	5.2	5.3	6.8	6.5	7.0	1
DALZ8516	3.7a	4.5a	6.0a	5.7	5.7	6.8	7.0	3
Belair	4.8a	3.8	5.8	5.2	6.0	7.3	7.3	1
El Toro	4.6a	5.5a	7.3a	7.5a	7.7a	8.0a	8.0a	7
Emerald	3.5	6.0a	7.5a	7.8a	7.5a	8.0a	8.2a	6
Meyer	4.0a	5.8a	7.2a	6.5	6.3	7.2	8.2a	5

Entry	Quality 1-9, 9=best							
	April	May	June	July	August	September	October	PS
DALZ8501	1.7	2.7	4.7	6.0a	7.5a	7.5a	8.3a	4
DALZ8502	1.7	3.8	5.8a	6.0a	6.8	7.2a	7.5	3
DALZ8508	1.3	4.0	5.0	5.2	6.2	6.0	6.3	0
DALZ8516	2.7a	3.8	5.5a	5.5	5.3	6.5	6.5	2
Belair	3.3a	3.5	4.7	4.8	5.5	7.5a	6.8	2
El Toro	4.0a	5.5a	7.3a	7.8a	8.3a	8.0a	8.3a	7
Emerald	2.8a	6.3a	7.3a	8.0a	7.8a	7.8a	8.5a	7
Meyer	3.7a	6.0a	7.5a	6.8a	6.5	7.3a	8.0a	6

Entry	Ground coverage 1-9, 9=best						Chlorosis 1-9, 9=most green		PS
	June	July	August	September	October	PS	August	September	(overall)
DALZ8501	4.8	5.8a	8.2a	7.8a	8.0a	4	8.5a	8.0a	14
DALZ8502	6.0a	6.3a	7.0a	7.7a	7.3a	5	8.0a	8.0a	14
DALZ8508	4.8	5.3a	6.5	6.8	6.3	1	7.5a	7.7	3
DALZ8516	4.5	5.0	5.7	6.5	6.0	0	6.3	7.0	5
Belair	4.8	5.0	6.5	7.8a	6.8	1	6.0	7.3	4
El Toro	7.7a	7.8a	8.5a	8.2a	8.3a	5	8.0a	8.0a	21
Emerald	7.3a	7.8a	8.3a	8.2a	8.2a	5	7.7a	8.7a	20
Meyer	7.3a	7.3a	8.2a	7.3a	8.2a	5	6.2	7.3	16

[1] PS = phenotypic stability, the number of times an entry received superior ratings based on least significant differences (LSD).
[2] Means followed by the same letter within a column are not significantly different based on LSD.

Table 21. January through July 1990 cover, color, texture, and turf score ratings for the University of California - Riverside zoysiagrass regional trial established summer, 1989.

Entry	Cover 1-9, 9=full cover March	April	May	June	July	PS[1] Cover	Turf Score 1-9 9 = best July
DALZ8501	2.0e[2]	3.7b	5.7cde	5.0e-h	6.0de	0	7.3a
DALZ8502	2.0e	2.0e	4.3fgh	4.7f-i	6.0de	0	7.3a
DALZ8507	3.0c	5.3a	6.3bc	7.0abc	8.0ab	3	7.0ab
DALZ8512	4.3ab	6.0a	8.0a	8.3a	8.7a	5	6.7ab
DALZ8514	4.7a	5.7a	8.0a	8.3a	8.7a	5	6.7ab
DALZ8701	2.0e	3.3bc	5.7cde	6.7bcd	7.0bcd	0	7.0ab
Belair	2.3de	2.3de	3.0i	3.3i	3.3f	4	4.0e
El Toro	4.0b	5.3a	7.3ab	7.3ab	7.7ab	0	7.0ab
Emerald	2.0e	2.7cde	3.9ghi	4.0ghi	5.4e	0	6.5abc
Meyer	2.0e	2.3de	3.7hi	3.7hi	6.0de	0	5.7cd

