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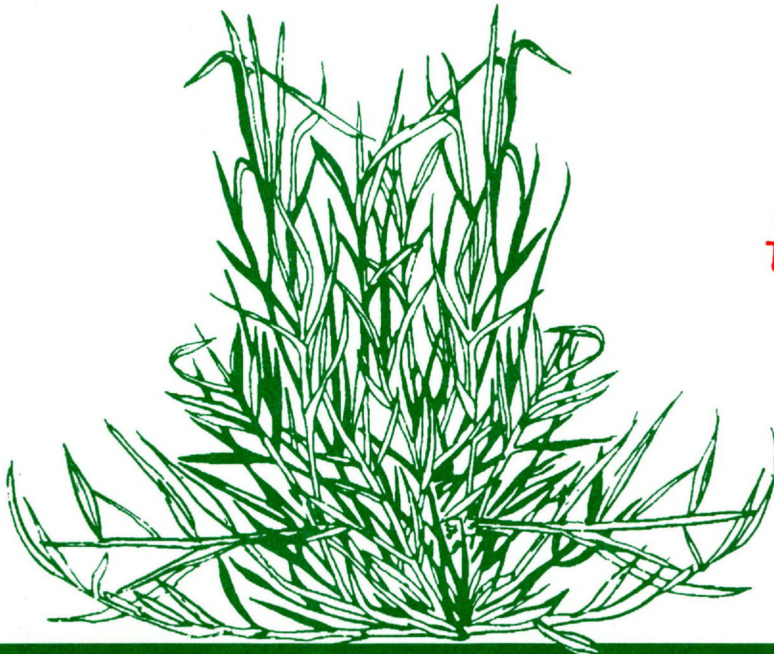

Texas Turfgrass Research–1991

Texas Agricultural Experiment Station
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The Texas A&M University System
College Station, Texas

Texas Turfgrass Research—1991

Preface

Texas Turfgrass Research represents a consolidation of articles reporting progress of research accomplished by individuals within the Texas A&M University System and The Texas Agricultural Experiment Station Turfgrass Program. Texas Turfgrass Research is published to disseminate information to turfgrass managers, research scientists, extension specialists, and others involved with turfgrass management. Much of the information contained in this publication is preliminary and should not be construed as a final recommendation or endorsement by the Texas Agricultural Experiment Station. Mention of a trademark or a proprietary product does not constitute a guarantee or a warranty of the product by The Texas Agricultural Experiment Station and does not imply its approval to the exclusion of other products that also may be suitable. Some of the articles that appear in this report contain metric units of measure. A brief table is provided on the inside back cover to facilitate conversion of metric to English units. A special thanks to those who have submitted papers and to the turfgrass industry whose interest and support greatly enhance the effectiveness of the Texas turfgrass program.

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Turfgrass Usage in Texas

Size and Contributions

Texas is a major urban state with nearly 88 percent of its population living in urban settings. Houston, the Dallas/Fort Worth Metroplex, and San Antonio rank among the 10 most populated regions of the United States and account for nearly 15 million people. The increase in Texas population has been dramatic over the past several decades as a result of a continued migration of people into sunbelt states. The Turfgrass industry in Texas is estimated to produce $3.5 billion in annual revenues. Nationally, the industry is estimated to exceed $27 billion, mostly for new construction, replacement, and renovation cost and routine maintenance. Total acreage maintained as turf in Texas for various functional, recreational, and aesthetic uses exceeds 1.4 million hectares, with an annual maintenance cost estimated at over $600 million. Highway rights-of-way in Texas cover more that 73,000 hectares and cost nearly $40 million annually for mowing alone. There are approximately 2.6 million single-family dwellings in Texas, with the balance of the population living in multifamily units such as townhouses, condominiums, and apartments. Although the bulk of acreage in turf resides in municipal, industrial, and recreational facilities, the majority of financial, chemical, labor, and natural resources are expended on individual residential lawns.

With the increase in the inner-urban population, greater emphasis is being placed on the development of extensive greenbelts. Greenbelts are intended to provide aesthetic appeal, and both physical and mental sources for relaxation. Since the 1970s, our society has turned to local verses regional or national activities for expenditure of leisure time. Such activities include using recreational outlets such as parks, playgrounds, and sports fields for general public use, as well as intense landscaping and aesthetic enhancement of the immediate home environment. Proper and well maintained landscaping adds 15 percent to a home's value according to a Gallop Surey, and the investment recovery rate is 100 to 200 percent for landscape improvement, as compared to 40 to 70 percent recovery for a swimming pool, patio, or deck.

Turf per se serves a multi-functional role in supporting the urban population. The primary roles of turf are in soil stabilization, water conservation, and environmental enhancement. Actively growing turf is highly effective in control of environmental pollution, including the suppression of dust, glare, and noise, and in heat dissipation, especially in the arid and semi-arid regions of the United States. Differential surface temperataures up to 25°C can occur between actively growing versus summer dormant turf or non-active surfaces such as concrete, asphalt, or even bare soil. It is estimated that the front lawn of an average home has the cooling capacity of a 10 ton air conditioner, while the average home central air unit has a 3 to 4 ton capacity.

Turfgrasses are reported to absorb rainfall six times more effectively than a wheat field, and four times better than a hay field. Sodded lawns absorb 10 to 12 times more water than seeded lawns, even 2 to 3 years after establishment, providing excellent erosion control and soil stabilization. Healthy growing turfs are effective biological filters and absorb carbon dioxide, ozone, hydrogen fluoride, and perosyacetyle nitrate. They purfify surface water entering underground aquifers by their root mass and soil microbes acting as a filter to capture and break down many types of environmental pollutants. At the present, however, little published information is available to document these implied values of turf.

Projected Changes and Research Needs

The six most critical issues facing the turfgrass industry as identified in the Texas A&M Univsersity Agricultural Programs Strategic Plan are as follows: (1) Develop turf ecosystems to reduce impact of environmental pollutants; (2) Develop educational programs to emphasize efficient production and management technologies; (3) Develop improved technologies for the management of weeds, diseases, insects, and other pests; (4) Develop landscape management systems that conserve natural resources; (5) Integrate urban landscape systems to enhance quality of life; and (6) Develop decision tools for management of recreational and landscape surfaces. These involve improvements in significant water conservation and reduction in cultural inputs, expecially chemicals, while retaining the full functional benefits of turf which contribute directly to the quality of life.

The increase in population and the intensity of demand for public and private recreataional areas dictate the need to broaden our information base on the use, performance, and development of turfs for the arid, semi-arid, and humid climates of Texas. The diverse environmental stresses that occur in our region dictate the need for research to develop improved species, root zones, and cultural systems that can sustain growth and survive under intensive use. It is equally important that these turfgrasses and cultural systems possess adequate tolerance to environmental stresses such as temperature extremes, low light levels, and salinity and must possess resistance to pests common to the region.

The turfgrass problems and research needs of the residents of Texas are great and very diverse. The pool of fundamental knowledge is small compared to the traditional agricultural commodity areas. Research must rigidly focus on environmental issues and natural resource conservation and contribute solutions at this time before imposed restrictions drastically impair the use of turfgrass; thus in turn, creating a decline in our quality of life.

Acknowledgment of Research Support

A substantial portion of the research results reported herein could not have been accomplished without grant support and contributions of equipment, chemicals, and plant materials from foundations, associations, and companies within the turfgrass industry.

Of special note is the major grant commitment of the United States Golf Association. They have contributed nearly $1.25 million since 1983 to Drs. Beard, Engelke, and Horst for the development of minimal maintenance, water conserving turfgrasses and cultural systems.

In addition, general grants for support of the Turfgrass Field Laboratory operations were provided by the Texas Golf Association, Texas Sod Producers Association, and the Texas Turfgrass Association. There are also grants, such as those from Bentgrass Research, Inc., provided for specific research objectives. The specific granting agency is acknowledged at the end of the Progress Report describing research being supported.

Numerous turfgrass equipment manufacturing firms and suppliers have provided equipment, chemicals, seed, and allied materials that are so vital to the continuing operation of the turfgrass research facilities. Due to their donations, operational monies can be utilized primarily for employment of personnel needed to maintain the experimental plots. Their assistance is gratefully acknowledged. A complete summary of the companies that have given donations of equipment, chemicals, and materials is on the following page.

Vital major donations of equipment have been given by Goldthwaites of Texas, Jacobsen Manufacturing Comapny, The Toro Company, Watson Distribution Company, and Brower Turf Equipment Limited.

Donations Acknowledged

Recognition is given to those who have generously provided equipment and materials during the recent past to aid in the development of the Texas Agricultural Experiment Station and Texas A&M University Turfgrass Research, Teaching, and Extension programs.

Equipment

Bollens Co.-D
Buckner Irrigation-D
Dow Chemical USA-D
E-Z GO Div. of Textron-C,D
Gail's Flags-D
Goldthwaites of Texas-C
Jacobsen Manufacturing Co.-C
John Deere-C,D
Las Colinas Sports Club-D
North Texas Golf Course Superintendents Assoc.-D
O.M. Scott & Sons-C
Rainbird Sprinkler Corp.-C,D
Ryan Division, OMC Lincoln-D
Sioux Industries-D
Spraying Devices Inc.-D
Spraying Systems Co.-C
Strittmatter Irrigation-D
The Toro Company-C,D
Thompson Manufacturing-D
Texas Industries-D
Warren's Turf Nursery-D
Watson Distributing Co.-C,D
Yazoo Manufacturing-D

Seed, Sod, and Sprigs

Conlee Seed Co., Inc.-D
Coastal Turf Nursery-C,D
Crenshaw & Douget Turfgrass Co.-D
Harpool's Seed, Inc.-D
International Seeds, Inc.-C,D
Jim Lincoln Corp.-D
Lofts Seed, Inc.-C,D
Milberger Turf Farms-C,D
Northrup King and Sons-C,D
O.M. Scott & Sons-C
Pickseed West, Inc.-C,D
Pursley Turf Farm, Inc.-D
Quality Turf-D
Southern Turf Nurseries, Inc.-C
Texas Sodgrowers Assoc.-D
Thomas Brothers Grass Co.-D
Trinity Turf-D
Turf Seed, Inc.-C,D
Winrock Grass Farms-C,D

Soil Amendments

Back to Earth Resources-D
Big Sandy Sand Co.-D
Conlee Seed Co., Inc.-D
Don Caylor Trucking Co.-C
McMaster's-C,D
Pioneer Peat, Inc.-C
Rinehart Trucking-C
Sunshine, Inc.-D

Fertilizers, Pesticides, Chemicals

American Cyanamid Corp.-C,D
Aquatrols Corp. of America-C
ATT-D
BASF Wyandotte Corp.-C
Bonus Crop Fertilizer-D
Chevron Chemical Co.-C,D
Ciba-Geigy Corp. Agricultural Div.-C,D
Diamond Shamrock Corp.-C,D
Dow Elanco-C,D
E.I. DuPont de Nemours & Co., Inc.-D
Emerald Isle, Ltd.-D
Grace/Sierra Chemical Co.-D
Gustafson Inc.-D
Helena Chemical Co.-D
Hoechst-Roussel Agri-Ver Co.-C
ISK Biotech Corp.-C,D
Kaiser/Estech-D
Lesco Products-C,D
Milliken Chemicals-C
Milwaukee Metropolitan Sewerage District-D
Mobay Chemical Corp.-C,D
Monsanto Co.-C,D
Moyer and Son, Inc.-D
Nelson Plant Food-C
NORAM Chemical Co.-C,D
Parkway Research, Corp.-D
PBI/Gordon Corp.-C
Reuter Laboratories, Inc.-D
Rhone-Poulenc, Inc. Agric. Div.-C,D
Ricerca, Inc.-D
Sandoz-C,D
Uniroyal Chemical Co.-C,D
Valent-D
W.A.Cleary Corp.-C

Other Cooperators

Augusta National G.C.-D
American Cyanamid Co.-C,D
American Sod Producers Assoc.-C
Banyan Golf Club-D
Bentgrass, Inc.-D
Bent Tree C.C.-D
Biosis-D
Bowie Industries, Inc.-D
Brenham C.C.-C
Briarcrest Country Club-C
Canyon Creek Country Club-D
Champions C.C.-C
Colonial C.C.-C
The Dallas Arboretum-D
Davenport Seed Co.-C
FMC Corp.-D
Fort Worth Parks and Recreation Dept.-D
Hydro Separation Systems, Inc.-D
ICI American-D
Legends Golf Course-C
Los Angeles Turf Club-C
Milberger Turf Farms-C
Mobay Chem Co.-D
National Turfgrass Evaluation Program-D
Netlon Ltd.-C
Northwood C.C.-D
NPI. Inc.-D
Plano Parks and Recreation Dept.-D
Richardson Parks and Recreation Dept.-D
S. Reg. Pesticide Impact Assessment Prog.-D
Texas A&M Univ. Athletic Department-C
Texas A&M Univ. Landscape Maintenance-C
Texas A&M University Golf Course-C
Texas Dept. of Agriculture-D
Texas Golf Association-C
Texas Highway Dept.-D
Texas Transportation Institute-C,D
Texas Turfgrass Association-C,D
U.S. Dept. of Agriculture-D
USDA-SCS-D
USGA Green Section-C,D
Warren's Turf Nursery-C

C=College Station
D=Dallas

PR-4881

Effects of Three Plant Growth Regulators on Shoot Growth and Turf Quality of Tifway Bermudagrass (*Cynodon* sp.)

W. G. Menn, J. B. Beard, and M. H. Hall

Introduction

Plant growth regulators (PGRs) have been evaluated for use in turfgrass management for over 40 years and many of the earlier concerns about their use are still valid today. How will they affect turf quality? How long will this effect last? Will the effect be uniform? In general, the results of PGRs have been much more favorable and predictable on cool-season than on warm-season turfs. This study was conducted to assess and compare the effectiveness of two experimental PGRs plus flurprimidol (Cutless®) on a simulated bermudagrass golf fairway.

Materials and Methods

The study was conducted on a 15-year-old stand of Tifway bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) growing in College Station, Texas. Soil type in the area was a Lufkin fine sandy loam which overlies a hard, massive clay pan at about a 6- to 8-inch (15-20 cm) depth. Soil pH in the test area measured 8.0 to 8.5 mainly due to irrigating with water having pH of 8.3. The area was treated prior to PGR application with a complete (21-7-14) fertilizer at a rate of 5.0 lbs of material per 1,000 square feet (2.44 kg/are^{-1}). Grass in the area was maintained at a height of 0.5 inch (1.25 cm) by mowing twice weekly with a reel-type mower. The test area was irrigated as necessary to prevent visual signs of wilt.

PGR treatments were applied on 27 June 1990, using a small hand-held, CO_2 pressurized plot sprayer. PGRs were applied to plots measuring 6 x 8 feet (1.8 x 2.4 m) arranged in a randomized block design. There were four replications of each treatment. Temperature at the time of application was 87°F (30.5°C) and the soil moisture level was at field capacity. Following PGR application, mowing on one-half of each treatment plot was discontinued for the remainder of the study. This allowed better visual estimation of shoot growth suppression during the experiment.

Clipping samples were harvested from the mowed portion of each treatment plot at 3 and 6 weeks after treatment (WAT) using an 18-inch (45-cm) manually pushed reel-type mower equipped with a catcher. The samples were dried for 72 hours in a forced draft oven set at 140°F (60°C) and then weighed and recorded as grams of dry weight per 6.75 ft^2 (0.63 m^2).

Another characteristic evaluated was a visual estimation of the effects of the PGRs on turfgrass quality which included a composite of shoot color, density, and uniformity.

Results

CGA163935 was applied at two rates and compared with flurprimidol (Cutless®) applied at a single label rate. Overall, CGA163935 appeared to produce a very good level of shoot growth reduction in Tifway bermudagrass with only a negligible amount of initial leaf discoloration. As shown in Table 1, phytotoxic effects were minimal at 1 WAT, decreased at 2 WAT, and were not visible at 3 WAT. On a scale of 1 to 9 any rating of phytotoxicity less than 3 is acceptable by the turf manager. The phytotoxicity caused by CGA163935 was not a leaf burn, but rather the grass turned a pale or lighter shade of green.

Table 1. An evaluation of phytotoxic effects produced by three plant growth regulators on Tifway Bermudagrass. College Station, Texas.

Treatment	Formulation[1]	Application rate lbs ai/A (kg ai/ha)	Shoot phytotoxicity ratings[2] by date	
			7/3/90	7/12/90
Untreated Check	—	—	1.25 a[3]	1.00 c
CGA163935	2EC	0.36 (0.4)	1.50 a	1.25 bc
CGA163935	2EC	0.72 (0.8)	2.25 a	2.00 ab
Flurprimidol	50WP	0.50 (0.56)	1.25 a	2.25 a

[1]EC = emulsifiable concentrate; WP = wettable powder.
[2]Rating scale based on 1 = no phyto and 9 = severe phyto.
[3]Values followed by the same letter are not significantly different at the 5 percent level of Duncan's multiple range test.

Visual estimations of shoot growth suppression were made at 2, 3, 5, and 7 WAT (Table 2). There was a significant amount of growth suppression at all rating dates, except for flurprimidol at 7 WAT. However, the greatest degree of suppression based on visual observations was at 3 WAT. The higher rate of CGA163935 produced a significantly greater degree of suppression than that observed under the flurprimidol treatment at 3, 5, and 7 WAT.

The effects of the three PGRs on turfgrass quality of Tifway bermudagrass were measured at 3, 5, and 7 WAT (Table 3). At 3 WAT, CGA163935 and flurprimidol were causing a reduction in the turf quality of the Tifway bermudagrass. Flurprimidol and the higher rate of CGA163935 continued to produce lower quality ratings at 7 WAT; however, the effect was hardly noticeable. At 7 WAT, CGA163935 appeared to be producing a slightly higher quality turf than the untreated check. The loss of turf quality early on was attributed mainly to an apparent loss of shoot density which increased visibility of the thatch layer underneath.

Data from clipping harvests at 3 and 6 WAT confirm the results from the visual estimation of shoot growth suppression during those periods, especially at 3 WAT (Table 4). The sixth WAT showed the lower rate of CGA163935 to have no effect on reducing clippings; however, the higher rate appeared to be quite active at this time. Flurprimidol was beginning to lose its shoot growth suppression activity at 6 WAT.

One other attribute noted as a result of the CGA163935 treatment was a color enhancement of the grass. Both rates of CGA163935 promoted a very noticeable dark green color in the leaves of Tifway bermudagrass. This color enhancement persisted for several weeks after the cessation of shoot growth suppression.

Summary

1. The results of this study show CGA163935 to be quite active in reducing the shoot growth of Tifway bermudagrass.
2. The growth regulator effect lasted 6+ weeks.
3. Any leaf phytotoxicity associated with the application of CGA163935 was minimal and within acceptable limits for most turf managers.
4. CGA163935 caused the grass to turn a darker green color which lasted for at least 10 weeks after treatment under the conditions of this study.

Acknowledgment

This study was partially supported by a grant from Ciba-Geigy Corp., Agricultural Products Division.

Table 2. A visual estimation of growth suppression produced by three plant growth regulators on Tifway Bermudagrass. College Station, Texas.

Treatment	Formulation[1]	Application rate lbs ai/A (kg ai/ha)	Suppression shoot growth ratings[2] by date			
			7/12/90	7/19/90	8/2/90	8/14/90
Untreated Check	—	—	1.0 b[3]	1.0 c	1.0 c	1.0 b
CGA163935	2EC	0.36 (0.4)	6.0 a	7.0 ab	4.0 ab	3.3 a
CGA163935	2EC	0.72 (0.8)	7.3 a	7.8 a	5.0 a	3.3 a
Flurprimidol	50WP	0.50 (0.6)	5.8 a	6.3 b	3.5 b	2.0 b

[1] EC = emulsifiable concentrate; WP = wettable powder.
[2] Rating scale based on a 9 to 1 scale, with 9 = total suppression and 1 = no suppression.
[3] Values followed by the same letter are not significantly different at the 5 percent level of Duncan's multiple range test.

Table 3. Effects of three plant growth regulators on turfgrass quality of Tifway Bermudagrass. College Station, Texas.

Treatment	Formulation[1]	Application rate lbs ai/A (kg ai/ha)	Quality turfgrass ratings[2] by date		
			7/19/90	8/2/90	8/14/90
Untreated Check	—	—	6.8 a[3]	7.0 a	7.0 ab
CGA163935	2EC	0.36 (0.4)	4.8 b	6.5 ab	7.8 a
CGA163935	2EC	0.72 (0.8)	3.5 c	6.0 bc	7.8 a
Flurprimidol	50WP	0.50 (0.6)	4.0 bc	5.8 c	6.5 b

[1]EC = emulsifiable concentrate; WP = wettable powder.
[2]Rating scale based on a 9 to 1 scale, with 9 = best and 1 = poorest, and 5 and above = acceptable bermudagrass fairway.
[3]Values followed by the same letter are not significantly different at the 5 percent level of Duncan's multiple range test.

Table 4. The effects of three plant growth regulators on vertical shoot growth of Tifway Bermudagrass as determined by the measurement of dry weight of harvested clippings.

Treatment	Formulation[1]	Application rate lbs ai/A (kg ai/ha)	Grams dry wt. per 6.75 ft² (0.63 m²)	
			7/19/90	8/7/90
Untreated Check	—	—	2.05 a[2]	2.65 ab
CGA163935	2EC	0.36 (0.4)	0.25 b	2.73 a
CGA163935	2EC	0.72 (0.8)	0.10 b	0.60 c
Flurprimidol	50WP	0.50 (0.6)	0.35 b	1.23 ab

[1] EC = emulsifiable concentrate; WP = wettable powder.
[2] Values followed by the same letter are not significantly different at the 5 percent level of Duncan's multiple range test.

Comparative Inter- and Intraspecific Differentials in Genetic Potential for Root Growth of Bermudagrass (*Cynodon* spp.) Genotypes

S. I. Sifers and J. B. Beard

Introduction

Two long duration studies to assess the intraspecific rooting potentials of 24 bermudagrass genotypes have been completed in a Column Root Assessment Facility constructed in the Turfgrass Research Glasshouse at Texas A&M. This study followed an earlier investigation by Casnoff and Beard (1) which revealed significant interspecies differences in the genetic rooting potential among seven warm-season turfgrasses. As in the cited study, an objective of this research was to identify bermudagrass genotypes with deep extensive root systems that would be able to absorb water from a larger portion of the soil profile and thus improve their drought resistance via dehydration avoidance. Another objective was to compare any genetic variation that exists in root growth characteristics of these 24 genotypes over 160-day and 210-day assessment periods.

Materials and Methods

Twenty-four bermudagrass (*Cynodon* spp.) genotypes were evaluated for root growth potential under nonlimiting moisture conditions in the Texas A&M Turfgrass Glasshouse. The Column Root Assessment Facility consisted of six metal racks each capable of supporting 22 columns (Figure 1). Each column was constructed of weathered 4-inch (100-mm) diameter Schedule 40 PVC precut into seven sections, each of which was 12 inches (300 mm) in length. These sections were externally joined at the seams by duct tape forming a 7-ft (2.1-m) tall column. The bottom section had a PVC cap base with drainage holes. This section was filled with pea gravel and the above sections were filled with washed masonry sand having over 50 percent of the particles in the 0.25 to 0.5 mm range. Water was supplied to each column by a drip irrigation system functioning through a timing device to provide a nonlimiting moisture level.

The 24 bermudagrass genotypes were each grown from single 1-inch (25-mm) shoots with 2.5 inches (50 mm) of roots that had been initially propagated in individual growth cones and then transplanted into the larger columns when established. Fertility was applied at a rate of 2 lbs N/1,000 sq ft per month (1 kg N 100 m^2) using 20N-20P-20K analysis liquid applied on a weekly schedule. Due to the leaching rate, this fertility level gave a plant response equivalent to a 0.5-lb (0.25-kg) N rate in the field. Turfs were clipped at 1-inch (25 mm) weekly, with the clippings removed. No disease or insect damage was detected. The temperatures in the glasshouse were maintained between 77 and 95°F (25 and 35°C) throughout the two studies.

The first portion of the study was harvested after 160 days of growth by sectionalizing the columns every 12 inches (300 mm), counting the root intersections at 12-, 24-, 36-, 48-, 60-, 72- and 84-inch (0.3-, 0.6-, 0.9-, 1.2-, 1.6-, 1.8- and 2.1-m) intervals, obtaining shoot dry weights, total root dry weights, and root dry weights for roots in each 12-inch (300-mm) segment. The second portion of the study was completed with all conditions and turfs being comparable, except that the growth

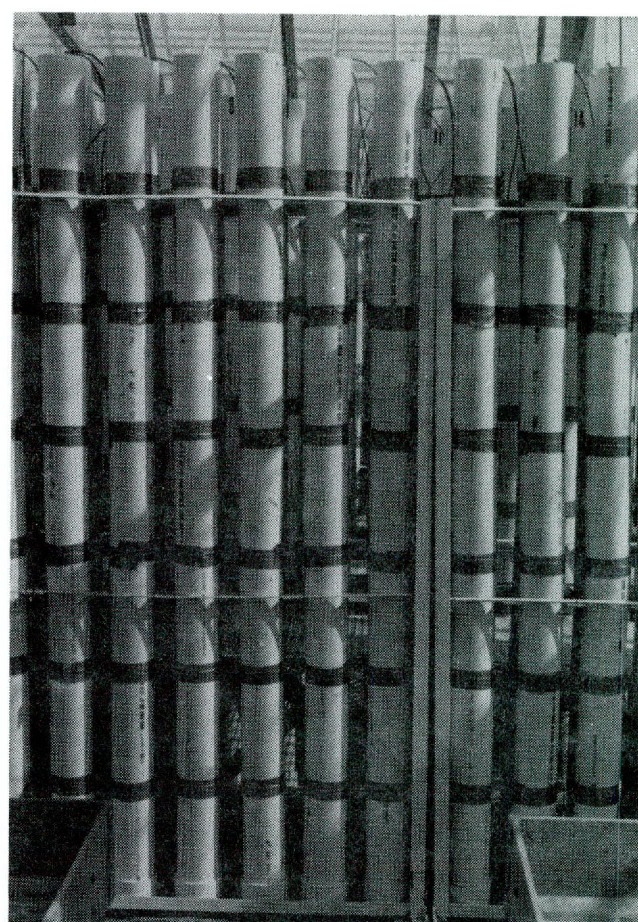

Figure 1. Column root assessment facility in Texas A&M Turfgrass Glasshouse.

period was 210 days. Data from the two studies were analyzed using LSD T Test at alpha = 0.05.

Results

The 84-inch (2.1-m) maximum rooting length possible in these tests was obtained by at least one genotype each of *Cynodon dactylon* and *C. dactylon* x *C. transvaalensis* (Table 1). Therefore, the individual genus did not relate to the rooting potential for the cultivars assessed. Likewise, both total shoot and root weights were not reliable predictors of rooting potential, as genotypes such as Tifdwarf, Midway, Vamont, and Tifway had substantial root and shoot dry weights, but ranked lower in rooting length. Rooting depth and density did appear to be factors in the relative dehydration avoidance found among bermudagrass genotypes by Sifers and Beard (3).

The study by Casnoff et al. (1) contained four of the same bermudagrass cultivars, FB-119, Tifgreen, Tifway and Texturf 10. The duration of this earlier study was 130 days and the longest root extension reported as 73 inches (1.83 m) for FB-119. Other bermudagrass root lengths were 62 inches (1.55 m) for Tifgreen, 55 inches (1.38 m) for Texturf 10, and 49 inches (1.22 m) for Tifway. These data are similar in cultivar ranking to results of the 160-day study. Neither of these studies were of sufficient duration to adequately describe the full genetic rooting potentials of these turfs in comparison to the 210-day duration. The results of these three studies confirm that there are significant inter- and intraspecies differences in genetic rooting potential among the bermudagrasses under nonlimiting water conditions.

Table 1. Comparative genetic potential for root depth and total root mass of 24 bermudagrass genotypes following 210 days of growth in a column root assessment facility under nonlimiting moisture conditions.

Relative ranking[1]	Rooting depth	Total root mass
Excellent	Ormond Santa Ana Texturf 1F Sunturf Tiflawn Bayshore	FB-119 Ormond Santa Ana Sunturf Texturf 1F
Good	Texturf 10 FB-119 A-29	Texturf 10 A-29 Tiflawn
Medium	Tiffine Tifgreen Common U-3	Tifdwarf Midiron Midway Vamont Tifgreen Common
Medium fair	Tifdwarf Tifgreen II Vamont Tufcote Midway	Tufcote Tifway U-3 Tifgreen II Bayshore Tiffine A-22
Fair	Tifway Pee Dee Everglades Tifway II Midiron	Pee Dee Tifway II Everglades

[1] Ranking comparisons are made only within the *Cynodon* species, with no relationship to other species.

Summary

Rooting depths, total root weights, and shoot weights of 24 bermudagrass (*Cynodon*) genotypes varied substantially. A duration of 210 days is required to conduct a reliable assessment of genetic rooting potential. Certain *Cynodon* spp. have a genetic rooting potential of at least 84 inches (2.1 m) in depth. The rooting potential of *Cynodon* spp. is a major contributor to the overall drought resistance mechanism of this species via the dehydration avoidance component (3). Shoot biomass was not a reliable predictor in selecting deep rooting plants within the *Cynodon* spp.

Acknowledgment

This investigation was partially supported by a grant from the United States Golf Association.

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Comparative Intraspecific Differentials in Genetic Potential for Root Growth of St. Augustinegrass (*Stenotaphrum secundatum*) Genotypes

J. B. Beard and S. I. Sifers

Introduction

Following the two long duration studies to assess the intraspecific rooting potentials of 24 bermudagrasses (2) and 11 zoysiagrasses reported previously in this research report, a long-term study was completed in 1989 to assess the intraspecific rooting potentials of 11 St. Augustinegrass (*Stenotaphrum secundatum*) genotypes under nonlimiting moisture conditions.

Materials and Methods

The procedures followed in the Column Root Assessment Facility were identical to those described in the other two studies, with the duration of 270 days chosen for this test to equal the growth period allowed the zoysiagrasses. The genotypes studied included six commercially available cultivars used in the southern United States and five experimental selections developed at the Texas A&M Department of Soil and Crop Sciences, College Station and at the Texas A&M Agricultural Research and Extension Center at Dallas.

Results

Two genotypes, Floralawn and Bitter Blue, had root intersections the full length of the 7-ft (210-cm) deep column, TxSA8208 rooted to 6 ft (180 cm), five others had rooting to 5 feet (150 cm), genotypes 2 to 4 ft (120 cm), and only one was limited to the 1- to 2-ft (30- to 60-cm) segment.

However, unlike the zoysiagrasses and bermudagrasses, the root dry weight per 1-ft (30-cm) column segment was very light, by approximately a factor of 10 and was not statistically significant. This deep rooting and light weight per column segment would describe a long, but not dense or fibrous, root system. The root system described indicates the drought resistance mechanism may involve dehydration avoidance through the ability of the root system to probe deeper into the soil profile to extract available moisture (3).

Summary

The intraspecies differences in rooting potential are very significant as regards depth of rooting, but not root density. Breeding for increased root depth appears possible in terms of the germplasm resources available. St. Augustinegrasses have a long, but low density root system. Shoot dry weight is approximately double the total root weight. The long root length aids in drought resistance of St. Augustinegrass through the dehydration avoidance mechanism (3). Dehydration tolerance is also a key contributing component.

Acknowledgment

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Table 1. Comparative genetic potential for root depth and total root mass of eleven St. Augustinegrass genotypes following 270 days of growth in a column root assessment facility under nonlimiting moisture conditions.

Relative ranking[1]	Rooting depth	Total root mass
Medium good	Floralawn Bitter Blue TxSA 8208	Texas Common Floralawn TxSA 8208
Medium	Texas Common Floratam	Bitter Blue Floratam Seville
Medium fair	DALSA 8403 DALSA 8402 Seville DALSA 8401	DALSA 8403 DALSA 8401 Raleigh DALSA 8402
Fair	Raleigh TxSA8262	TxSA 7262

[1] Ranking comparisons are made only within the *Stenotaphrum secundatum* species, with no relationship to other genera or species.

Root Development in Selected Varieties of Each of Four Warm-season Turfgrass Genera

M.C. Engelke, R.H. White, S.J. Morton, and K.B. Marcum

Introduction

An important drought avoidance mechanism in plants is the ability of the roots to extend into portions of the soil where plant available moisture exists (Levitt 1972). Extensive root depth and root branching are important root system characteristics favoring water uptake and survival in dry conditions (Russell 1977).

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, the determination of the relationship between root characters and drought resistance, and to confirm greenhouse screening procedures for root distribution.

The use of flexible tubes to assess root growth in the greenhouse is a technique for efficiently screening large numbers of plant materials in rapid fashion, whereas similar field studies are more laborious and time consuming. By simultaneously examining identical clones in both field and root tubes, greater assurance may be credited to the root tube procedure.

Materials and Methods

Construction of the Turfgrass Root Investigation Facility (TRIF) was completed in May 1988. TRIF measures 18 x 7.5 m with 2.13 m of fine, washed sand overlying 0.3 m of pea gravel covering floor drain lines. The system drains to the culvert housing an automatic sump pump.

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 in 10 cm^2 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, which included maximum and third maximum root length, and root number and root mass at 10 cm increments, of each root system. 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 (1988). Previously propagated entries were planted as 2.5 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 weekly to supply 0.25 kg N are^{-1}. 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, root number and weight at 10 cm increments, root extension rate, and total leaf area. Results from greenhouse and field studies were compared utilizing Spearman's rank correlation procedure.

Results

Analysis of genera planted to TRIF indicated that there were no significant differences as to root length or number between genera (Tables 1 and 3). However, centipedegrass had greater root mass in the top 10 cm section than the three other genera evaluated (Table 2).

Table 1. Mean maximum and mean third maximum root lengths of warm season turfgrasses planted to TRIF.

Genus	Root Length, mm: Third Maximum	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 where k=100.

Table 2. Mean root mass (mg) per 10 cm vertical root section for warm season grass genera planted to TRIF.

	Root Mass (mg)						
Genus	0-10	10-20	20-30	30-40	40-50	Total mass	PS[2]
Zoysia	452	171	92	39	3	756	0
St.Aug.	533	260	53	0	13	860	0
Centipede	820a	170	45	10	0	1045	1
Buffalo	369	213	88	31	0	700	0
MSD[1]	217	ns	ns	ns	ns	ns	

[1] Minimum significant difference for comparison of genus means within columns based on the Waller-Duncan k ratio t test where k=100.
[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

Table 3. Mean numbers of roots per 100 cm vertical root section for warm season grass genera planted to TRIF.

	Numbers of Roots				
Genus	0-10	10-20	20-30	30-40	40-50
Zoysia	14	8.3	4.3	1	0
St.Aug.	19	9.8	1.7	0	0
Centipede	18	8.7	2.6	1	0
Buffalo	16	8.5	2.2	1	0
MSD[1]	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 where k=100.

Among the zoysiagrasses, DALZ8508 had the longest roots, and also had relatively large root weights and numbers (Tables 4-6). Other zoysiagrasses which scored relatively highly in the three variables above include DALZ8510, DALZ8516, DALZ8523, TAES3361, TAES3365, and TAES3477. These grasses would be expected to have good drought tolerance, providing shoot physiologies allow. Relatively poor performers, with short roots, low root mass and numbers include TAES3357, TAES3358, TAES3359, DALZ8504, and Meyer. TAES3477 had the highest root mass, and also scored highly in root length and number. Emerald, with low root numbers and short roots, had relatively high root total mass, indicating that these roots are large, and may have large water-conducting xylem. Only TAES lines, specifically 3360, 3361, 3365, and 3366 had any root mass greater than 40 cm.

Among the buffalograsses, Comanche had much higher root length, mass, and number (Tables 7-9). In addition, it was the only buffalograss with roots, greater than 30 cm. There were no significant differences among the centipedegrasses, but Common and AC44 tended to have greater root growth than the others. The same was true with the St. Augustinegrasses. Raleigh tended to do more poorly in root length, mass, and number than the other three DALS lines.