Entry	Color 1-9, 9 = best January	March	May	June	PS Color	Texture 1-9, 9 = best June	PS Total
DALZ8501	5.3abc	6.0abc	7.0b	7.0b	2	7.0cd	3
DALZ8502	6.0a	6.0abc	7.7ab	8.0a	4	8.7a	6
DALZ8507	5.7ab	6.7ab	7.0b	7.3b	2	8.0b	6
DALZ8512	3.0fg	6.0abc	8.0a	7.0b	2	4.0h	8
DALZ8514	3.0fg	5.3bcd	8.0a	7.0b	1	4.0h	7
DALZ8701	5.7ab	6.0abc	7.7ab	7.3b	3	6.7d	4
Belair	1.0h	4.7cd	5.7c	6.0d	0	5.0g	0
El Toro	2.7g	5.3bcd	8.0a	7.0b	1	4.0h	6
Emerald	5.0bcd	7.3a	6.9b	7.0bc	1	7.4bc	2
Meyer	1.0h	5.0cd	7.0b	7.3b	0	5.0g	0

[1] PS = phenotypic stability, the number of times an entry received superior ratings based on least significant differences (LSD).

[2] Means followed by the same letter within a column are not significantly different based on LSD.

Table 22. March through September 1990 dormancy, quality and mower scalping ratings for the University of California - Santa Clara Field station zoysiagrass regional trial established 6/23/87 or 8/26/87.

Entry	Dormancy 1-5, 5=dormant March	April	Quality 1-9, 9=best March	August	September	Mower scalping 1-9, 9=least April	Aug. 2	Aug. 15	September	Total PS[1]
DALZ8501	3.7e[2]	1.0	2.3e	5.3cd	4.7b	4.0g	3.3fg	1.7g	4.3de	0
DALZ8502	4.0e	1.0	2.3e	5.0de	4.7b	3.3g	3.0g	1.3g	3.7e	0
DALZ8508	1.7ab	1.0	6.0bc	6.0bc	6.3a	4.0g	4.3ef	2.3fg	5.0cde	2
DALZ8516	1.0a	1.0	7.0a	6.7ab	6.7a	5.0f	5.7cd	3.3ef	6.0bcd	4
Belair	3.3de	1.0	2.7e	4.3ef	4.3b	7.7ab	7.3a	8.7a	8.0a	4
BK-7	1.7ab	1.0	6.0bc	7.0a	6.7a	7.0bcd	7.3a	5.7c	8.0a	5
El Toro	3.0cde	1.0	5.3cd	6.3ab	6.0a	5.7ef	6.7abc	5.7c	7.0ab	4
Emerald	1.0a	1.0	7.0a	7.0a	7.0a	5.3f	6.3a-d	4.0de	6.7abc	6
KorCom1[3]	3.0cde	1.0	4.7d	4.0f	4.3b	7.3abc	5.3de	5.3c	8.0a	2
KorCom2[3]	2.0abc	1.0	4.7d	4.7def	4.3b	8.0a	6.7abc	7.0b	8.3a	4
Meyer	2.7bcd	1.0	5.3cd	7.0a	6.0a	6.3de	7.0ab	5.7c	7.3ab	4
Sunburst	1.3e	1.0	6.7ab	5.3cd	4.7b	6.7cd	6.0bcd	5.0cd	6.7abc	3

[1] PS = Phenotypic Stability, the number of times an entry received superior ratings based on least significant differences (LSD).
[2] Means followed by the same letter within a column are not significantly different based on LSD.
[3] KorCom = Korean Common seeded at 1 lb. N/1000 ft² (KorCom1) and 2 lb. N/1000 ft² (KorCom2).

Table 23. September 1990 quality ratings of zoysias maintained under putting green conditions, recorded by J. Murray and P. Busey at Banyan Golf Club West Palm Beach, Florida.

Entry	September 12 J. Murray	September 13 P. Busey	Mean
DALZ8501	4.0	4.7b[1]	4.3c
DALZ8502	8.2	8.8a	8.5a
DALZ8508	5.0	4.8b	4.9c
DALZ8701	7.0	8.8a	7.9ab
Emerald	6.3	6.5ab	6.4abc
TAES3477	5.3	6.2ab	5.8bc

[1] Means followed by the same letter within a column are not significantly different based on the Waller-Duncan K-ratio t test (K-ratio = 100).

Table 24. August and September leaf texture ratings (1-9, 9 = finest texture) for the 1990 parent-progeny zoysiagrass space planting initiated 7 July, 1990.