The same root parameters were measured in the flexible tube greenhouse experiments. In addition, other parameters were more easily measured than in TRIF, such as total leaf area and number per plant, and root extension rate. In general, the St. Augustinegrasses had much higher root masses, root extension rates, and total leaf area than the other genera (Tables 10 and 11). However, the centipedegrasses had the highest root numbers at all depths (Table 12), as well as relatively high root length and mass. Centipedegrass also had the highest number of roots in TRIF, but only in the top 10 cm. In general, the zoysiagrasses had shorter roots, lower root extension rates, and lower root mass than the other genera.

Among the zoysiagrasses, DALZ8522 had the longest roots, and also one of the highest root extension rates (Table 13). Long first and third roots, together with high root extension rates, also ocurred in DALZ8505, DALZ8511, DALZ8512, and TAES3362, TAES3363, and TAES3366. DALZ8517 had the shortest first and third roots, as well as the slowest root extension rate among the zoysias. TAES3366 had by far the highest total root mass of all the zoysias (Table 14), as well as high root numbers (Table 15), root lengths, and root extension rates. DALZ8505 and DALZ8512, and TAES3362 and TAES3366 scored high in root length, mass, and number, and would be expected to have superior drought tolerance. In addition, TAES3366, DALZ8505, and DALZ8512 had high total leaf areas (Table 13). High total leaf area was generally associated with root length,

Table 4. Mean maximum and mean third maximum root lengths of zoysiagrasses planted to TRIF.

	Root Lengths, mm		
Entry	Third Maximum	Maximum	PS[2]
Belair	165	228a	1
El Toro	176	245a	1
Emerald	110	149	
FC13521	190	209a	1
Meyer	112	179	
DALZ8501	183	219a	1
DALZ8502	137	184	
DALZ8503	162	161	
DALZ8504	113	138	
DALZ8505	170	220a	1
DALZ8506	179	214a	1
DALZ8507	244a	256a	2
DALZ8508	257a	349a	2
DALZ8510	339a	344a	2
DALZ8511	214a	271a	2
DALZ8512	231a	264a	2
DALZ8513	183	214a	1
DALZ8514	242a	262a	2
DALZ8515	260a	265a	2
DALZ8516	294a	318a	2
DALZ8517	168	205a	1
DALZ8522	238a	260a	2
DALZ8523	234a	286a	2
DALZ8524	211a	244a	2
DALZ8701	195a	166	1
TAES3356	176	228a	1
TAES3357	125	157	
TAES3358	140	157	
TAES3359	116	98	
TAES3360	125	236a	1
TAES3361	303a	271a	2
TAES3362	155	296a	1
TAES3363	239a	285a	2
TAES3364	92	194a	1
TAES3365	342a	244a	2
TAES3366	285a	322a	2
TAES3367	262a	343a	2
TAES3372	190	187a	1
TAES3477	316a	337a	2
MSD entry[1]	152	165	

[1] MSD = Minimum significant difference for comparison of entry means within columns based on the Waller-Duncan k ratio t test where k=100.

[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

mass, and number in the zoysiagrasses (Tables 13-15). DALZ8501, DALZ8502, DALZ8503, DALZ8507, DALZ8517, and DALZ8524 had relatively poor root growth.

There were no significant differences among the buffalograsses as to root length, mass, or number (Tables 16-18). AC44 had the longest roots of the centipedegrasses, and also ranked high in total root mass. Tennessee Hardy had the least root growth. There were no significant differences in root numbers among the centipedegrasses. DALS8401 had significantly shorter first and third roots than the other St. Augustinegrasses (Table 16), and also had relatively low root mass across all depths, though the data was not significant. DALS8403 had significantly more roots in the 10 to 20 cm depth than did the other St. Augustinegrasses (Table 18).

Spearman's rank correlation procedure revealed no positive correlation between the TRIF and the flexible root tube data. This indicates that greenhouse flexible root tubes may not provide an accurate reflection of root development in the field. This may be a function of field sampling techniques. Also, it should be noted that there was nematode damage on some plants in TRIF. However, no damage was found on greenhouse plants. This may have been a contributing factor to the lack of positive correlation between the TRIF and greenhouse flexible root tube studies.

Table 5. Mean root mass (mg) per 10 cm vertical root section for zoysiagrasses planted to TRIF.

	Root mass (mg)						
Entry	0-10	10-20	20-30	30-40	40-50	Total mass	PS[2]
Belair	675	100	25	0	0	800	
El Toro	475	75	50	0	0	600	
Emerald	700	267	0	0	0	967a	1
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	1100a	1
DALZ8510	400	275	350a	100	0	1125a	2
DALZ8511	300	150	50	425	0	925a	1
DALZ8512	375	200	225a	0	0	800	1
DALZ8513	500	100	50	25	0	675	
DALZ8514	475	225	50	0	0	750	
DALZ8515	375	125	50	0	0	550	
DALZ8516	450	200	225a	275	0	1150a	2
DALZ8517	300	125	50	0	0	475	
DALZ8522	525	150	125	100	0	900a	1
DALZ8523	400	325	225a	0	0	950a	2
DALZ8524	1025	250	50	25	0	1350a	1
DALZ8701	1025	200	50	0	0	1275a	1
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	200a	100	25	1125a	2
TAES3362	350	75	75	25	0	525	
TAES3363	300	100	50	0	0	450	
TAES3364	650	25	25	0	0	700	
TAES3365	250	400	375a	225	25	1275a	2
TAES3366	420	100	40	60	40	660	
TAES3367	275	125	150	25	0	575	
TAES3372	250	125	25	0	0	400	
TAES3477	1025	450	350a	100	0	1925a	2
MSD[1]	ns	ns	210	ns	ns	1061	

[1] MSD = Minimum significant difference for comparison of entry means within columns based on the Waller-Duncan k ratio t test where k=100.
[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

Table 6. Mean numbers of roots per 10 cm vertical root section for zoysiagrasses planted to TRIF.

	Number of roots						
Entry	0-10	10-20	20-30	30-40	40-50	Total number	PS[2]
Belair	10	7a	2	0	0		1
El Toro	16	6a	4	1	0		1
Emerald	9	4a	0	0	0		1
FC13521	17	6a	2	0	0		1
Meyer	18	3a	2	0	0		1
DALZ8501	11	8a	2	3	0		1
DALZ8502	19	6a	1	0	0		1
DALZ8503	17	11a	2	0	0		1
DALZ8504	13	3	1	0	0		
DALZ8505	12	12a	6	0	0		1
DALZ8506	6	3	5	1	0		
DALZ8507	11	16a	7	2	0		1
DALZ8508	21	11a	11	2	0		1
DALZ8510	11	15a	11	3	0		1
DALZ8511	15	9a	3	1	0		1
DALZ8512	10	11a	5	1	0		1
DALZ8513	10	5a	4	2	0		1
DALZ8514	15	14a	5	1	0		1
DALZ8515	14	6a	4	0	0		1
DALZ8516	17	14a	11	8	1		1
DALZ8517	13	5a	1	0	0		1
DALZ8522	20	13a	7	2	0		1
DALZ8523	29	19a	9	0	0		1
DALZ8524	11	8a	4	1	0		1
DALZ8701	11	6a	1	0	0		1
TAES3356	14	8a	4	0	0		1
TAES3357	7	2	1	0	0		
TAES3358	10	3	1	0	0		
TAES3359	12	4a	1	0	0		1
TAES3360	13	4a	0	0	1		1
TAES3361	22	15a	10	8	2a		2
TAES3362	10	3	2	2	0		
TAES3363	17	10a	5	0	0		1
TAES3364	9	2	0	0	0		
TAES3365	20	14a	9	6	0		1
TAES3366	20	12a	7	3	1a		2
TAES3367	9	8a	11	3	0		1
TAES3372	19	9a	4	0	0		1
TAES3477	24	15a	11	3	0		1
MSD[1]	ns	16					

[1] MSD = Minimum significant difference for comparison of entry means within columns based on the Waller-Duncan k ratio t test where k=100.
[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

Table 7. Mean maximum and mean third maximum root lengths of buffalograss, centipedegrass, and St. Augustinegrass planted to TRIF.

Genus	Entry	Root Length, mm Third Maximum	Maximum
Buffalo	Comanche	254a	286a
Buffalo	DALB8201	132	153
Buffalo	DALB8202	118	157
Buffalo	Texoka	175a	186
MSD entry[1]		81	99
Centipede	AC44	238	277
Centipede	Centennial	17	94
Centipede	Common	248	348
Centipede	DALC8501	134	192
Centipede	DALC8502	160	178
Centipede	DALC8503	132	201
Centipede	Tennessee Hardy	130	245
MSD entry		ns	ns
St. Augustine	DALS8401	169	290
St. Augustine	DALS8402	264	283
St. Augustine	DALS8403	174	236
St. Augustine	Raleigh	141	145
MSD entry		ns	ns

[1] MSD = Minimum significant difference for comparison of entry means within columns based on the Waller-Duncan k ratio t test where k=100.

Table 8. Mean root mass (mg) per 10 cm vertical root section for buffalograss, centipedegrass, and St. Augustinegrass planted to TRIF.

Genus/Entry	Root mass (mg) 0-10	10-20	20-30	30-40	40-50	Total mass	PS[2]
Buffalograss							
Comanche	625a	600a	350	125	0	1700a	3
DALB8201	500a	100	0	0	0	600	1
DALB8202	150	50	0	0	0	200	
Texoka	200	100	0	0	0	300	
MSD[1]	361	188	ns	ns	ns	472	
Centipedegrass							
AC44	967	300	133	67	0	1467	
Centennial	800	133	0	0	0	933	
Common	867	333	167	0	0	1367	
DALC8501	1333	167	0	0	0	1500	
DALC8502	733	100	0	0	0	833	
DALC8503	700	0	0	0	0	700	
Tenn.Hardy	300	100	0	0	0	400	
MSD	ns	ns	ns	ns	ns	ns	
St.Augustinegrass							
DALS8401	500	167	33	0	0	700	
DALS8402	500	275	75	0	50	900	
DALS8403	640	340	80	0	0	1060	
Raleigh	433	200	0	0	0	633	
MSD	ns	ns	ns	ns	ns	ns	

[1] MSD = Minimum significant difference for comparison of entry means within columns based on the Waller-Duncan k ratio t test where k=100.

[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

Table 9. Mean numbers of roots per 10 cm vertical root section for buffalograss, centipedegrass, and St. Augustinegrass planted to TRIF.

Genus/Entry	Mean Number of roots per section 0-10	10-20	20-30	30-40	40-50	Total number	PS[2]
Buffalograss							
Comanche	27a	18	9	4	0		1
DALB8201	14	5	0	0	0		
DALB8202	12	5	0	0	0		
Texoka	10	7	0	0	0		
MSD[1]	13	ns	ns	ns	ns		
Centipedegrass							
AC44	15	15	6	2	0		
Centennial	19	6	1	0	0		
Common	22	11	5	2	0		
DALC8501	15	7	0	0	0		
DALC8502	15	10	3	0	0		
DALC8503	24	7	1	0	0		
Tenn.Hardy	14	5	2	1	0		
MSD	ns	ns	ns	ns	ns		
St.Augustinegrass							
DALS8401	16	7	2	1	0		
DALS8402	17	11	2	0	1		
DALS8403	27	16	3	0	0		
Raleigh	14	3	0	0	0		
MSD	ns	ns	ns	ns	ns		

[1] MSD = Minimum significant difference for comparison of entry means within columns based on the Waller-Duncan k ratio t test where k=100.

[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

Table 10. Mean maximum and third maximum root lengths, mean root extension rates, and mean total leaf areas and leaf numbers for warm season turfgrasses planted in flexible tubes.

Genus	Root Length Maximum	Third Maximum	Root Extension Rate	Total Leaf Area	Number	PS[2]
	mm	mm	mm/day	cm^2		
Zoysia	387	174	10.0	17.4	37.4a	1
St. Augustine	552a	255	22.5a	82.2a	30.7a	4
Centipede	554a	455a	11.9	30.8	29.8a	3
Buffalo	498a	190	18.1	16.8	18.6	1
MSD[1]	82	62	2.9	8.8	10.9	

[1] MSD = Minimum significant difference for comparison of entry means within columns based on the Waller-Duncan k ratio t test where k=100.

[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

Table 11. **Mean root mass per 10 cm vertical root section and mean total root mass for warm season turfgrasses planted in flexible tubes.**

Genus	Root Mass(mg) per 10cm Section							Total	
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	mass	PS[2]
Zoysia	226	53	49	24	13	8	0	374	
St.August.	996a	350a	188a	167	142a	158a	0	2000a	6
Centipede	328	191	172a	153a	144a	116	0	1103	3
Buffalo	157	91	61	35	48	35	0	426	
MSD[1]	120	45	85	37	34	40	ns	259	

[1] MSD = Minimum significant difference for comparison of entry means within columns based on the Waller-Duncan k ratio t test where k=100.
[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

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Table 12. Mean numbers of roots per 10 cm vertical root section and mean total root number for warm season turfgrasses planted in flexible tubes.

Genus	Root numbers per 10cm Section							PS[2]
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	
Zoysia	4.4	3.2	2.3	1.9	1.6	1.5	0	
St.August.	6.2	4.6	3.4	2.6	1.9	1.7	1.5	
Centipede	8.5a	7.4a	5.9a	5.3a	4.5a	3.8a	0	6
Buffalo	4.3	3.0	2.3	2.2	1.7	1.7	2.0	
MSD[1]	1.3	1.0	0.8	0.8	0.8	0.8	ns	

[1] MSD = Minimum significant difference for comparison of entry means within columns based on the Waller-Duncan k ratio t test where k=100.
[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

Table 13. Mean maximum and third maximum root lengths, mean root extension rates, and mean total leaf areas for zoysiagrasses planted in flexible tubes.

Entry	Root length, mm		Root		
	Maximum	Third Maximum	Extension rate	Total leaf area	PS[2]
	mm	mm	mm/day	cm^2	
BELAIR	230	53	6.4	9.2	
DALZ8501	264	87	6.4	10.6	
DALZ8502	253	123	6.6	4.6	
DALZ8503	128	84	2.8	21.4	
DALZ8504	469a	218	14.4a	22.7	2
DALZ8505	433a	266a	12.2a	34.8a	4
DALZ8506	323a	200	6.3	10.5	1
DALZ8507	276	66	6.3	8.7	
DALZ8508	423a	76	10.8a	5.2	2
DALZ8510	358a	136	7.8a	13.6	2
DALZ8511	489a	289a	15.2a	26.5	3
DALZ8512	473a	267a	13.3a	42.0a	4
DALZ8513	277	162	7.8a	20.5	1
DALZ8514	410a	189	8.0a	29.5a	3
DALZ8515	384a	114	7.7a	11.6	2
DALZ8516	359a	121	9.6a	14.5	2
DALZ8517	93	44	3.0	7.3	
DALZ8522	556a	247	13.7a	13.7	2
DALZ8523	441a	172	12.0a	10.2	2
DALZ8524	246	162	4.5	5.8	
DALZ8701	372a	162	10.4a	8.9	2
ELTORO	425a	195	12.9a	19.8	2
EMERALD	491a	127	13.3a	12.0	2
FC13521	446a	169	8.5a	13.3	2
MEYER	453a	230	13.0a	20.5	2
TAES3356	481a	232	14.6a	28.4a	3
TAES3357	532a	236	15.8a	32.2a	3
TAES3358	494a	234	11.9a	28.9a	3
TAES3359	302a	125	8.3a	12.5	2
TAES3360	323a	123	7.6a	13.1	2
TAES3361	291a	102	6.8	9.7	1
TAES3362	458a	275a	10.8a	25.4	3
TAES3363	516a	264a	13.7a	9.5	3
TAES3364	464a	174	9.8a	33.5a	3
TAES3365	449a	160	11.6a	13.4	2
TAES3366	530a	440a	13.1a	35.4a	4
TAES3367	331a	155	9.4a	17.0	3
TAES3372	486a	185	12.6a	15.3	2
TAES3477	307a	165	7.8a	12.0	2
MSD[1]	273	180	8.3	14.5	

[1] MSD = Minimum significant difference for comparison of entry means within columns based on Waller-Duncan k ratio t test where k=100.
[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test

Table 14. Mean root mass per section and mean total root mass for zoysiagrasses planted in flexible tubes.

Entry	Root Mass(mg) per 10cm Section							Total mass	PS[2]
	0-10	10-20	20-30	30-40	40-50	50-60	60-70		
BELAIR	160	20	20	0	0	0	0	200	
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	143a	86	86	57a	0	0	900	2
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	150a	83	50	17	17	0	717	1
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	
ELTORO	300	117	500	50	33a	17	0	1017	1
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	
TAES3356	383	83	50	67	50a	33	0	667	1
TAES3357	267	117	83	67	50a	17	0	600	1
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	580a	120	120	60	40a	40	0	960	2
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	217a	233	150a	83a	17	0	1583a	4
TAES3367	150	50	17	17	0	0	0	233	
TAES3372	183	67	33	17	0	0	0	300	
TAES3477	233	33	0	0	0	0	0	267	
MSD[1]	301	74	ns	61	60	ns	ns	539	

[1]MSD = Minimum significant difference for comparison of entry means within columns based on Waller-Duncan k ratio t test where k=100.

[2]PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

Table 15. Mean numbers of roots per 10 cm vertical root section for zoysiagrasses planted in flexible tubes.