		August				September			
Entry	N	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
DALZ8501	4	8	9	8.2	0.5	6	7	6.5	0.6
progeny	16	7	9	7.6	0.7	5	8	6.4	0.8
DALZ8502	4	7	9	8.5	1.0	5	7	5.8	1.0
progeny	16	6	9	7.7	0.9	6	8	6.8	0.5
DALZ8511	4	5	8	6.5	1.3	3	5	4.0	0.8
progeny	16	3	7	5.6	1.2	2	6	3.8	1.0
DALZ8512	4	1	5	3.5	1.9	2	3	2.2	0.5
progeny	16	2	7	4.9	1.7	2	5	3.6	1.1
DALZ8513	4	6	8	7.0	0.8	5	5	5.0	0.0
progeny	16	5	8	6.2	0.9	4	6	5.1	0.6
DALZ8514	4	4	6	5.2	1.0	2	3	2.2	0.5
progeny	16	3	7	5.6	1.3	2	6	3.7	1.0
DALZ8516	4	7	8	7.5	0.6	5	6	5.8	0.5
progeny	16	3	8	6.8	1.2	3	7	5.5	1.0
DALZ8523	4	7	8	7.5	0.6	6	7	6.2	0.5
progeny	16	6	8	7.2	0.5	5	7	6.2	0.6
BELAIR	4	2	6	4.5	1.9	3	4	3.5	0.6
progeny	16	2	7	5.1	1.6	2	6	4.1	1.3
CASHMERE	4	7	8	7.8	0.5	6	7	6.5	0.6
progeny	16	5	9	7.9	1.0	5	8	6.3	0.9
EL TORO	4	4	7	5.0	1.4	2	3	2.2	0.5
progeny	16	2	8	5.1	1.7	3	5	3.8	0.6

Table 25. August and September color ratings (1-9, 9 = darkest green and 5 = acceptable) for the 1990 parent-progeny zoysiagrass space planting initiated 7 July, 1990.

Entry	N	August Min.	August Max.	August Mean	August SD	September Min.	September Max.	September Mean	September SD
DALZ8501	4	4	7	5.5	1.3	4	6	5.2	1.0
progeny	16	4	8	6.6	1.2	3	6	4.9	0.7
DALZ8502	4	4	6	5.5	1.0	5	7	5.8	1.0
progeny	16	5	8	6.5	1.0	5	7	5.8	0.7
DALZ8511	4	6	7	6.8	0.5	6	7	6.5	0.6
progeny	16	5	8	6.8	1.0	5	6	5.5	0.5
DALZ8512	4	3	7	5.0	1.6	6	7	6.5	0.6
progeny	16	5	8	6.2	0.9	5	7	5.8	0.5
DALZ8513	4	4	7	6.0	1.4	5	6	5.8	0.5
progeny	16	5	8	6.3	0.9	5	7	5.5	0.6
DALZ8514	4	5	7	6.0	1.2	6	7	6.5	0.6
progeny	16	5	8	6.2	1.0	4	6	5.3	0.6
DALZ8516	4	6	8	7.0	1.2	6	9	7.8	1.3
progeny	16	5	8	6.4	1.0	5	8	6.4	0.9
DALZ8523	4	4	8	6.0	1.6	6	6	6.0	0.0
progeny	16	4	8	6.3	1.2	5	7	5.6	0.6
BELAIR	4	5	7	6.2	1.0	7	9	7.8	1.0
progeny	16	5	8	6.3	1.0	5	7	5.6	0.6
CASHMERE	4	5	6	5.5	0.6	6	6	6.0	0.0
progeny	16	5	8	6.9	1.1	5	7	5.6	0.6
EL TORO	4	5	7	6.0	0.8	6	7	6.5	0.6
progeny	16	5	9	6.8	1.1	4	7	5.2	0.8

Table 26. August spread ratings (1-9, 9 = greatest spread) and September density ratings (1-9, 9 = most dense) for 1990 parent-progeny zoysiagrass space planting initiated 7 July, 1990.