Entry	Root Numbers per 10cm Section							PS[2]
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	
BELAIR	3.20	2.67	2.67a	2.00a	1.50	2.00	0.0	2
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	3.50a	4.00a	2.00	2.00	0.0	2
DALZ8504	5.67a	3.17	2.00	1.60a	1.33	1.50	0.0	2
DALZ8505	7.17a	5.00	3.20a	2.25a	1.25	1.00	0.0	3
DALZ8506	4.00	2.33	1.50	1.50a	1.00	1.00	0.0	1
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	5.83a	3.67	3.40a	2.20a	2.33	2.50	0.0	3
DALZ8512	4.60	3.75	3.00a	2.25a	1.67	1.33	0.0	2
DALZ8513	5.33	5.67	4.67a	2.67a	1.33	1.33	0.0	2
DALZ8514	4.80	3.25	3.00a	2.25a	1.67	1.50	0.0	2
DALZ8515	4.00	1.75	1.25	1.33	0.00	0.00	0.0	
DALZ8516	4.50	2.40	1.75	2.00a	1.50	1.00	0.0	1
DALZ8517	2.86	2.00	1.00	1.00	1.00	1.00	0.0	
DALZ8522	5.17	3.67	2.50a	2.20a	1.60	1.20	0.0	2
DALZ8523	2.83	2.20	2.00	1.60a	1.25	1.50	0.0	1
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	
ELTORO	4.17	3.20	2.20	1.75a	1.75	1.50	0.0	1
EMERALD	5.57a	3.29	1.83	1.50a	1.33	1.50	0.0	2
FC13521	5.00	3.33	2.67a	1.33	1.00	0.00	0.0	1
MEYER	3.67	2.80	2.20	2.50a	1.75	1.50	0.0	1
TAES3356	5.67a	3.00	2.60a	2.00a	1.75	2.00	0.0	3
TAES3357	5.83a	4.17	3.50a	2.80a	2.60	1.75	0.0	3
TAES3358	5.60a	4.20	3.60a	2.60a	2.20	2.20	0.0	3
TAES3359	3.17	3.00	2.33a	1.33	1.00	0.00	0.0	1
TAES3360	4.00	2.83	1.75	1.50a	1.00	1.00	0.0	1
TAES3361	3.40	2.00	1.67	2.00a	2.00	1.00	0.0	1
TAES3362	9.17a	5.67	3.60a	2.50a	1.50	1.25	0.0	3
TAES3363	3.00	3.20	2.40a	2.00a	1.60	1.40	0.0	2
TAES3364	3.83	2.80	2.00	1.75a	1.25	1.33	0.0	1
TAES3365	3.67	2.60	1.60	1.33	1.00	0.00	0.0	
TAES3366	6.33a	4.67	3.67a	3.33a	2.60	2.00	0.0	3
TAES3367	4.00	3.50	2.50a	1.33	1.00	1.00	0.0	1
TAES3372	5.33	3.17	1.83	1.40	1.00	1.00	0.0	
TAES3477	4.00	3.00	1.80	1.33	1.00	0.00	0.0	
MSD[1]	3.69	ns	2.37	2.54	ns	ns	ns	

[1] MSD = Minimum significant difference for comparison of entry means within columns based on Waller-Duncan k ratio t test where k=100.

[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

Table 16. Mean maximum and third maximum root lengths, mean root extension rates, and mean total leaf areas of warm-season turfgrasses planted in flexible tubes.

Genus/Entry	Root Length Maximum	Root Length Third Maximum	Root Extension Rate	Total Leaf Area	PS[2]
	mm	mm	mm/day	cm^2	
Buffalograss					
Comanche	445	180	17.6	13.8	
DALB8201	498	188	18.6	20.6	
DALB8202	579	178	22.4	23.0	
Texoka	466	219	12.8	7.6	
MSD[1]	ns	ns	ns	ns	
Centipedegrass					
AC44	608a	590a	16.2a	38.8	3
Centennial	509a	355	11.8a	20.8	2
Common	580a	448a	9.2	26.7	2
DALC8501	614a	571a	18.0a	51.8	3
DALC8502	600a	415	6.5	16.9	1
DALC8503	568a	425	12.9a	22.7	2
Tenn. Hardy	319	229	5.4	18.9	
MSD	146	164	7.4	ns	
St. Augustinegrass					
DALS8401	374	231	13.3	93.2	
DALS8402	600a	187	25.4a	78.4	2
DALS8403	617a	308	24.3a	70.2	2
RALEIGH	617a	293	26.9a	87.0	2
MSD	137	ns	8.3	ns	

[1] MSD = Minimum significant difference for comparison of entry means within columns based on Waller-Duncan k ratio t test where k=100.
[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

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

	Root Mass(mg) per 10cm Section							Total	
Genus/Entry	0-10	10-20	20-30	30-40	40-50	50-60	60-70	Mass	PS[2]
Buffalograss									
Comanche	133	50	50	17	17	17	0	283	
DALB8201	18	—	83	33	50	33	0	500	
DALB8202	183	133	67	50	100	83	0	617	
Texoka	120	60	40	40	20	0	0	280	
MSD[1]	ns	ns	ns	ns	ns	ns	ns	ns	
Centipedegrass									
AC44	367	250	183	183a	167	133	0	1283a	2
Centennial	200	117	100	67	50	17	0	550	
Common	260	160	140	100	120	80	0	860	
DALC8501	517	300	317	367a	367a	333a	0	2200a	4
DALC8502	267	167	167	100	100	100	0	900	
DALC8503	400	233	200	100	67	33	0	1033	
Tenn.Hardy	233	33	33	33	0	0	0	333	
MSD	ns	ns	ns	222	182	141	ns	1018	
St. Augustinegrass									
DALS8401	108	—	150	117	83	50	0	1833	
DALS8402	1033	333	267	250	233	317	0	2433	
DALS8403	1000	317	150	83	83	100	0	1733	
RALEIGH	867	400	183	217	167	167	0	2000	
MSD	ns	ns	ns	ns	ns	ns	ns	ns	

[1] MSD = Minimum significant difference for comparison of entry means within columns based on Waller-Duncan k ratio t test where k=100.
[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

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

Genus/Entry	Root Numbers per 10cm Sections							
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	PS[2]
Buffalograss								
Comanche	2.80	2.20	1.60	1.50	1.50	2.00	0.0	
DALB8201	4.57	3.86	2.71	2.67	1.80	1.67	2.0	
DALB8202	5.17	2.83	2.33	2.20	2.00	1.60	0.0	
Texoka	4.20	3.00	2.50	2.00	1.25	2.00	0.0	
MSD[1]	ns	ns	ns	ns	ns	ns	ns	
Centipedegrass								
AC44	9.67	8.33	6.33	6.17	4.83	4.00	0.0	
Centennial	6.83	5.33	3.83	3.67	2.40	1.50	0.0	
Common	8.60	7.80	5.40	4.40	4.00	3.00	0.0	
DALC8501	14.00	11.00	9.67	9.00	8.50	6.67	0.0	
DALC8502	6.00	5.67	5.00	3.67	3.33	3.00	0.0	
DALC8503	7.33	6.33	5.33	4.00	2.00	1.50	0.0	
Tenn.Hardy	4.33	4.50	3.00	2.00	2.00	1.00	0.0	
MSD	ns	ns	ns	ns	ns	ns	ns	
St. Augustinegrass								
DALS8401	7.67	3.83	3.50	3.00	3.00	2.50	0.0	
DALS8402	3.00	2.17	2.17	2.00	1.83	1.67	0.0	
DALS8403	8.17	7.83a	4.67	3.00	1.50	1.33	1.5	1
Raleigh	6.00	4.50	3.17	2.50	2.00	1.83	0.0	
MSD	ns	3.29	ns	ns	ns	ns	ns	

[1] MSD = Minimum significant difference for comparison of entry means within columns based on Waller-Duncan k ratio t test where k=100.
[2] PS = phenotypic stability, the number of times an entry received superior ratings based on the Waller-Duncan k ratio t test.

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PR-4885

National Turfgrass Evaluation Program (NTEP) Tall Fescue Quality Evaluation I. Effect of Mowing Height

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Introduction

Turf-type tall fescue (*Festuca arundinacea* Schreb.) development has escalated rapidly within the past 15 years, providing several cultivar choices within this species. TAMU-Dallas was selected as one of the NTEP test sites for the evaluation of recently developed varieties and established cultivars. As a part of the NTEP evaluation, a test of cultural methods, with emphasis on mowing height, was designed.

Materials and Methods

Two complete sets of the tall fescue NTEP trial, each containing 65 entries replicated three times, were seeded to 4 X 6-ft plots on blackland clay loam soil at the Texas A&M Research and Extension Center at Dallas in January 1988. The planting was irrigated daily until established and as needed to prevent wilt after establishment.

Both trials were grown under full sun, fertilized annually with 34-0-0 at 2 lbs N per 1,000 sq ft, and irrigated to maintain active growth during the growing season. One set was maintained at a 2.5-inch mowing height (Trial A), which is representative of typical cultural practice for turf-type tall fescues. The other set was cut to 1.5 inches (Trial B).

Quality ratings using the component assessment system (Hickey and Engelke 1984) were collected at monthly intervals. Density (1-3), uniformity (0-2), smoothness (0-1), color (0-2), and texture (0-1) ratings were summed for a total possible value ranging from one to nine, with nine equal to the highest quality. A total score of five is the lowest acceptable quality rating.

A greenbug infestation in February 1990 was rated 1 to 9 with 9 representing the most severe damage (no green leaves). Endophyte levels on similar seed lots from the NTEP, measured by researchers at Rutgers University (Saha and Johnson-Cicalese 1988), were compared to mean ratings for Trial A to determine the correlation between greenbug resistance and endophytic levels.

Results and Discussion

Trial A

During the 3 years of the trial, quality ratings for Trial A were significantly different among entries within dates for most of the 27 monthly evaluations (Tables 1-3). Even in months where significant differences were present, the actual number of entries excluded from the highest rating group (noted in the tables as those values accompanied by the letter 'a') was minimal (Tables 1 - 3, 7).

In 1989, the first year after establishment, the best quality for most entries was observed during early February and during April. Topping the group of most highly ranked entries was Rebel, which expressed its best quality during February. Consistently good performers (TQ ≈ 6.0) included Rebel, PST-5AP, Tip, and Winchester. The highest annual averages were observed of Crossfire, Taurus, Trailblazer, Trident, and Twilight. Standard variety, KY-31, exhibited the poorest annual average turf quality.

Tall fescue ratings were poorer in the second year of the trial (1990) (Table 2). Peak quality in 1990 earned a good quality rating (TQ ≈ 6.0) and was observed for many entries during April. Other months had no entries with good quality, except during December, in which Twilight was among those so ranked. High average qualities were observed of Cochise, Guardian, Normarc25, Normarc77, Twilight, and Tribute, yet none of the averages ranked as acceptable ratings (TQ ≈ 5.0).

1991 is especially important in the ranking of tall fescue performance in these trials because the entries are well established, and it is the third year of the trials, which means quality ratings noted this year reflect long-term quality of the entries. The highest first semiannual average turf quality for 1991 was 5.0, which was observed for Aztec, Eldorado, PST-5MW, and Trailblazer (Table 3). The best quality this year, and for the 3 years of Trial A was observed in June 1991, when turf quality was good for all entries. Those entries which had June ratings ≈ 7.0 include Hubbard87, PST-5AG, PST-5OL, and Trailblazer.

Trial B

During the 3 years of the trials, turf qualities observed in Trial B were more similar among entries within date classes than was observed of turf quality ratings in Trial A, yet the annual averages for 1990 and the semiannual averages for 1991 ratings were significantly different among entries (Tables 4 - 6). Again, in months where significant differences were present, the actual number of entries excluded from the statistically highest rated group was small (Tables 4 - 7).

Quality ratings were not significantly different among entries on any 1989 evaluation date or for the yearly average (Table 4). The low level of differences among entries in either trial may be partially attributed to soil erosion problems during stand development. Good turf quality ratings (TQ ≈ 6.0) were observed of the greatest number of lines during early February.

None of the lines expressed good quality during 1990 (Table 5). Among the highest average ratings in 1990 were 4.6, 4.5, and 4.4, for PST-5AG, Guardian, and Avanti, respectively. As expected, significant differences among entries occurred during the summer months, when cool-season tall fescues are generally heat-stressed. The standard cultivar, KY-31, invariably had poor turf quality during summer 1990.

For the first half of 1991, acceptable turf quality was observed on 36 of the 65 entries, as illustrated by the quality ratings of Guardian, PST-5AG, and Trailblazer (5.1, 5.1, and 5.2, respectively) (Table 6). Good turf quality was observed of all entries in May and June, and poor quality was most frequent in February.

Overall Quality

For all years, Trial B quality ratings were lower than Trial A ratings, indicating that reducing mowing heights for tall fescues may not be desirable. (Tables 1 - 6). The cumulative phenotypic stability index (cumulative over 2.5 years) emphasized that poor quality was consistently observed for KY-31 in both mowing trials (Table 7). Most entries were frequently in the highest statistically significant group, which suggests that most tall fescues might respond favorably to the abiotic environmental factors typical of Dallas, Texas, given optimal cultural practices. Some of the entries which were consistently in the top quality group were Amigo, Avanti, Aztec, Bonanza, Crossfire, Falcon, Hubbard87, Normarc25, PE-7, PST-5AG, PST-5OL, Trailblazer, and Tribute.

Greenbug Infestation and Endophyte Level

A greenbug infestation, probably originating from a winter wheat field north of the tall fescue trials, occurred the third week of February 1990. Trial A, which was closer to the infestation origin, suffered greater damage than Trial B. Replications within each trial were significantly different, also corresponding to the distance of the rated plot from the infestation origin. An exception to this condition was the first two rows of Trial A. Although these rows were closest to the site of greenbug entry, they were among the least affected. This may have been due to drift from insecticide applied to the wheat field providing some protection to these rows. Trial B, further from the initial site of entry, had ratings which showed trends, but which were not significantly different among entries. Ratings for Trial A, however, were significantly different among entries with regard to greenbug damage (Table 8).

The correlation of endophyte level and greenbug damage was significant ($p < 0.0003$), with a Pearson Correlation Coefficient of 44. There were exceptions to this correlation. Titan and Syn Ga, for example had high reported endophyte levels (98 and 50 percent, respectively) but low resistance to the greenbugs. Conversely, KY-31 and Pacer, with no reported endophytes, had greenbug resistance levels comparable to high endophyte-containing entries. Caution is necessary in interpreting these comparisons since endophyte levels were not determined for the Dallas planting and endophyte levels in those samples may be different from samples used at Rutgers, even though they are the same cultivar. These contradictions may be resolvable with an endophytic analysis of field samples at the Dallas site.

Table 1. Turf quality in 1989 of 1987 NTEP tall fescue trial entries maintained at 2.5-inch mowing height. Quality ratings are based on a scale of 1 to 9, of which 9 indicates the best quality, and 5 is the lowest acceptable quality.