Entry	N	Spread				Density			
		Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
DALZ8501	4	1	2	1.8	0.5	4	6	5.0	0.8
progeny	16	1	6	2.1	1.3	2	8	5.1	1.4
DALZ8502	4	1	2	1.2	0.5	5	6	5.8	0.5
progeny	16	2	4	2.4	0.6	4	7	5.6	0.8
DALZ8511	4	1	3	1.5	1.0	4	4	4.0	0.0
progeny	16	2	7	3.6	1.5	2	7	4.0	1.3
DALZ8512	4	1	2	1.5	0.6	3	4	3.2	0.5
progeny	16	1	6	3.2	1.1	2	6	4.2	1.2
DALZ8513	4	1	3	2.0	0.8	3	7	4.8	1.7
progeny	16	2	4	2.6	0.7	3	8	5.4	1.2
DALZ8514	4	1	3	2.0	1.2	3	4	3.2	0.5
progeny	16	1	7	3.7	1.4	2	6	3.7	1.4
DALZ8516	4	1	1	1.0	0.0	4	5	4.5	0.6
progeny	16	1	3	1.8	0.8	1	6	4.0	1.5
DALZ8523	4	1	2	1.8	0.5	3	6	4.5	1.3
progeny	16	1	3	2.4	0.8	3	7	4.9	1.0
BELAIR	4	1	2	1.2	0.5	2	6	4.2	1.7
progeny	16	1	5	2.7	1.2	2	6	4.1	1.1
CASHMERE	4	1	3	2.0	0.8	4	5	4.5	0.6
progeny	16	1	4	2.6	0.8	4	7	5.5	1.1
EL TORO	4	2	3	2.2	0.5	3	5	4.2	1.0
progeny	16	2	7	4.7	1.9	3	6	4.2	0.9

Table 27. September stolon count and average stolon length (5 measurements per plot) for the 1990 parent-progeny zoysiagrass space planting initiated 7 July, 1990.

Entry	N	Stolon Count				Stolon Length			
		Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
DALZ8501	4	0	3	1.2	1.3	0.0	6.5	1.0	1.4
progeny	16	1	73	10.3	17.8	57.0	10.3	11.2	
DALZ8502	4	0	16	5.2	7.3	0.0	8.5	3.0	3.4
progeny	16	3	29	14.6	7.7	0.0	20.5	25.1	54.6
DALZ8511	4	1	5	2.8	1.7	0.0	27.5	6.8	5.8
progeny	16	8	61	37.8	15.9	0.0	51.0	24.6	6.0
DALZ8512	4	2	69	27.0	31.1	0.0	39.0	19.5	11.4
progeny	16	3	103	35.3	27.9	0.0	39.0	23.9	6.8
DALZ8513	4	5	32	13.0	12.8	5.0	18.0	9.8	3.0
progeny	16	4	68	20.8	19.2	0	30	16.3	4.9
DALZ8514	4	8	32	18.2	10.0	10.0	40.5	24.4	6.6
progeny	16	3	122	38.8	30.0	0.0	45.0	22.9	7.9
DALZ8516	4	3	8	5.2	2.1	0.0	13.0	6.3	1.1
progeny	16	0	43	14.5	14.3	0.0	30.0	10.6	9.2
DALZ8523	4	4	9	6.0	2.2	0.0	15.0	9.1	2.9
progeny	16	3	34	15.4	9.5	0.0	28.0	14.2	5.7
BELAIR	4	3	45	15.0	20.2	0.0	19.0	10.5	4.1
progeny	16	5	67	32.6	18.2	4.0	35.5	20.8	6.3
CASHMERE	4	4	14	9.2	4.3	0.0	20.5	9.6	6.2
progeny	16	4	39	16.8	10.1	0.0	32.0	17.3	5.6
EL TORO	4	7	34	21.0	14.0	13.0	34.5	20.2	2.0
progeny	16	12	84	37.5	20.9	10.0	39.5	23.7	5.4

Table 28. September internode length ratings (1-9, 9 = longest) and internode color for the 1990 parent-progeny zoysiagrass space planting initiated 7 July, 1990.