	1989												
Entry	01 Feb	25 Feb	03 Apr	04 May	06 Jun	22 Jun	25 Jul	21 Aug	26 Sep	31 Oct	27 Nov	Avg	PS[1]
Adventure	6.0a	4.7a	5.3a	4.7	5.3	4.3a	4.7a	4.7a	4.3a	5.0a	3.3a	4.6a	10
Amigo	5.0a	4.0a	5.3a	5.0	4.7	5.3a	5.7a	5.0a	5.0a	5.0a	4.7a	4.8a	10
Apache	5.0a	4.7a	5.3a	5.0	5.3	4.7a	5.0a	4.7a	5.3a	5.0a	3.3a	4.7a	10
Arid	5.0a	3.7a	5.3a	4.7	4.0	3.3	4.7a	4.7a	4.7a	4.7a	4.3a	4.4a	9
Avanti	4.7a	4.3a	5.7a	4.7	4.0	4.7a	5.3a	5.3a	5.0a	4.7a	3.7a	4.6a	10
Aztec	4.0a	3.3a	4.3a	4.3	4.0	5.0a	5.7a	5.0a	5.3a	5.0a	3.3a	4.4a	10
Barnone	6.0a	5.7a	5.7a	4.7	3.7	5.0a	5.3a	5.0a	4.3a	5.0a	3.0	4.7a	9
Bel 86-1	4.0a	3.3a	5.0a	4.0	3.7	4.0a	4.0	4.0a	4.0	4.0	2.7	3.8a	6
Bel 86-2	4.3a	3.7a	5.0a	4.7	4.0	4.3a	5.3a	5.0a	4.3a	4.7a	4.7a	4.4a	10
Bonanza	4.3a	3.7a	5.0a	5.3	3.3	4.3a	5.7a	5.3a	5.0a	5.0a	3.3a	4.4a	10
Carefree	4.3a	3.7a	4.0a	4.3	3.7	4.0a	4.7a	4.3a	4.3a	4.7a	2.7	3.9a	9
Chieftain	4.3a	4.7a	5.0a	5.0	4.3	4.7a	4.7a	5.0a	4.7a	4.7a	3.0	4.4a	9
Cimmaron	6.7a	5.0a	5.7a	4.0	4.3	4.3a	5.3a	4.7a	4.7a	4.3a	3.7a	4.6a	10
Cochise	3.0	3.3a	5.0a	6.3	5.0	4.7a	5.0a	4.7a	5.0a	5.3a	3.7a	4.5a	9
Crossfire	5.3a	5.7a	6.0a	5.3	4.3	5.7a	6.0a	4.7a	5.0a	5.0a	4.0a	5.0a	10
Eldorado	4.0a	3.3a	4.3a	4.7	4.3	5.0a	4.0	4.7a	4.3a	4.3a	3.3a	4.1a	9
Emperor	4.3a	3.7a	5.3a	5.3	4.0	4.7a	5.7a	4.3a	4.0	5.0a	3.0	4.4a	8
Falcon	4.7a	4.7a	5.3a	4.7	5.0	4.0a	5.0a	4.7a	5.0a	4.7a	3.3a	4.5a	10
Fatima	4.0a	3.7a	4.3a	5.0	3.7	3.7	4.3a	4.0a	4.3a	4.0	2.7	3.9a	7
Finelawn 5GL	5.3a	5.0a	5.7a	5.0	4.3	4.7a	4.3a	4.7a	4.0	4.3a	3.0	4.4a	8
Finelawn I	5.3a	4.3a	5.3a	5.0	3.7	4.3a	4.0	3.7a	5.0a	4.7a	3.3a	4.3a	9
Guardian	4.0a	4.3a	5.3a	4.7	4.3	5.7a	4.7a	4.7a	5.0a	4.7a	3.3a	4.5a	10
Hubbard 87	4.0a	4.0a	5.7a	6.0	3.7	5.7a	5.7a	5.0a	5.3a	5.7a	3.3a	4.8a	10
Jaguar	6.0a	5.7a	5.7a	4.0	3.3	5.3a	5.3a	5.0a	4.7a	5.0a	3.3a	4.7a	10
Jaguar II	5.0a	4.3a	5.3a	4.7	4.0	5.0a	4.7a	5.3a	5.0a	5.3a	4.3a	4.7a	10
JB-2	5.0a	5.3a	5.3a	5.3	4.3	5.3a	5.0a	4.7a	4.7a	4.7a	3.0	4.6a	9
KWS-DUR	4.3a	3.3a	4.7a	4.7	3.3	3.7	4.7a	4.3a	4.0	4.3a	2.7	3.9a	7
KY-31	4.3a	4.3a	5.3a	3.7	4.3	2.7	4.3a	3.3	3.0	3.0	3.0	3.7a	4
Legend	4.3a	4.7a	5.0a	5.3	5.0	4.3a	5.0a	4.3a	4.0	4.3a	3.0	4.3a	8
Maverick II	5.0a	3.7a	5.7a	6.0	4.7	5.0a	5.0a	4.7a	5.0a	4.7a	3.0	4.6a	9
Mesa	4.0a	4.3a	5.7a	5.3	3.0	5.0a	4.7a	4.3a	5.0a	4.3a	3.3a	4.3a	10
Monarch	3.7	3.7a	5.7a	4.7	4.0	5.0a	5.0a	5.0a	5.0a	4.7a	3.3a	4.4a	9
Murietta	3.7	3.0	3.7	4.0	3.3	4.7a	4.3a	4.3a	4.7a	4.3a	3.0	3.8a	6
Normarc 25	4.3a	4.0a	5.0a	5.3	3.7	4.7a	5.3a	4.7a	4.7a	5.0a	4.0a	4.5a	10
Normarc 77	4.3a	5.0a	5.3a	4.7	3.7	5.0a	5.3a	4.7a	4.7a	5.0a	3.0	4.5a	9
Normarc 99	4.3a	3.7a	5.0a	5.7	4.0	5.0a	5.0a	4.7a	5.0a	5.0a	3.0	4.5a	9
Olympic	4.3a	3.3a	4.3a	4.7	4.0	5.0a	4.7a	4.7a	4.7a	4.7a	3.7a	4.3a	10
Pacer	4.3a	4.7a	6.0a	4.7	4.0	5.0a	5.0a	4.7a	4.3a	4.7a	2.7	4.4a	9
PE-7	4.7a	4.0a	5.7a	4.7	4.0	5.0a	5.3a	5.3a	5.7a	5.7a	3.7a	4.8a	10
PST-5AG	4.7a	3.7a	5.0a	5.0	4.7	5.3a	6.0a	5.3a	5.0a	5.0a	4.3a	4.8a	10
PST-5AP	5.7a	5.3a	5.3a	5.7	5.0	5.7a	5.7a	5.0a	4.7a	5.0a	4.3a	5.0a	10
PST-5DM	4.7a	4.0a	4.7a	4.7	4.3	4.7a	5.0a	5.0a	4.3a	4.7a	3.0	4.3a	9
PST-5EN	5.0a	4.3a	5.3a	5.0	4.0	5.0a	5.0a	5.0a	5.0a	4.7a	3.0	4.5a	9
PST-5MW	3.7	3.7a	3.7	4.0	3.3	4.0a	4.3a	4.3a	4.3a	4.3a	3.0	3.8a	7
PST-5OL	5.0a	4.3a	6.0a	5.0	5.3	5.7a	6.0a	5.0a	5.0a	4.7a	4.0a	4.9a	10
PST-DBC	5.3a	4.3a	4.7a	5.7	3.3	3.7	4.7a	5.0a	4.7a	4.7a	3.7a	4.4a	9
Rebel	7.0a	6.0a	6.3a	5.3	3.7	4.3a	5.0a	4.7a	4.7a	4.7a	3.7a	4.9a	10
Rebel II	5.0a	4.7a	5.7a	5.0	4.3	4.7a	6.3a	4.7a	5.3a	4.7a	3.7a	4.8a	10
Richmond	5.0a	5.0a	6.0a	5.0	4.7	3.7	4.3a	4.3a	4.0	4.7a	3.0	4.4a	7
Shenandoah	3.7	3.0	3.7	4.3	3.7	4.3a	5.3a	4.7a	4.3a	4.7a	3.7a	4.0a	7
Shortstop	4.0a	2.7	4.0a	4.3	3.7	4.7a	5.0a	4.7a	4.3a	4.3a	3.0	3.9a	8
Silverado	4.3a	3.7a	4.3a	4.7	3.0	5.3a	5.0a	5.0a	4.7a	4.3a	3.0	4.2a	7
Sundance	5.3a	5.0a	5.7a	5.3	3.7	4.3a	5.0a	5.0a	5.0a	5.0a	3.3a	4.6a	10
SynGA	4.3a	4.7a	5.7a	5.3	4.0	4.3a	4.7a	5.0a	5.0a	4.7a	3.3a	4.5a	10
Taurus	5.7a	5.7a	5.7a	6.0	4.7	5.7a	5.3a	5.0a	5.0a	5.0a	4.0a	5.1a	10
Thoroughbred	4.3a	4.0a	5.0a	4.7	4.0	4.3a	5.0a	4.0a	4.3a	4.0	3.0	4.1a	8
Tip	6.0a	5.3a	6.0a	4.7	4.3	4.7a	5.0a	4.3a	4.0	4.7a	3.3a	4.6a	9
Titan	4.3a	3.3a	4.0a	4.3	4.3	3.7	4.7a	4.0a	4.0	4.0	2.7	3.8a	6
Trailblazer	6.0a	4.3a	6.3a	5.3	5.0	5.3a	5.3a	5.0a	5.3a	4.7a	4.0a	5.0a	10
Tribute	4.7a	4.3a	5.0a	5.3	4.3	4.7a	5.3a	5.0a	5.0a	4.7a	4.0a	4.6a	10
Trident	6.0a	5.0a	6.3a	5.3	3.7	5.3a	5.0a	4.7a	5.0a	4.3a	3.7a	4.8a	10
Twilight	5.0a	4.0a	6.0a	6.3	3.7	5.7a	6.0a	5.7a	5.7a	6.0a	3.3a	5.1a	10
Willamette	5.0	4.0a	6.0a	5.3	5.0	5.0a	4.3a	4.3a	4.7a	4.3a	3.3a	4.5a	10
Winchester	6.0a	5.0a	6.3a	5.3	3.3	4.7a	5.0a	4.3a	4.0	4.0	3.3a	4.5a	8
Wrangler	4.0a	4.3a	4.7a	4.7	4.0	4.7a	4.3a	3.7a	3.7	3.3	3.0	3.9a	7
MSD[2]	3.1	2.8	2.5	n.s.	n.s.	1.7	2	2.2	1.6	1.7	1.7	1.5	

[1] PS is the phenotypic stability indicating superior adaptability to test conditions.

[2] MSD is the Minimum Significant Difference for comparison of means within dates based on the Waller-Duncan k-ratio t Test (k-ratio = 100). 'n.s.' indicates means were not significantly different.

Table 2. Turf quality in 1990 for 1987 series NTEP tall fescue trial maintained at 2.5-inch mowing height.

Entry	1990													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	PS[1]
Adventure	3.0a	1.0	4.7	4.7	3.7	3.7	3.7a	3.7a	3.7a	4.3a	4.7a	4.7a	3.8	7
Amigo	3.3a	1.7	4.0	5.7	4.3	4.7	4.7a	4.3a	4.3a	4.7a	4.3a	4.7a	4.2	7
Apache	2.7a	1.0	3.0	5.0	3.7	3.7	3.7a	4.3a	4.3a	4.7a	5.0a	5.3a	3.9	7
Arid	2.7a	3.0a	4.3	4.7	3.7	3.7	3.7a	4.0a	3.3a	4.7a	4.7a	4.7a	3.9	8
Avanti	2.7a	1.7	3.7	5.3	4.7	4.7	4.3a	4.0a	4.0a	4.3a	4.7a	4.7a	4.1	7
Aztec	2.7a	1.0	4.0	5.7	4.7	4.7	5.0a	4.7a	4.0a	5.0a	5.0a	5.3a	4.3	7
Barnone	3.0a	1.7	3.3	5.0	3.7	3.7	4.0a	3.7a	3.7a	4.3a	4.7a	5.0a	3.8	7
Bel 86-1	2.3a	1.0	2.0	4.0	3.7	4.0	3.7a	3.7a	4.0a	3.7a	3.7	4.7a	3.4	6
Bel 86-2	3.3a	3.0a	4.7	5.7	4.3	4.3	4.3a	4.3a	4.3a	4.7a	4.3a	4.3	4.3	7
Bonanza	3.3a	1.0	3.0	4.3	3.7	3.7	3.7a	4.0a	3.7a	4.3a	4.7a	5.0a	3.7	7
Carefree	2.7a	1.0	2.3	4.3	4.0	4.0	3.7a	3.3	3.3a	4.0a	4.3a	4.7a	3.5	6
Chieftain	2.7a	1.0	2.7	4.0	3.7	3.7	3.7a	4.3a	4.0a	4.7a	5.0a	5.0a	3.7	7
Cimmaron	3.0	1.0	2.7	4.7	4.3	4.3	5.0a	4.7a	5.0a	5.3a	5.7a	5.3a	4.3	6
Cochise	3.0a	1.7	5.3	6.7	5.3	5.3	5.0a	4.7a	4.3a	4.7a	5.0a	5.0a	4.7	7
Crossfire	2.7a	1.7	4.3	6.0	4.7	4.7	4.3a	4.3a	3.7a	4.7a	5.3a	5.0a	4.3	7
Eldorado	2.7a	1.0	4.0	5.7	5.0	5.0	4.7a	5.0a	4.7a	5.0a	5.0a	5.3a	4.4	7
Emperor	2.7a	1.7	2.7	3.7	3.7	4.0	4.3a	4.7a	4.7a	4.7a	5.3a	5.3a	3.9	7
Falcon	2.7a	1.0	3.0	4.7	4.0	4.0	3.7a	3.7a	3.3a	4.3a	4.7a	4.7a	3.6	7
Fatima	2.7a	1.0	4.7	4.3	3.7	4.0	4.0a	3.7a	3.0a	3.3a	3.3	3.7	3.4	6
Finelawn 5GL	2.7a	1.0	3.7	5.7	4.7	4.3	4.3a	4.3a	3.3a	4.3a	4.0a	5.0a	3.9	7
Finelawn I	3.0a	1.0	3.7	4.7	4.0	4.0	4.0a	3.7a	3.7a	4.0a	4.0a	4.7a	3.7	7
Guardian	3.0a	1.7	4.7	5.3	5.0	5.0	5.0a	5.0a	5.0a	5.0a	5.0a	4.7a	4.5	
Hubbard 87	3.0a	1.0	3.3	5.3	4.3	4.3	4.0a	4.0a	3.7a	4.3a	4.7a	5.0a	3.9	7
Jaguar	3.0a	1.7	3.3	5.7	5.0	5.0	4.7a	5.0a	4.3a	4.7a	4.7a	4.3	4.3	6
Jaguar II	3.0a	1.0	4.3	5.7	4.7	4.7	4.3a	4.3a	4.3a	5.0a	5.3a	5.0a	4.3	7
JB-2	2.7a	1.0	3.0	5.3	4.3	4.3	4.0a	4.3a	4.0a	4.7a	4.7a	5.3a	4.0	7
KWS-DUR	2.3a	1.0	4.0	5.3	4.0	4.0	4.0a	4.0a	3.7a	4.3a	4.7a	5.3a	3.9	7
KY-31	2.7a	2.3a	4.7	4.0	3.3	4.0	4.0a	3.7a	3.3a	3.7a	4.0a	3.3	3.6	7
Legend	2.7a	1.7	5.0	5.7	4.0	4.0	4.0a	4.7a	3.3a	4.7a	5.0a	4.7a	4.1	7
Maverick II	2.7a	1.0	2.7	4.3	4.0	4.0	4.3a	4.0a	4.3a	4.3a	4.7a	5.3a	3.8	7
Mesa	3.0a	3.0a	4.3	5.7	5.0	4.0	3.3a	3.0	3.0a	3.3a	3.3	4.3	3.8	5
Monarch	3.0a	2.3a	4.7	5.7	5.0	4.7	4.3a	4.3a	4.0a	4.0a	3.7	4.7a	4.2	7
Murietta	2.7a	1.0	3.3	4.7	4.0	4.0	4.0a	4.0a	4.0a	4.3a	4.3a	5.0a	3.8	7
Normarc 25	2.3a	1.0	4.3	5.7	5.0	5.0	5.0a	5.0a	4.7a	5.3a	5.0a	5.3a	4.5	7
Normarc 77	3.0a	1.0	5.0	6.0	5.0	5.3	5.0a	5.3a	5.0a	4.7a	4.7a	5.0a	4.6	7
Normarc 99	3.0a	1.7	4.0	5.3	4.3	4.3	4.3a	4.3a	4.0a	4.7a	4.7a	5.3a	4.2	7
Olympic	3.0a	1.0	4.0	5.3	5.0	5.0	4.7a	4.0a	3.7a	4.0a	4.0a	5.0a	4.1	7
Pacer	3.0a	2.3a	4.0	5.0	4.0	4.0	4.0a	3.7a	3.3a	4.0a	4.3a	4.7a	3.9	8
PE-7	3.0a	1.0	4.3	6.3	5.3	5.3	4.7a	4.0a	4.0a	4.3a	4.3a	4.7a	4.3	7
PST-5AG	3.3a	1.0	4.0	5.0	4.0	4.3	4.0a	4.3a	4.0a	5.0a	5.3a	5.3a	4.1	7
PST-5AP	3.0a	1.0	4.0	5.7	4.3	4.3	4.7a	4.7a	4.7a	4.7a	4.7a	4.7a	4.2	7
PST-5DM	2.7a	1.7	4.0	5.7	4.7	4.7	4.7a	3.7a	3.3a	4.3a	4.0a	4.7a	4.0	7
PST-5EN	3.0a	1.0	3.7	5.0	4.3	4.3	4.3a	4.3a	3.3a	4.7a	4.7a	5.3a	4.0	7
PST-5MW	3.0a	1.0	3.7	5.3	4.7	4.7	4.3a	4.7a	4.7a	5.0a	5.0a	5.3a	4.3	7
PST-5OL	3.3a	1.7	4.3	6.0	4.7	4.7	4.3a	4.3a	3.7a	4.3a	4.7a	5.0a	4.3	7
PST-DBC	3.0a	3.0a	4.7	5.0	4.0	4.3	4.0a	3.7a	4.0a	4.0a	4.3a	5.0a	4.1	8
Rebel	2.7a	1.0	2.0	3.7	4.0	4.0	4.0a	4.0a	4.0a	5.0a	5.0a	5.3a	3.7	7
Rebel II	3.0a	1.0	3.3	5.3	4.7	5.0	4.7a	4.7a	4.3a	4.7a	5.0a	5.0a	4.2	7
Richmond	2.7a	1.0	3.7	5.0	4.0	4.0	3.7a	3.7a	3.3a	3.7a	3.7	4.3	3.6	
Shenandoah	2.3a	2.3a	3.7	5.0	4.0	4.0	4.0a	4.0a	3.3a	4.3a	4.3a	5.0a	3.9	8
Shortstop	3.0a	1.0	3.3	4.7	4.0	4.3	4.3a	4.3a	4.3a	4.7a	4.7a	5.0a	3.9	7
Silverado	2.7a	1.7	3.3	3.7	4.0	4.3	4.3a	4.3a	4.3a	4.7a	5.7a	5.0a	4.0	7
Sundance	3.0a	1.0	2.3	4.7	4.3	4.3	4.0a	4.3a	4.0a	4.7a	4.7a	5.0a	3.8	7
SynGA	3.0a	1.0	4.0	5.0	3.7	3.7	4.0a	4.3a	4.0a	4.3a	5.0a	4.0	3.8	7
Taurus	3.0a	1.0	4.7	5.7	3.3	4.3	4.0a	4.3a	4.0a	4.7a	5.7a	5.3a	4.2	7
Thoroughbred	3.0a	1.7	2.3	4.3	4.0	4.3	4.3a	4.3a	4.3a	4.7a	5.0a	5.0a	3.9	7
Tip	3.0a	1.0	4.0	5.0	4.0	4.0	4.0a	4.0a	3.7a	4.0a	3.3	4.7a	3.7	6
Titan	2.3a	1.0	2.0	3.7	3.3	3.7	3.3a	3.7a	3.3a	4.0a	4.3a	4.7a	3.3	7
Trailblazer	3.0a	1.7	3.3	5.3	4.3	4.3	4.3a	4.3a	4.0a	5.0a	5.0a	5.3a	4.2	7
Tribute	2.7a	2.7a	5.7	6.7	5.0	5.0	4.7a	4.7a	4.3a	4.7a	5.0a	5.0a	4.7	8
Trident	3.0a	1.0	3.0	5.7	4.7	4.7	4.3a	4.0a	3.7a	4.0a	4.0a	5.0a	3.9	7
Twilight	3.0a	1.0	5.3	6.0	5.0	5.0	4.3a	4.3a	4.0a	5.0a	4.7a	6.0a	4.5	7
Willamette	3.0a	0.7	3.0	4.3	4.0	4.0	4.0a	4.0a	3.7a	4.3a	4.3a	4.7a	3.7	7
Winchester	2.7a	2.3a	4.0	6.3	4.7	4.7	4.7a	4.3a	4.0a	4.3a	4.3a	4.7a	4.5	8
Wrangler	2.7a	1.0	4.0	5.0	4.0	4.0	4.7a	4.3a	4.3a	5.0a	5.0a	5.0a	4.1	7
MSD[2]	1.5	1.2	n.s.	n.s.	n.s.	n.s.	2.4	2.0	2.4	2.2	1.9	1.6	n.s.	

[1] PS is the phenotypic stability indicating superior adaptability to test conditions.
[2] MSD is the Minimum Significant Difference for comparison of means within dates based on the Waller-Duncan k-ratio t Test (k-ratio = 100). 'n.s.' indicates means were not significantly different.

Table 3. Turf quality in 1991 for 1987 series NTEP tall fescue trial maintained at 2.5-inch mowing height.

	1991					
Entry	Feb	Mar	May	Jun	Avg	PS[1]
Adventure	2.0	2.7	6.0	6.7a	4.3	1
Amigo	3.0	3.7	6.0	6.3a	4.8a	2
Apache	2.0	3.0	5.7	7.0a	4.4	1
Arid	2.3	3.3	6.7	7.0a	4.8a	2
Avanti	2.3	3.7	6.0	6.7a	4.7a	2
Aztec	2.7	3.7	6.3	7.3a	5.0a	2
Barnone	2.3	3.0	6.0	6.3a	4.4	1
Bel 86-1	2.0	2.7	5.3	6.3a	4.1	1
Bel 86-2	1.7	2.7	6.7	7.0a	4.5a	2
Bonanza	2.0	3.3	6.3	7.3a	4.8a	2
Carefree	2.0	2.7	6.3	6.3a	4.3	1
Chieftain	2.0	2.7	6.3	7.0a	4.5a	2
Cimmaron	2.0	3.0	6.0	7.3a	4.6a	2
Cochise	2.0	3.3	6.0	6.7a	4.5a	2
Crossfire	2.3	3.0	6.0	6.3a	4.4	1
Eldorado	2.7	3.7	6.3	7.3a	5.0a	2
Emperor	2.0	3.0	6.0	6.7a	4.4	1
Falcon	2.0	2.7	6.0	7.3a	4.5a	2
Fatima	1.3	1.7	6.3	6.3a	3.9	1
Finelawn 5GL	2.0	3.0	5.7	6.3a	4.3	1
Finelawn I	2.0	3.0	5.7	6.7a	4.3	1
Guardian	2.0	3.3	5.7	6.0	4.3	–
Hubbard 87	2.3	3.0	6.7	7.3a	4.8a	2
Jaguar	2.0	3.3	5.7	6.7a	4.4	1
Jaguar II	1.7	3.0	5.7	7.3a	4.4	1
JB-2	2.0	3.0	6.0	6.7a	4.4	1
KWS-DUR	1.7	3.3	6.3	7.3a	4.7a	2
KY-31	2.0	2.3	5.7	6.3a	4.1	1
Legend	2.0	3.0	5.7	7.0a	4.4	1
Maverick II	2.0	3.0	6.3	7.3a	4.7a	2
Mesa	2.0	2.0	5.3	6.0	3.8	—
Monarch	2.0	2.0	5.7	6.3a	4.0	1
Murietta	2.0	2.3	6.3	6.7a	4.3	1
Normarc 25	2.0	4.0	6.3	7.0a	4.8a	2
Normarc 77	2.0	3.0	6.0	6.3a	4.3	1
Normarc 99	2.0	3.3	5.3	6.3a	4.3	1
Olympic	1.7	3.0	6.0	6.3a	4.3	1
Pacer	2.0	2.7	6.0	6.0	4.2	—
PE-7	2.0	3.0	6.3	7.0a	4.6a	2
PST-5AG	2.3	3.0	7.0	7.0a	4.8a	2
PST-5AP	2.3	3.3	6.0	7.3a	4.8a	2
PST-5DM	2.0	2.0	6.0	7.0a	4.3	1
PST-5EN	2.0	2.7	6.3	3.7a	4.4	1
PST-5MW	2.3	3.7	6.3	7.7a	5.0a	2
PST-5OL	2.0	3.0	7.0	7.3a	4.8a	2
PST-DBC	2.0	3.0	6.0	7.0a	4.5a	2
Rebel	2.0	2.7	6.0	7.3a	4.5a	2
Rebel II	2.0	2.7	6.0	7.0a	4.4	1
Richmond	2.0	2.3	5.0	6.7a	4.0	1
Shenandoah	2.0	3.0	6.7	7.3a	4.8a	2
Shortstop	2.0	3.3	5.7	6.7a	4.4	1
Silverado	2.7	2.7	6.7	7.0a	4.8a	2
Sundance	2.0	3.7	5.7	7.0a	4.6a	2
SynGA	2.0	3.0	6.0	6.3a	4.3	1
Taurus	2.0	2.3	5.7	6.3a	4.1	1
Thoroughbred	2.0	3.0	5.7	7.0a	4.2	1
Tip	2.0	2.0	6.0	7.0a	4.3	1
Titan	2.0	3.0	6.7	6.0	4.4	—
Trailblazer	2.3	3.7	6.7	7.3a	5.0a	2
Tribute	2.3	3.3	6.7	6.7a	4.8a	2
Trident	1.7	2.7	5.3	6.7a	4.1	1
Twilight	1.7	2.3	5.7	6.7a	4.1	1
Willamette	2.0	2.3	6.0	7.0a	4.3	1
Winchester	2.0	3.0	6.0	6.3a	4.3	1
Wrangler	2.0	3.0	5.7	7.3a	4.5a	2
MSD[2]	n.s.	n.s.	n.s.	1.4	0.6	

[1] PS is the phenotypic stability indicating superior adaptability to test conditions.
[2] MSD is the Minimum Significant Difference for comparison of means within dates based on the Waller-Duncan k-ratio t Test (k-ratio = 100). 'n.s.' indicates means were not significantly different.

Table 4. Turf quality in 1989 of 1987 NTEP tall fescue trial entries maintained at 1.5-inch mowing height. Quality ratings are based on a scale of 1 to 9, of which 9 indicates the best quality, and 5 is the lowest acceptable quality.

	1989											1990	
Entry	01 Feb	25 Feb	03 Apr	04 May	06 Jun	30 Jun	25 Jul	21 Aug	26 Sep	31 Oct	27 Nov	06 Jan	Avg
Adventure	5.7	4.7	5.3	4.0	4.0	3.7	4.0	4.0	4.0	4.0	3.3	2.3	4.1
Amigo	4.0	3.0	3.7	4.0	4.3	4.0	4.7	4.0	4.3	3.7	3.3	2.3	3.8
Apache	4.0	4.0	4.3	4.0	3.7	4.7	4.0	4.0	4.3	4.0	3.3	2.0	3.9
Arid	4.0	3.3	4.0	3.0	3.0	3.0	4.3	4.0	4.0	4.0	3.3	2.0	3.5
Avanti	5.3	3.0	5.3	5.3	3.7	4.7	5.0	4.0	4.0	4.0	3.3	2.0	4.1
Aztec	5.3	4.0	4.3	4.0	4.7	4.7	4.7	4.0	4.3	4.3	3.3	2.0	4.1
Barnone	4.7	4.3	4.7	4.7	4.3	4.3	4.3	4.0	4.3	4.3	3.3	2.0	4.1
Bel 86-1	3.3	3.3	4.3	4.0	3.7	4.0	3.3	3.3	4.0	3.7	3.0	2.3	3.5
Bel 86-2	4.7	2.7	4.3	5.0	4.3	4.7	5.3	4.3	4.7	4.7	3.7	2.3	4.2
Bonanza	5.0	4.3	4.7	5.0	4.3	4.0	4.0	4.7	4.0	4.0	3.0	2.3	4.1
Carefree	3.3	3.0	3.7	3.3	3.3	3.3	3.7	3.7	3.7	3.7	3.0	2.0	3.3
Chieftain	3.7	3.0	4.3	3.7	3.3	3.3	4.0	3.3	3.0	3.3	3.0	2.0	3.3
Cimmaron	5.7	4.0	5.3	4.0	4.7	4.3	4.0	4.3	4.3	4.3	3.7	2.7	4.3
Cochise	5.0	3.0	4.3	4.0	3.7	4.7	4.3	4.7	4.3	4.7	3.0	2.3	4.0
Crossfire	4.7	3.0	4.7	4.0	3.7	5.0	4.3	4.0	4.0	4.0	3.3	2.3	3.9
Eldorado	3.7	4.0	3.7	4.3	4.3	5.0	4.7	4.3	4.0	4.0	3.7	2.3	4.0
Emperor	5.0	4.3	4.3	4.3	5.0	4.3	4.3	4.3	4.3	4.0	3.3	2.7	4.2
Falcon	5.3	5.7	4.7	5.7	5.3	4.7	4.7	4.0	4.0	4.3	3.3	2.3	4.5
Fatima	5.0	4.3	4.7	3.0	4.7	4.7	3.7	4.3	4.7	4.0	3.0	2.0	4.0
Finelawn 5GL	4.7	3.0	4.3	3.0	3.3	3.7	4.0	3.7	3.7	3.3	3.3	2.3	3.5
Finelawn I	4.3	4.0	4.3	4.3	3.7	4.7	4.0	3.7	4.0	4.0	3.0	2.3	3.9
Guardian	5.7	4.3	6.0	4.3	4.3	4.7	4.0	4.3	4.0	4.7	4.0	2.3	4.4
Hubbard 87	5.0	3.3	3.0	4.0	4.3	4.0	4.7	4.0	4.0	4.0	3.3	2.3	4.0
Jaguar	5.7	5.3	5.3	4.3	5.0	4.7	5.0	4.3	4.7	4.7	4.0	2.7	4.6
Jaguar II	4.7	4.7	4.3	4.3	4.0	4.7	4.0	4.0	4.0	4.0	3.3	2.7	4.1
JB-2	4.0	4.0	4.7	4.7	4.0	4.0	4.0	4.0	3.3	3.7	3.0	2.0	3.8
KWS-DUR	3.7	3.3	4.0	3.7	4.7	4.7	4.3	4.0	4.3	4.7	3.0	2.3	3.9
KY-31	3.7	3.3	4.3	3.0	3.0	3.3	3.7	3.7	4.0	4.0	3.0	2.0	3.4
Legend	4.7	3.7	5.0	4.3	3.7	4.7	4.3	4.0	3.7	4.3	3.0	2.7	4.0
Maverick II	5.0	4.3	5.3	5.7	4.0	4.7	4.0	4.3	4.3	4.3	3.7	2.7	4.4
Mesa	5.0	3.7	4.3	4.3	3.7	4.3	4.3	3.7	4.0	4.0	3.3	2.0	3.9
Monarch	4.0	4.0	4.0	3.3	3.7	4.3	4.0	4.0	4.3	4.0	3.0	2.3	3.8
Murietta	3.3	2.3	3.7	2.7	3.7	3.7	3.3	3.7	3.7	3.7	3.3	2.0	3.3
Normarc 25	4.0	3.3	4.3	4.7	3.7	4.3	4.3	4.3	4.3	4.7	3.3	2.3	4.0
Normarc 77	5.3	3.7	4.7	4.7	4.7	4.7	4.3	4.3	4.7	4.7	3.3	2.7	4.3
Normarc 99	4.0	4.0	5.3	4.7	4.0	5.3	4.3	4.0	4.0	4.3	3.0	2.7	4.1
Olympic	4.7	4.3	4.7	3.0	4.0	4.3	4.3	4.0	4.3	4.3	3.3	2.0	3.9
Pacer	5.0	5.0	4.7	5.0	4.7	4.7	4.7	4.0	4.0	4.3	3.3	2.3	4.3
PE-7	3.7	3.7	5.0	4.0	3.7	3.7	4.0	4.0	4.0	4.0	2.3	2.0	3.7
PST-5AG	5.0	4.7	5.0	5.3	5.0	5.0	4.3	4.3	4.7	4.7	4.3	2.7	4.6
PST-5AP	4.7	4.0	4.3	4.0	4.3	4.3	4.0	4.0	4.0	4.0	3.7	2.3	4.0
PST-5DM	5.7	4.3	5.0	4.3	4.3	4.0	4.3	4.3	4.0	4.7	3.0	2.7	4.2
PST-5EN	6.0	4.0	4.3	3.3	5.0	4.0	4.3	4.0	4.0	3.7	3.0	2.3	4.0
PST-5MW	5.0	3.3	5.0	4.3	3.7	4.0	5.0	4.7	4.0	4.0	3.3	2.3	4.1
PST-5OL	4.3	4.3	6.0	5.3	5.0	5.0	4.7	4.3	4.3	4.7	3.3	2.7	4.5
PST-DBC	5.3	4.3	5.0	5.0	4.7	3.7	4.3	4.0	4.0	4.3	3.7	2.3	4.2
Rebel	4.7	3.7	3.7	4.0	3.3	3.3	3.3	3.3	3.3	3.7	3.7	2.0	3.5
Rebel II	6.0	5.0	4.7	5.0	4.3	4.3	4.3	4.3	4.0	4.3	3.0	2.3	4.3
Richmond	5.0	4.3	5.0	3.3	4.3	4.3	4.3	4.0	4.0	4.0	3.7	2.0	4.0
Shenandoah	4.3	3.3	4.7	5.7	5.0	4.7	4.7	4.3	4.3	4.3	3.7	2.3	4.3
Shortstop	4.0	3.3	3.7	4.3	4.0	5.3	5.0	4.7	4.0	3.7	2.7	2.3	3.9
Silverado	3.7	3.3	3.3	4.0	3.7	4.0	4.0	3.7	3.7	3.7	3.0	2.0	3.5
Sundance	4.3	3.7	4.0	3.0	3.7	3.7	3.7	3.7	3.3	3.3	2.7	2.3	3.4
SynGA	5.0	3.3	4.3	3.7	4.0	3.7	4.0	4.0	4.0	4.3	3.3	2.0	3.8
Taurus	4.0	3.3	4.3	3.7	4.0	4.3	3.7	4.3	4.0	4.0	3.0	2.0	3.7
Thoroughbred	4.7	3.7	4.7	4.0	4.0	4.3	4.0	4.0	4.0	4.0	3.7	2.3	3.9
Tip	6.0	4.7	4.3	3.7	4.3	4.0	4.3	4.0	4.0	4.0	3.3	2.0	4.1
Titan	4.3	3.0	3.7	4.0	4.3	4.3	4.0	4.0	4.0	4.3	3.0	2.3	3.8
Trailblazer	5.3	4.0	4.3	4.7	3.3	5.0	5.0	4.3	4.3	4.3	3.7	2.0	4.2
Tribute	3.7	3.0	4.0	3.3	3.3	3.7	3.7	4.0	3.7	4.0	3.0	2.0	3.4
Trident	6.0	3.7	4.7	4.0	4.7	4.7	4.3	4.0	4.3	4.0	3.3	2.3	4.2
Twilight	4.0	2.3	4.7	4.0	4.0	5.3	4.7	5.0	4.7	4.0	3.0	2.3	4.0
Willamette	4.0	3.0	3.7	3.7	3.7	3.3	3.7	3.7	4.0	3.7	3.0	2.0	3.4
Winchester	4.3	3.7	5.0	4.3	3.7	3.7	4.0	3.7	3.7	3.7	2.7	2.0	3.7
Wrangler	5.0	4.3	5.3	4.0	5.0	4.7	4.0	4.0	4.0	4.7	3.0	2.3	4.2

No significant differences were determined among means on any date or for the overall average.

Table 5. Turf quality in 1990 for 1987 series NTEP tall fescues maintained at 1.5-inch mowing height.