		Internode length				Number Plants per Internode Color			
Entry	N	Min.	Max.	Mean	SD	White	Light Purple	Purple/ Red	Not Visible
DALZ8501	4	2	3	2.8	0.5	0	0	0	4
progeny	16	2	7	3.1	1.1	3	4	1	8
DALZ8502	4	2	5	2.8	1.5	0	1	0	3
progeny	16	2	5	2.9	0.7	1	6	5	4
DALZ8511	4	3	5	4.5	1.0	0	0	1	3
progeny	16	3	6	5.3	1.0	2	1	13	0
DALZ8512	4	5	6	5.5	0.6	0	0	3	1
progeny	16	3	6	5.1	0.7	6	0	10	0
DALZ8513	4	3	3	3.0	0.0	0	4	0	0
progeny	16	3	5	3.6	1.0	0	7	5	4
DALZ8514	4	3	6	5.2	1.5	0	0	4	0
progeny	16	2	7	4.4	1.7	5	0	10	1
DALZ8516	4	2	3	2.8	0.5	0	2	1	1
progeny	16	1	6	3.1	1.3	0	2	10	3
DALZ8523	4	3	3	3.0	0.0	0	0	3	1
progeny	16	3	3	3.0	0.0	0	4	8	4
BELAIR	4	3	5	4.5	1.0	3	0	0	1
progeny	16	3	6	4.9	0.9	2	1	12	0
CASHMERE	4	2	5	3.2	1.3	0	0	3	1
progeny	16	2	6	3.9	1.3	0	4	11	1
EL TORO	4	3	6	5.0	1.4	0	0	4	0
progeny	16	3	6	4.8	1.2	2	0	14	0

Table 29. September growth habit ratings for the 1990 parent-progeny zoysiagrass space planting initiated 7 July, 1990.

Entry	N	Overall Plant Growth Habit 1 = upright to 5 = prostrate Min.	Max.	Mean	SD	Vegetative propagation patterns 1 = stoloniferous to 4 = rhizomatous Min.	Max.	Mean	SD
DALZ8501	4	1	1	1.0	0.0	4	4	4.0	---
progeny	16	1	5	2.8	1.7	1	4	3.1	1.3
DALZ8502	4	1	4	1.8	1.5	4	4	4.0	0.0
progeny	16	2	5	4.2	1.0	1	4	3.5	1.0
DALZ8511	4	1	4	1.8	1.5	2	4	3.5	1.0
progeny	16	4	5	4.6	0.5	1	4	1.5	1.0
DALZ8512	4	4	4	4.0	0.0	1	4	2.5	1.7
progeny	16	2	5	3.8	1.2	1	4	1.6	0.9
DALZ8513	4	1	4	2.5	1.7	1	4	3.2	1.5
progeny	16	1	5	3	1.5	1	4	2.9	1.3
DALZ8514	4	4	5	4.5	0.6	1	2	1.2	0.5
progeny	16	1	5	3.8	1.2	1	4	1.6	1.0
DALZ8516	4	1	5	2.8	2.1	1	4	2.8	1.5
progeny	16	1	5	3.3	1.7	1	4	1.8	1.1
DALZ8523	4	4	5	4.5	0.6	2	4	3.2	1.0
progeny	16	2	5	4.4	0.9	2	4	3.1	0.9
BELAIR	4	1	2	1.5	0.6	1	4	2.5	1.7
progeny	16	4	5	4.3	0.5	1	2	1.5	0.5
CASHMERE	4	5	5	5.0	0.0	1	4	2.8	1.3
progeny	16	2	5	4.2	1.0	1	4	2.8	1.1
EL TORO	4	2	4	3.5	1.0	1	4	2.5	1.3
progeny	16	2	5	4.1	1.1	1	4	1.9	1.1

Figure 1. Temperatures and rainfall for TAES—Dallas, 1989.