	1990													
Entry	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	PS[1]
Adventure	2.3	1.7	4.0	3.3	3.7	3.7	3.7a	3.7a	3.7a	3.7a	3.7	4.7a	3.5a	6
Amigo	2.3	3.0	4.3	4.3	4.0	4.0	4.0a	4.7a	4.0a	4.7a	4.7	4.7a	4.1a	6
Apache	2.0	1.7	3.3	3.3	3.0	3.3	4.0a	4.3a	4.3a	4.3a	4.3	4.7a	3.6a	6
Arid	2.7	3.0	3.7	3.7	3.7	3.3	4.0a	4.0a	4.0a	4.0a	3.7	4.3	3.7a	5
Avanti	2.3	2.3	4.0	6.0	4.3	4.3	4.7a	4.7a	4.3a	5.3a	5.0	5.7a	4.4a	6
Aztec	2.7	1.7	3.0	4.0	3.7	3.7	4.3a	4.3a	4.7a	4.7a	5.0	4.7a	3.9a	6
Barnone	2.7	3.0	3.7	3.3	3.7	3.7	4.0a	4.3a	4.0a	4.7a	4.7	5.3a	3.9a	6
Bel 86-1	2.7	2.3	4.0	4.3	3.7	3.7	4.0a	4.3a	4.3a	4.7a	3.7	5.3a	3.9a	6
Bel 86-2	2.7	2.3	4.3	3.7	4.3	4.3	4.3a	4.3a	4.0a	4.7a	4.7	5.0a	4.1a	6
Bonanza	2.7	1.7	3.3	4.7	4.3	4.3	4.7a	4.7a	4.3a	4.7a	4.3	5.0a	4.1a	6
Carefree	2.3	1.7	3.0	4.0	3.7	3.7	4.0a	4.0a	4.0a	4.0a	4.0	4.7a	3.6a	6
Chieftain	2.0	1.7	3.7	3.3	3.3	3.7	4.0a	4.0a	4.0a	4.0a	3.7	4.7a	3.5a	6
Cimmaron	3.0	2.3	4.7	4.0	3.3	4.0	4.7a	4.7a	4.3a	4.7a	4.7	4.7a	4.1a	6
Cochise	2.7	2.3	4.0	4.7	4.0	4.0	4.7a	5.0a	4.7a	5.3a	5.0	5.0a	4.3a	6
Crossfire	2.3	2.3	4.0	4.7	4.3	4.3	4.3a	4.0a	4.3a	4.7a	4.7	5.0a	4.1a	6
Eldorado	2.3	1.7	4.3	3.3	4.0	4.0	4.0a	4.0a	3.7a	4.0a	4.0	4.3	3.6a	5
Emperor	2.7	2.3	4.0	3.7	4.0	4.0	4.0a	3.7a	3.7a	4.0a	4.0	4.7a	3.7a	6
Falcon	3.0	1.7	5.3	4.7	4.3	4.7	4.3a	4.0a	3.7a	4.7a	4.7	5.0a	4.2a	6
Fatima	2.3	1.7	3.7	3.7	3.7	3.3	3.7a	3.7a	4.0a	3.7a	4.0	3.7	3.4a	5
Finelawn 5GL	2.3	2.3	4.0	3.7	3.3	3.7	3.7a	3.3a	3.3a	3.3	3.7	4.3	3.4a	4
Finelawn I	2.7	1.0	3.7	4.3	3.3	3.7	3.7a	4.0a	4.0a	3.7a	3.7	4.3	3.5a	5
Guardian	2.7	3.0	5.3	5.3	5.0	5.3	4.7a	4.7a	4.0a	4.7a	4.7	5.0a	4.5a	6
Hubbard 87	2.3	3.0	4.7	4.3	4.3	4.7	4.3a	4.3a	4.0a	4.7a	5.0	5.7a	4.3a	6
Jaguar	3.0	2.3	4.7	4.0	4.3	4.3	4.3a	4.3a	4.0a	5.0a	5.0	5.0a	4.2a	6
Jaguar II	3.0	2.3	3.0	4.3	4.3	4.0	4.3a	3.7a	3.7a	4.0a	4.0	5.0a	3.8a	6
JB-2	2.3	1.7	4.0	5.0	3.7	3.7	4.0a	4.7a	4.3a	4.7a	4.3	4.7a	3.9a	6
KWS-DUR	2.7	2.3	4.0	3.7	4.3	4.0	4.3a	4.7a	4.3a	4.7a	4.3	5.0a	4.0a	6
KY-31	2.0	2.3	3.0	3.3	3.0	3.0	3.0	3.0	3.0	3.0	3.3	2.3	2.8	—
Legend	2.7	2.3	3.7	4.0	4.0	4.0	4.3a	4.3a	4.3a	4.3a	4.3	5.0a	3.9a	6
Maverick II	2.7	2.3	4.3	4.3	4.7	4.7	4.3a	4.7a	4.3a	4.7a	5.0	4.7a	4.2a	6
Mesa	2.7	3.0	4.7	4.3	4.0	4.0	4.7a	4.3a	4.0a	4.3a	4.3	4.7a	4.1a	6
Monarch	2.3	2.3	3.3	4.3	3.7	3.3	3.7a	4.0a	4.0a	4.3a	4.3	5.0a	3.7a	6
Murietta	2.0	1.7	3.3	3.3	3.0	3.3	3.3a	4.0a	4.3a	3.7a	3.3	3.7	3.3a	5
Normarc 25	3.0	1.7	3.7	3.7	4.0	4.0	4.0a	4.7a	4.7a	4.7a	4.3	5.0a	3.9a	6
Normarc 77	2.7	1.7	3.7	5.0	4.3	4.3	4.3a	4.7a	4.3a	4.7a	4.7	5.0a	4.1a	6
Normarc 99	2.7	3.0	4.7	5.0	4.7	4.7	4.7a	4.3a	4.0a	4.3a	4.3	4.7a	4.3a	6
Olympic	2.7	1.0	3.7	3.7	4.0	4.0	4.3a	4.3a	4.0a	4.3a	4.3	5.0a	3.8a	6
Pacer	2.3	2.3	4.3	3.7	3.3	3.7	3.7a	4.0a	4.0a	4.0a	4.0	4.7a	3.7a	6
PE-7	2.0	1.0	3.7	4.0	3.3	3.3	4.0a	4.0a	4.3a	4.0a	3.7	5.0a	3.5a	6
PST-5AG	3.3	2.3	5.7	5.3	4.7	5.3	5.0a	4.7a	4.3a	4.7a	5.0	5.0a	4.6a	6
PST-5AP	2.7	2.3	4.7	5.0	4.0	4.0	4.0a	4.0a	4.0a	4.0a	3.3	4.3	3.8a	5
PST-5DM	2.7	1.7	3.0	4.0	3.7	3.3	3.7a	4.0a	4.0a	4.0a	4.0	5.0a	3.6a	6
PST-5EN	2.3	2.3	3.3	3.0	3.7	3.7	3.7a	4.0a	4.3a	4.0a	4.0	4.3	3.6a	5
PST-5MW	2.3	1.7	4.0	4.0	3.7	3.7	3.7a	4.7a	4.3a	5.0a	5.0	5.7a	3.9a	6
PST-5OL	2.7	1.7	4.7	4.7	4.0	4.3	5.0a	5.0a	4.7a	5.0a	5.0	5.0a	4.3a	6
PST-DBC	2.3	3.0	4.3	3.7	3.3	3.7	3.7a	4.3a	4.3a	4.3a	4.0	4.3	3.8a	5
Rebel	2.3	3.0	3.7	3.7	3.7	3.3	4.0a	4.3a	4.0a	3.7a	3.7	4.3	3.6a	5
Rebel II	2.3	1.7	5.3	4.0	3.7	4.3	4.0a	4.3a	4.3a	4.3a	4.0	4.7a	3.9a	6
Richmond	2.0	1.7	4.0	3.3	4.3	4.3	4.7a	4.7a	4.3a	4.7a	4.7	5.0a	3.9a	6
Shenandoah	2.7	3.0	5.0	4.3	3.7	4.0	4.0a	4.3a	4.0a	4.3a	4.3	5.0a	4.1a	6
Shortstop	2.3	1.7	3.7	3.7	4.0	4.0	4.0a	4.0a	4.0a	4.0a	4.0	5.0a	3.7a	6
Silverado	2.3	2.3	3.0	3.7	3.3	3.0	4.0a	4.3a	4.3a	4.3a	4.3	4.7a	3.6a	6
Sundance	2.3	2.3	4.3	4.0	3.3	3.7	4.0a	4.0a	4.3a	4.0a	4.0	4.3	3.7a	5
SynGA	2.3	3.0	4.0	3.3	3.3	3.3	3.7a	4.0a	4.0a	4.0a	4.0	4.3	3.6a	5
Taurus	2.0	1.7	4.3	3.7	4.0	4.0	4.0a	4.0a	4.3a	4.3a	4.3	4.7a	3.8a	6
Thoroughbred	2.7	2.3	3.7	3.3	4.0	4.0	3.7a	4.3a	4.3a	4.3a	4.3	5.0a	3.8a	6
Tip	3.0	1.7	4.0	4.3	4.3	4.3	4.0a	4.0a	4.0a	4.3a	4.3	5.0a	3.9a	6
Titan	3.0	1.7	4.3	4.7	4.7	4.3	4.7a	4.3a	4.0a	4.3a	4.3	4.7a	4.1a	6
Trailblazer	2.7	2.3	4.7	5.3	5.0	5.0	5.0a	4.7a	4.7a	4.7a	4.7	4.7a	4.4a	6
Tribute	2.0	3.0	3.3	4.0	3.7	3.3	4.0a	4.0a	4.3a	4.3a	4.7	5.0a	3.8a	6
Trident	2.3	1.7	3.0	3.3	3.7	3.7	4.0a	4.0a	4.0a	4.0a	4.0	4.7a	3.5a	6
Twilight	2.3	1.0	3.0	3.7	4.0	3.7	4.0a	4.0a	4.3a	4.3a	3.7	5.3a	3.6a	6
Willamette	2.3	3.0	3.7	3.7	3.0	3.3	3.7a	3.7a	3.7a	4.0a	4.0	4.3	3.5a	5
Winchester	2.3	2.3	4.0	4.3	3.3	3.3	4.0a	4.0a	4.3a	4.3a	4.3	4.7a	3.8a	6
Wrangler	2.3	1.7	4.3	5.0	3.7	3.7	4.0a	4.3a	4.3a	4.0a	4.0	5.0a	3.9a	6
MSD[2]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	1.9	1.9	1.6	1.7	n.s.	1.2	1.4	—

[1] PS is the phenotypic stability indicating superior adaptability to test conditions.
[2] MSD is the Minimum Significant Difference for comparison of means within dates based on the Waller-Duncan k-ratio t Test (k-ratio = 100). 'n.s.' indicates means were not significantly different.

Table 6. Turf quality in 1991 of 1987 series NTEP tall fescues maintained at 1.5-inch mowing height.

Entry	1991 Feb	Mar	May	Jun	Avg	PS[1]
Adventure	2.0	3.0a	6.0	6.3	4.3	1
Amigo	2.3	3.7a	7.0	6.7	4.9a	2
Apache	2.3	3.7a	6.7	7.0	4.7a	2
Arid	2.7	3.3a	6.3	6.7	4.8a	2
Avanti	2.3	3.3a	6.7	7.0	4.8a	2
Aztec	2.3	4.0a	6.7	7.0	5.0a	2
Barnone	2.3	3.3a	6.7	7.0	4.8a	2
Bel 86-1	2.3	3.3a	6.3	6.7	4.7a	2
Bel 86-2	2.3	3.7a	6.7	7.3	5.0	1
Bonanza	2.0	3.7a	6.7	7.0	4.8a	2
Carefree	2.0	3.0a	6.0	6.7	4.4	1
Chieftain	2.0	2.7	6.3	6.7	4.4	—
Cimmaron	3.0	3.7a	6.0	6.3	4.8a	2
Cochise	2.0	3.7a	6.3	7.3	4.8a	2
Crossfire	2.3	3.0a	6.7	6.7	4.7a	2
Eldorado	2.3	3.0a	6.0	7.0	4.6	1
Emperor	2.0	3.0a	6.0	7.0	4.5	1
Falcon	2.0	3.3a	6.3	7.0	4.7a	2
Fatima	2.0	3.0a	6.0	6.3	4.3	1
Finelawn 5GL	2.3	2.7	6.0	6.7	4.4	—
Finelawn I	2.0	2.7	6.0	6.3	4.3	—
Guardian	2.3	4.3a	6.7	7.0	5.1a	2
Hubbard 87	2.3	4.0a	6.7	6.7	4.9a	2
Jaguar	2.0	3.0a	6.7	7.0	4.7a	2
Jaguar II	2.3	2.7	6.0	7.0	4.5	—
JB-2	2.3	3.0a	5.7	6.3	4.3	—
KWS-DUR	2.0	3.0a	6.3	7.0	4.6	—
KY-31	2.0	2.0	6.0	6.3	4.1	—
Legend	2.7	3.7a	6.3	7.0	4.9a	2
Maverick II	1.7	3.0a	6.3	7.0	4.5	1
Mesa	2.3	4.3a	6.7	6.7	5.0a	2
Monarch	2.0	3.3a	6.3	7.3	4.8a	2
Murietta	2.0	3.3a	6.0	6.7	4.5	1
Normarc 25	2.3	3.3a	6.3	7.0	4.8a	2
Normarc 77	2.0	3.0a	6.7	7.0	4.7a	2
Normarc 99	2.0	3.0a	6.7	7.0	4.7a	2
Olympic	2.0	3.0a	6.7	7.0	4.7a	2
Pacer	2.3	3.3a	6.7	6.3	4.7a	2
PE-7	2.0	3.0a	6.7	7.3	4.8a	2
PST-5AG	3.0	4.3a	6.3	6.7	5.1a	2
PST-5AP	2.3	2.7	5.7	6.3	4.3	—
PST-5DM	2.0	3.0a	6.3	7.0	4.6	1
PST-5EN	2.0	2.7	6.3	6.7	4.4	—
PST-5MW	2.7	3.7a	6.3	7.3	5.0a	2
PST-5OL	2.7	4.0a	6.3	7.0	5.0a	2
PST-DBC	2.0	3.0a	6.0	7.0	4.5	1
Rebel	2.7	3.3a	6.3	6.7	4.8a	2
Rebel II	2.3	3.3a	6.3	7.0	4.8a	2
Richmond	2.0	3.3a	7.0	7.0	4.8a	2
Shenandoah	2.3	3.0a	6.3	7.0	4.7a	2
Shortstop	2.0	3.0a	6.3	7.0	4.6	1
Silverado	2.3	3.0a	6.3	7.0	4.7a	2
Sundance	2.0	2.3	6.0	7.0	4.3	—
SynGA	2.0	3.0a	6.7	6.7	4.6	1
Taurus	2.0	3.0a	6.3	6.7	4.5	1
Thoroughbred	2.0	3.3a	6.7	7.0	4.8a	2
Tip	2.0	2.7	6.0	7.0	4.4	—
Titan	2.0	3.3a	6.0	7.3	4.7a	1
Trailblazer	2.7	3.7a	7.0	7.3	5.2a	2
Tribute	3.0	3.3a	6.3	7.0	4.9a	2
Trident	2.0	2.7	6.0	6.7	4.3	—
Twilight	2.0	2.7	6.0	6.7	4.3	—
Willamette	2.0	2.7	6.0	6.7	4.3	—
Winchester	2.0	3.7a	6.3	7.0	4.8a	2
Wrangler	2.0	3.0a	6.3	6.3	4.4	1
MSD[2]	n.s.	1.4	n.s.	n.s.	0.5	—

[1] PS is the phenotypic stability indicating superior adaptability to test conditions.
[2] MSD is the Minimum Significant Difference forcomparison of means within dates based on theWaller-Duncan k-ratio t Test (k-ratio = 100). 'n.s.' indicates means were not significantly different.

Table 7. Phenotypic stability for 1987 series NTEP tall fescue trials in Dallas, Texas.

	2.5-inch mow			1.5-inch mow			2.5
Entry	1989 PS	1990 PS	1991 PS	1989 PS	1990 PS	1991 PS	Year Cum
Adventure	10	7	1	—	6	1	25
Amigo	10	7	2	—	6	2	27
Apache	10	7	1	—	6	2	26
Arid	9	8	2	—	5	2	26
Avanti	10	7	2	—	6	2	27
Aztec	10	7	2	—	6	2	27
Barnone	9	7	1	—	6	2	25
Bel 86-1	6	6	1	—	6	2	21
Bel 86-2	10	7	2	—	6	1	26
Bonanza	10	7	2	—	6	2	27
Carefree	9	6	1	—	6	1	23
Chieftain	9	7	2	—	6	—	24
Cimmaron	10	6	2	—	6	2	26
Cochise	9	7	2	—	6	2	26
Crossfire	10	7	2	—	6	2	27
Eldorado	9	7	2	—	5	1	24
Emperor	8	7	1	—	6	1	23
Falcon	10	7	2	—	6	2	27
Fatima	7	6	1	—	5	1	20
Finelawn 5GL	8	7	1	—	4	—	20
Finelawn I	9	7	1	—	5	—	22
Guardian	10	7	—	—	6	2	25
Hubbard 87	10	7	2	—	6	2	27
Jaguar	10	6	1	—	6	2	26
Jaguar II	10	7	1	—	6	—	24
JB-2	9	7	1	—	6	1	24
KWS-DUR	7	7	2	—	6	1	23
KY-31	4	7	1	—	—	—	12
Legend	8	7	1	—	6	2	24
Maverick II	9	7	2	—	6	1	25
Mesa	10	5	—	—	6	2	23
Monarch	9	7	1	—	6	2	25
Murietta	6	7	1	—	5	1	20
Normarc 25	10	7	2	—	6	2	27
Normarc 77	9	7	1	—	6	2	25
Normarc 99	9	7	1	—	6	2	25
Olympic	10	7	1	—	6	2	26
Pacer	9	8	—	—	6	2	25
PE-7	10	7	2	—	6	2	27
PST-5AG	10	7	2	—	6	2	27
PST-5AP	10	7	2	—	5	—	24
PST-5DM	9	7	1	—	6	—	23
PST-5EN	9	7	1	—	5	—	22
PST-5MW	7	7	2	—	6	2	24
PST-5OL	10	7	2	—	6	2	27
PST-DBC	9	8	2	—	5	1	25
Rebel	10	7	2	—	5	2	26
Rebel II	10	7	1	—	6	2	26
Richmond	7	5	1	—	6	2	21
Shenandoah	7	8	2	—	6	2	25
Shortstop	8	7	1	—	6	1	23
Silverado	7	7	2	—	6	2	24
Sundance	10	7	2	—	5	—	24
SynGA	10	7	1	—	5	1	24
Taurus	10	7	1	—	6	1	25
Thoroughbred	8	7	1	—	6	2	24
Tip	9	6	1	—	6	—	22
Titan	6	7	—	—	6	1	20
Trailblazer	10	7	2	—	6	2	27
Tribute	10	8	2	—	6	2	28
Trident	10	7	1	—	6	—	24
Twilight	10	7	1	—	6	—	24
Willamette	10	7	1	—	5	—	23
Winchester	8	8	1	—	6	2	25
Wrangler	7	7	2	—	6	1	23

Table 8. Greenbug infestation on 1987 tall fescue National Turfgrass Evaluation Program (NTEP) trials planted in Dallas, Texas compared with endophyte levels reported by researchers at Rutgers University. Damage is rated on a scale of 1 to 9, of which 9 indicates the most damage.

	Greenbug Damage		
Entry	1.5-inch Mowing	2.5-inch Mowing	Percent Endophyte
Adventure	6.3	5.7	0
Amigo	4.7	4.3	16
Apache	5.0	4.3	18
Arid	5.3	2.7	48
Avanti	6.0	5.0	0
Aztec	5.3	7.0	0
Barnone	5.7	6.0	8
Bel 86-1	4.7	7.7	0
Bel 86-2	5.3	3.3	70
Bonanza	7.0	6.0	12
Carefree	6.7	6.3	0
Chieftain	6.3	8.0	6
Cimmaron	6.0	8.7	0
Cochise	6.3	5.3	16
Crossfire	6.0	7.0	12
Eldorado	6.3	7.0	0
Emperor	6.0	5.0	0
Falcon	6.7	8.7	0
Fatima	6.3	6.0	26
Finelawn 5GL	4.3	6.0	2
Finelawn I	6.7	6.0	16
Guardian	5.3	4.7	56
Hubbard 87	4.0	7.7	4
Jaguar	6.0	6.0	0
Jaguar II	6.0	5.0	0
JB-2	6.3	9.0	0
KWS-DUR	6.0	5.7	32
KY-31	5.0	2.3	0
Legend	5.0	6.3	0
Maverick II	5.0	7.3	0
Mesa	4.3	4.0	70
Monarch	5.7	5.3	0
Murietta	5.7	5.3	14
Normarc 25	6.0	7.7	20
Normarc 77	6.3	6.0	0
Normarc 99	5.7	3.0	42
Olympic	6.0	5.7	0
Pacer	5.3	4.0	0
PE-7	6.7	8.3	4
PST-5AP	5.7	3.3	18
PST-5DM	6.3	3.7	4
PST-DBC	4.7	3.7	88
PST-5OL	6.0	4.0	20
PST-5AG	5.3	4.0	12
PST-5MW	5.7	7.0	8
PST-5EN	6.0	7.7	24
Rebel	4.3	5.7	0
Rebel II	6.3	7.0	28
Richmond	5.3	7.0	0
Shenendoah	5.7	1.7	86
Shortstop	6.3	5.0	28
Silverado	5.7	7.7	0
Sundance	6.0	8.3	14
SynGA	5.0	6.3	50
Taurus	6.0	4.7	18
Thoroughbred	5.0	6.3	14
Tip	7.0	6.7	0
Titan	5.0	7.3	98
Trailblazer	5.7	7.0	0
Tribute	3.7	2.7	58
Trident	5.7	5.7	28
Twilight	7.0	8.0	0
Willamette	4.7	4.7	0
Winchester	5.7	2.0	24
Wrangler	6.0	7.0	0
MSD[1]	4.0	4.3	

[1]MSD is the Minimum Significant Difference for comparison of means within each column based on the Waller-Duncan k-ratio t Test (k-ratio = 100).