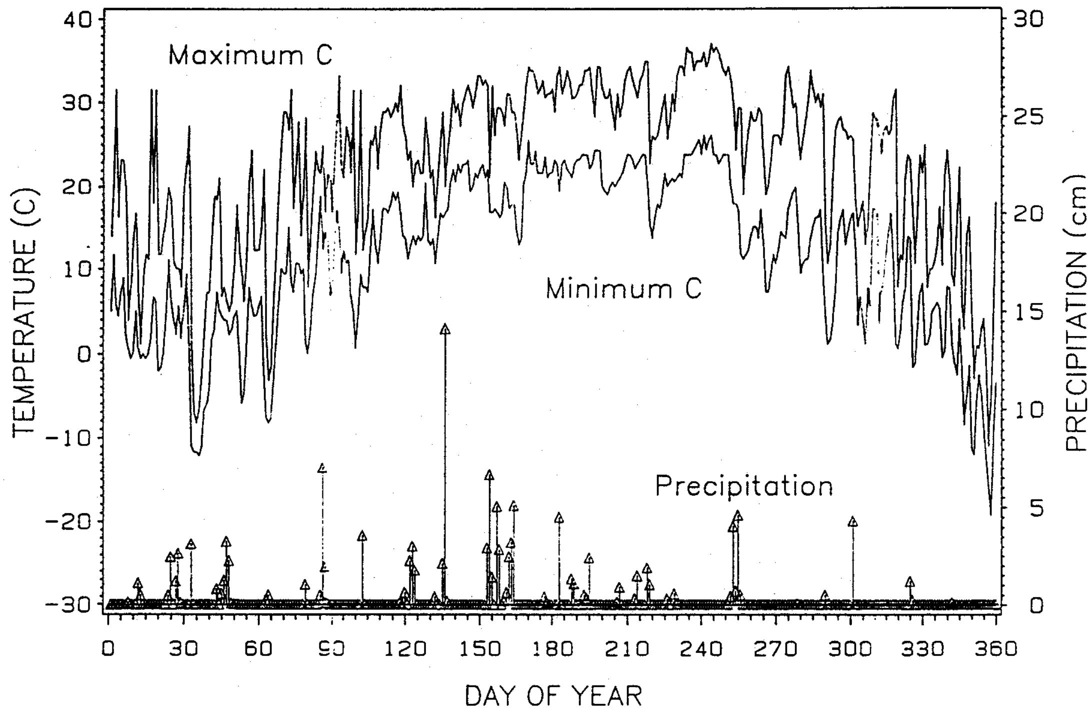


Figure 2. Temperatures and rainfall for TAES—Dallas, 1990.

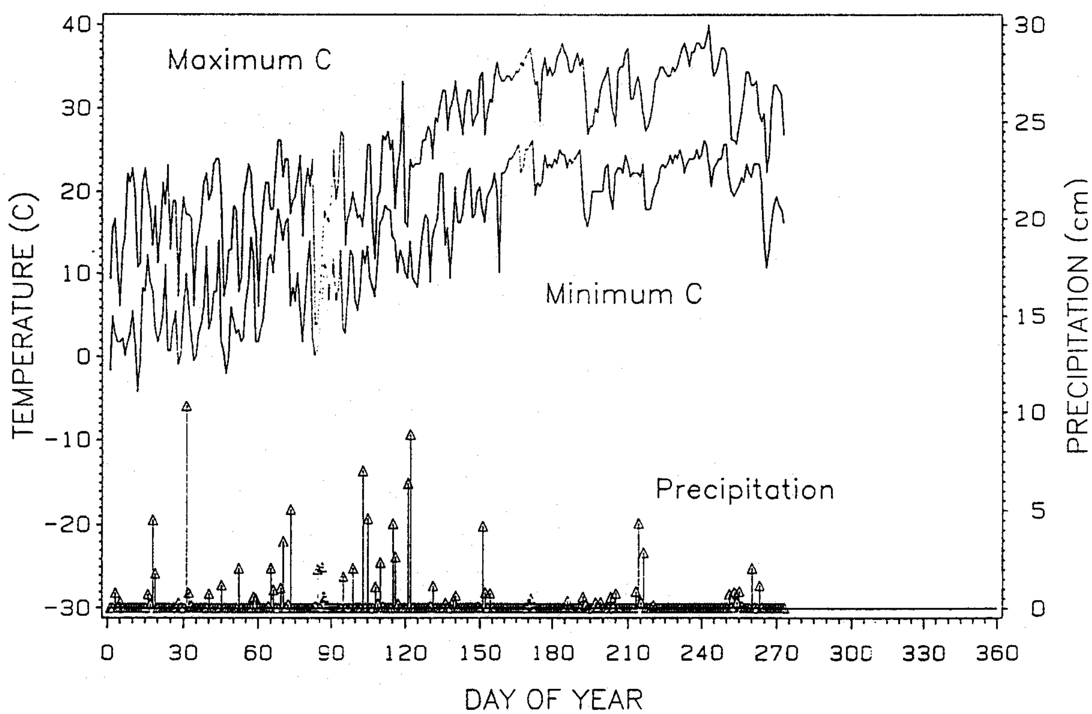
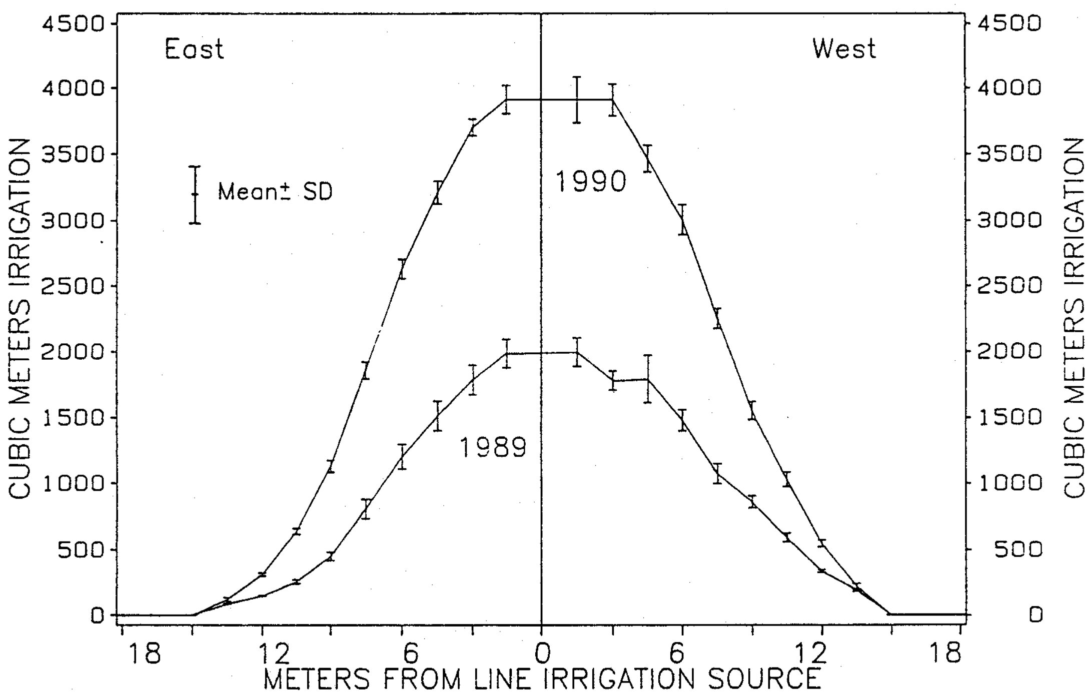
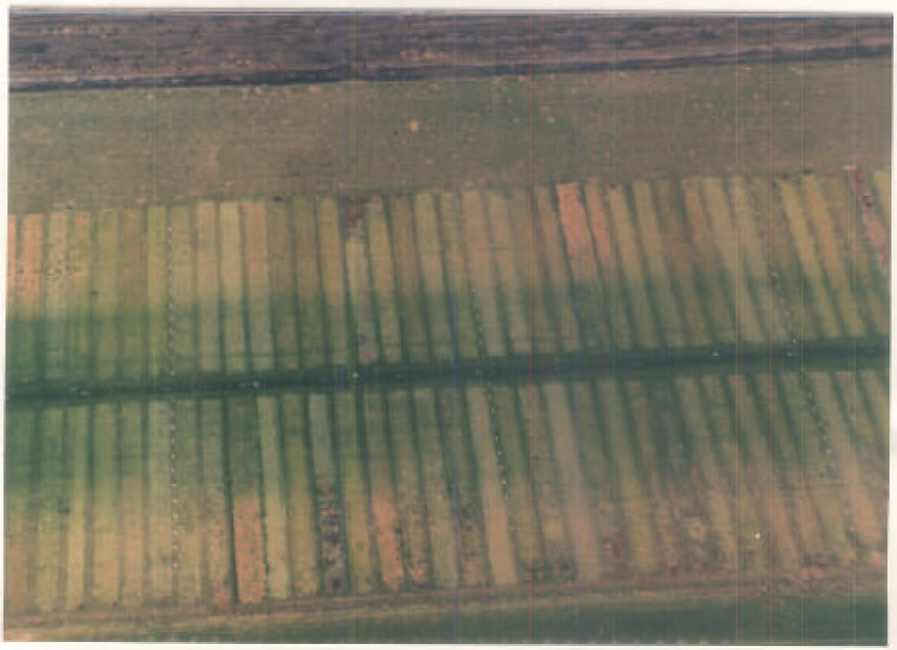
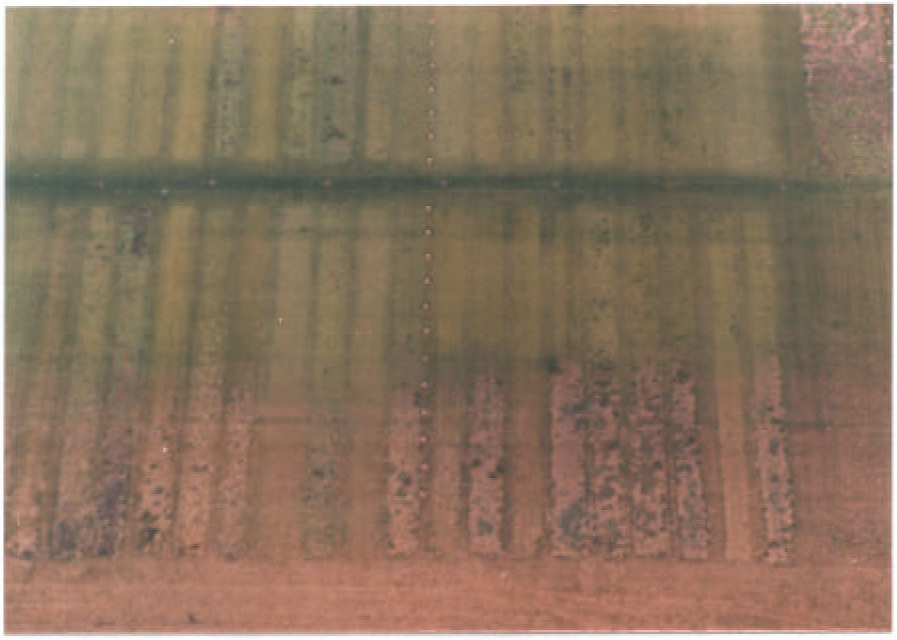


Figure 3. Irrigation distribution for LGIS at TAES—Dallas.

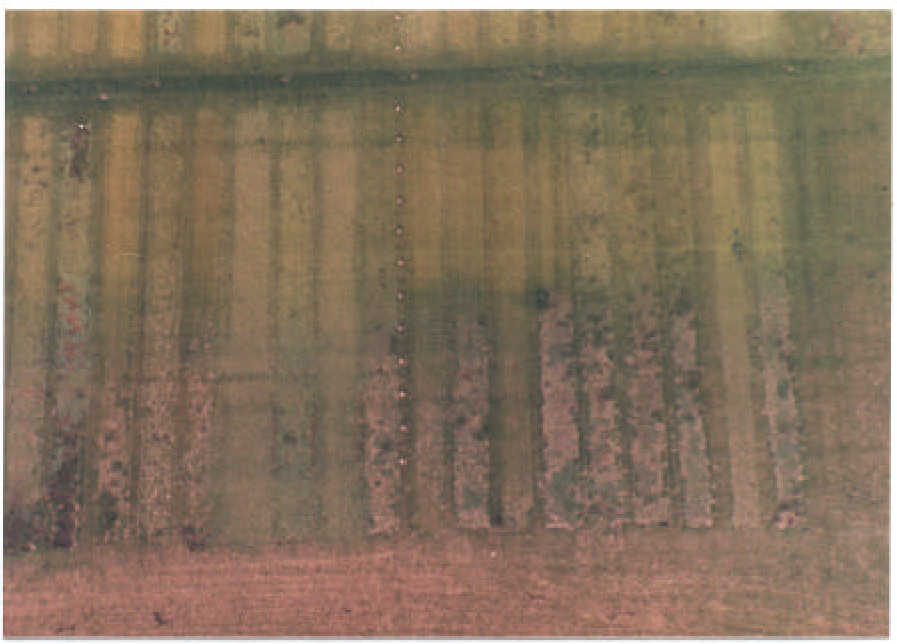




Photograph 1. Aerial overview of zoysiagrasses on LGIS at TAES-Dallas, Texas. Photograph taken 16 September 1989.



Photograph 2. Zoysiagrasses on LGIS during drought stress.
Photograph taken 8 September 1990



Photograph 3. Zoysiagrasses on LGIS 7 days after rainfall.
Photograph taken 18 September 1990