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Performance of St. Augustinegrass Varieties in the 1989 National Turf Evaluation Program (NTEP) at TAES-Dallas

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Introduction

St.Augustinegrass (*Stenotaphrum secundatum* Walt. Kuntze) is a warm-season, broad-leafed turfgrass species which is second in popularity only to bermudagrass for southern lawns. Generally, St. Augustinegrass has poor winter hardiness. Dallas, Texas is near the northern edge of its range of adaptation. The grasses greatest strength lies in its shade tolerance and excellent heat tolerance. Thus, there is an interest in developing and identifying St. Augustinegrass varieties which are able to tolerate the climatic extremes of this region.

The National Turf Evaluation Program (NTEP) established a St. Augustinegrass trial in 1989. Planting stock of commercial and experimental varieties was assembled at a common location in early 1989 for vegetative increase, and further distributed for field planting in August 1989. The trial involves 24 entries which includes nine commercially available cultivars and 15 experimental varieties. These trials provide information on adaptation and potential utility of the species as well as cultivars that are best adapted for regional use. Emphasis is placed on cold hardiness and general turf performance. Similar trials have been planted at approximately 20 other locations throughout the Southern United States.

Materials and Methods

Planting stock of 24 commercial and experimental varieties of St. Augustinegrass was received in early August 1989 and vegetatively established in a randomized complete block design with three replications. The soil site was tilled to a depth of 15 cm, leveled, and fertilized with a 13-13-13 starter fertilizer at the time of planting. Only moderate plant development and spread occurred prior to winter dormancy. The late planting in 1989 was poorly established, and consequently, none of the entries survived the winter. Additional material was propagated in the greenhouse at TAES-Dallas during the winter and the trials were reestablished in early July 1990.

Twelve 3-inch plugs were planted to each 3.2m x 2.4m plot on 0.8m centers. The field was maintained at a 2-inch mowing height and nitrogen was applied at a rate of 3 lbs./1000 sq ft/year, as six 0.5 lb. N applications. Notes were made of establishment, fall and winter color, winter color retention, and spring greenup.

Results

Fall color retention is highly desirable in a warm-season grass to maintain green active turf as long as possible. Seven experimental lines (M-1, three of the S-series, and the three MSA lines, Table 1), retained significantly greater percent green than other lines tested on December 19, 1990. 'Mercedes' was the greenest of the commercial cultivars. 'Floralawn' and 'Floratam' had less than 50 percent green cover, as did the excellent spring performer, FX-332 (Table 1). Full winter dormancy was not evident in any of the entries until about January 9, 1991, at which time all entries were dormant, in the course of several events of sub-freezing temperatures.

The first indications of spring greening were observed on 19 February 1991 (day = 50) with Floratam and FX-332. Greenup is defined as the appearance of new green leaves (Table 2). FX-332 was the first entry to exhibit greater than 75 percent green cover, and was one of the earliest to greenup (day 50). 'Raleigh', MSA-2, MSA-11, MSA-20, S71-2090, and DALSA 8401 exhibited both early greenup and rapid coverage. 'Delmar' was relatively early to greenup, but has been slow to cover, exhibiting only 13 percent coverage by June 5. Similarly, Floratam, with an early greenup date of 19 February exhibited only 37 percent green cover by June 5. Floratam is considered too winter tender for use in the Dallas area.

Table 1. Fall establishment and winter color retention of the 24 St. Augustinegrass varieties in the NTEP planted July 10, 1990, at TAES-Dallas.

Entry	Nov. 20	Dec. 12	Textural Class
	% Coverage		
DALSA8401	80.0a	66.7	Medium
FX-10	90.0a	66.7	Coarse
FX-261	91.7a	60.0	Fine
FX-313	92.7a	53.3	Fine
FX-33	93.7a	53.3	Med. Coarse
FX-332	90.7a	41.7	Med. Coarse
M1	80.0a	83.3a	Medium
MSA-2	83.3a	78.3a	Medium
MSA-11	83.3a	78.3a	Medium
MSA-20	85.0a	76.7a	Medium
S-6-71-138	85.0a	75.0a	Medium
S-6-72-107	78.3a	63.3	Med. Fine
S-71-2090	83.3a	75.0a	Medium
S-71-770	85.0a	81.7a	Medium
TR6-10	80.0a	65.0	Fine
TR6-3	78.3a	56.7	Med. Fine
Bitterblue	81.7a	51.7	Coarse
Delmar	81.7a	70.0a	Medium
Floralawn	92.7a	35.0	Coarse
Floratam	91.7a	36.7	Coarse
Jade	86.7a	76.7a	Med. Fine
Mercedes	92.7a	80.0a	Medium
Raleigh	81.7a	68.3	Med. Coarse
Seville	83.3a	63.3a	Med. Fine
Sunclipse	85.0a	70.0a	Fine
MSD[1]	16.7	15.9	

[1]MSD = Minimum Significant Difference for comparison of means within columns based on Waller-Duncan k-ratio t test (k-ratio = 100).

Floratam's early spring greening may result in repeated damage from late spring frosts. Several of the experimentals demonstrating the early spring greening also may be subjected to spring frost damage. Additional testing and evaluation will be required to substantiate their value in the Dallas area. Jade, FX-313, Sunclipse, and TR6-3 were among the last to greenup and were also slow in plot coverage (Table 2).

The highest quality St. Augustinegrasses with respect to early greenup and fastest spring growth were FX-332, MSA-20, MSA-2, MSA-11, and S71-2090. Of the commercial cultivars tested, Raleigh grew the most vigorously in the spring, while the poorest spring growth was evidenced by Jade and Sunclipse.

Generally, fine-textured entries had the latest greenup dates and the slowest plot coverage, while the medium-coarse textured types, such as FX-332, had the earliest greenup dates and the fastest plot coverage (Table 1 and Table 3). Entries of each textural class are found at all ranges of the spectrum of greenup qualities.

Summary

Considerable variability exists among the St. Augustinegrass cultivars and experimental varieties in the NTEP test. The performance of most varieties is marginal to poor in Dallas, Texas where temperature and moisture extremes are experienced annually. Experimental lines DALSA8401, FX-332, MSA-2, and S71-2090 were comparable in performance to Raleigh, all earning a Phenotypic Stability (PS) rating of 8 (Table 2). Mercedes, FX-33, and MSA-20 were intermediate in performance (PS 4-6). Seville, Floratam, Jade, Sunclipse, and Delmar were relatively poor (PS 0-2) in their performance this first year. Additional testing is essential before any definitive conclusions can be drawn.

Table 2. Spring greenup and rate of establishment of 24 St. Augustinegrass varieties planted July 10, 1990, at TAES-Dallas.

Entry	GNUP[1]	Percent Plot Green Cover									PS[2]
		2/12	2/26	3/12	3/28	4/5	4/17	5/1	5/15	6/5	
DALSA8401	63a	0.3	2.3a	4.0a	10.7a	12.7a	9.3a	18.7a	22.0a	50.3a	8
FX-10	65a	0.0	0.7	0.7	1.7	1.7	1.7	1.7	2.3	9.3	0
FX-261	60a	0.3	0.7	1.7	5.0	6.0	7.0	7.0	8.7	29.3	0
FX-313	91	0.0	0.0	0.3	0.7	1.3	1.7	1.7	2.0	3.0	0
FX-33	57a	0.0	1.0a	2.3a	5.3	6.0	15.0a	11.7a	17.7a	41.7	5
FX-332	50a	0.0	1.7a	3.3a	9.3a	15.0a	18.3a	21.7a	35.0a	76.7a	8
M1	72	0.3	0.7	1.3	3.0	3.0	3.0	4.0	4.0	15.3	0
MSA-2	52a	0.7	2.0a	4.3a	9.7a	14.0a	15.7a	18.3a	25.0a	56.7a	8
MSA-11	60a	0.3	1.7a	4.7a	10.3a	13.7a	19.3a	20.3a	24.3a	46.7a	8
MSA-20	58a	0.7	3.3a	6.0a	12.0a	14.0a	22.3a	23.3a	29.0a	57.7a	8
S6-71-138	62a	0.0	1.3a	2.7a	6.0	8.3	10.0a	11.7a	15.3	41.0	4
S6-72-107	69	0.0	0.3	1.3	3.3	4.0	4.0	5.7	8.3	21.0	0
S71-2090	55a	0.3	2.7a	5.0a	14.3a	15.7a	20.0a	21.0a	25.0a	51.7a	8
S71-770	72	0.3	1.0a	2.0	5.3	7.0	9.3a	11.7a	13.3	30.0	3
TR6-10	102	0.0	0.0	1.3	1.3	1.3	3.0	4.0	4.0	9.0	0
TR6-3	109	0.0	0.0	0.3	1.7	2.7	2.7	3.7	4.3	15.0	0
Bitterblue	71	0.3	1.7a	3.3a	5.7	5.7	7.3	8.7a	10.3	27.0	3
Delmar	59a	0.0	1.3a	2.3a	4.3	4.3	4.7	4.7	5.3	12.7	2
Floralawn	53a	0.3	0.7	2.0	5.3	5.3	6.0	8.7a	10.3	31.0	1
Floratam	50a	0.0	1.0a	2.3a	6.0	6.3	7.7	7.7	11.0	36.7	2
Jade	103	0.0	0.0	0.0	0.0	0.3	1.0	1.0	1.3	1.7	0
Mercedes	62a	0.0	1.0a	3.0a	9.0a	9.0a	11.3a	12.0a	15.7	41.0	6
Raleigh	55a	0.3	2.0a	5.0a	9.3a	12.3a	18.0a	20.3a	25.6a	60.0a	8
Seville	58a	0.0	0.7	1.7	3.0	3.3	4.7	5.0	9.7	36.7	0
Sunclipse	102	0.3	0.0	0.7	2.7	2.7	2.7	2.7	2.7	6.7	0
MSD[3]	43	n.s.	2.3	3.8	7.1	7.3	13.7	13.7	18.6	31.7	

[1] GNUP = Julian date of greenup in the spring, (i.e., April 1 = 91 days).
[2] PS = Phenotypic Stability, the number of times an entry was in the highest rating group for plot green cover.
[3] MSD = Minimum Significant Difference for comparison of means within columns based on Waller-Duncan k-ratio t test (k-ratio = 100).

Table 3. Spring greenup and rate of establishment of 24 St. Augustinegrass varieties planted July 10, 1990, at TAES-Dallas and classified according to textural type.

Entry	Percent Plot Green Cover-1991									GNUP[1]
	2/19	2/26	3/12	3/28	4/5	4/17	5/1	5/15	6/5	
Coarse	0.7a	1.0a	2.1a	4.7	4.8	5.7	5.7	8.5	26.0	60
Med.coarse	1.1a	1.6a	3.6a	8.0a	11.1a	17.1a	17.1a	26.1a	59.4a	54
Medium	1.1a	1.7a	3.5a	8.5a	10.2a	12.5a	12.5a	17.9	40.3	61
Med.fine	0.0	0.3	0.8	2.0	2.6	3.1	3.1	5.9	18.6	84
Fine	0.2	0.2	1.0	2.4	2.8	3.6	3.6	4.3	12.0	89
MSD[2]	0.6	0.8	1.5	3.1	3.6	5.6	5.6	7.9	15.4	17

[1] GNUP = Julian date of greenup in the spring,(i.e., April 1 = 91 days).

1991 Update to the Buffalograss Regional Trial Planted at TAES-Dallas

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

Introduction

Buffalograss (*Buchloe dactyloides* (Nutt.) Engelm) is a low-growing, stoloniferous, warm-season perennial, native to the short-grass prairies of the Great Plains in west-central United States. It is used primarily as a forage grass, but also offers potential as a low-maintenance turf. Until recently, no varieties of buffalograss were developed specifically for turfgrass uses. The purpose of the TAES-Dallas Buffalograss Regional Trial is to evaluate turf performance of both experimental and commercial varieties.

Materials and Methods

The buffalograss regional trial includes five female experimental Nebraska lines and two cultivars. The cultivars include a seeded variety, Texoka, and Prairie, a female cultivar released by TAES in September 1989.

The trial was planted at TAES-Dallas on May 17, 1988. Each entry was established vegetatively from eight 4- x 4-inch plugs planted into each of three 10- x 10-foot plots. Three replicates were arranged in a randomized complete block design. Fertilizer (34-0-0) is applied each spring and fall at the rate of 1 lb N per 1000 square feet at each application. This study is infrequently (3-5 times per year) mowed to a height of 2.5 inches with clippings removed. Plots are not irrigated, and are generally maintained as low maintenance turf.

Results and Discussion

Buffalograss is considered to be an excellent candi-

Table 1. Seasonal turf quality and Phenotypic Stability (PS) of two Commercial and five experimental buffalograsses planted at TAES-Dallas in May 1988. Quality is rated on a scale of 0 to 9, where 9 is best. PS is the number of times an entry was in the highest rating group on each date.

	1989									
Entry	08 Apr	06 May	27 May	20 Jun	10 Aug	13 Sep	21 Sep	31 Oct	23 Nov	89 PS
Prairie	6.0a[1]	7.3a	7.0a	8.0a	7.7a	7.3a	7.7a	8.3a	8.3a	9
Texoka	4.7	6.0a	6.3	6.0	6.3	4.0	4.7	4.0	4.7	1
84-609	6.3a	7.3a	8.0a	7.3a	9.0a	7.7a	8.7a	9.0a	8.7a	9
84-409	4.0	7.0a	4.7	5.7	6.0	5.7	5.0	5.3	4.3	1
84-304	8.0a	7.0a	7.3a	7.0a	7.7a	6.3	8.0a	6.7	6.7	6
84-315	6.0a	7.3a	6.0	5.7	6.3	3.3	3.7	3.3	3.3	2
85-378	5.3	7.7a	7.3a	7.0a	7.0	4.0	4.7	5.0	4.3	3
MSD[1]	2.4	n.s.	1.6	1.5	1.8	0.9	1.0	1.7	1.3	

	1990												
Entry	04 Jan	24 Jan	25 Feb	03 Apr	22 Apr	29 May	24 Jun	29 Jul	24 Sep	31 Oct	25 Nov	20 Dec	90 PS
Prairie	7.0a	6.0a	5.7a	6.0a	5.1a	6.8a	6.6a	6.1a	4.8a	4.5a	4.8a	3.8a	12
Texoka	4.3	4.0	3.7	3.7	4.0	4.3	4.0	3.1	3.0	2.3	2.7	2.1	0
84-609	7.0a	6.0a	5.7a	5.7a	4.6a	6.9a	6.9a	5.7a	5.2a	5.1a	4.5a	3.9a	12
84-409	4.0	4.3	2.7	3.7	4.2	4.2	4.3	3.8	4.6a	2.5	2.2	2.0	1
84-304	6.3a	6.0a	5.3a	2.7	3.3	6.5a	6.2	5.4a	4.1	4.3	4.5a	3.9a	7
84-315	3.3	3.0	3.0	5.8a	4.9a	6.8a	5.4	3.5	2.9	2.3	2.9	2.5	3
85-378	4.3	4.3	3.3	4.5	4.5a	6.6a	5.7	4.1	2.9	2.2	3.1	2.8	2
MSD	1.0	0.5	1.0	1.1	0.8	0.7	0.6	0.8	0.8	0.7	0.5	0.3	

	1991						
Entry	24 Feb	24 Mar	25 Apr	28 May	18 Jun	91 PS	Cumulative PS 89-91
Prairie	2.0a	5.6a	5.3	6.7a	5.9a	4	25
Texoka	1.7a	3.4	4.7	7.0a	5.6	2	3
84-609	2.0a	5.1	5.0	7.3a	5.8a	3	24
84-409	1.0	3.5	5.7	7.0a	5.3	1	3
84-304	2.7a	6.3a	7.0a	7.7a	6.4a	5	18
84-315	2.0a	2.5	5.3	7.0a	6.3a	3	8
85-378	2.0a	3.7	4.7	7.3a	6.0a	3	8
MSD	1.1	0.8	1.2	n.s.	0.8		

[1] MSD = Minimum Significant Difference for comparison of means within columns based on Waller-Duncan k-ratio t test (k-ratio = 100), where a's indicate the highest statistical group for computing PS.

date for a low maintenance turf as it is native to the Great Plains region of North America. As such, these trials were established with minimal irrigation (1988), and have received no supplemental irrigation since. Data are presented on the performance of the cultivars and varieties on turf quality (1989-1991) in Table 1. The seasonal performance of the varieties indicates considerable genetic variability among varieties, and that selected varieties consistently provided acceptable quality turf. For ease of summarization, the data is further compiled on the basis of comparative performance using a statistic referred to as Phenotypic Stability (PS). Phenotypic Stability is the frequency which an entry is within the most desirable statistical group. As an example, in 1989, a total of nine agronomic observations were made. During 1989 only Prairie and NE84-609 rated in the significantly highest group all nine times, in 1990 they rated 12 for 12. Since establishment, Prairie and NE84-609 have consistently out performed all other entries within the trial with PS ratings of 25 and 24 respectively for the 26 observations taken (Table 1). The next highest performer is NE84-304, at a distant third with a PS rating of 18 (Table 1).

Canopy temperatures (Table 2) and net radiation (NRAD) (Table 3) measurements varied among genotypes. NE84-315 and NE85-378 consistently had the highest canopy temperatures. NE84-315 averaged 3°C higher than NE84-609 (Oasis), with individual varietal differences as much as 4.7°C on 3 July 1990. More heat can be dissipated through selection of "cooler" varieties. Prairie, Oasis (NE84-609), NE84-409, and NE84-304 rated among the coolest, with NE84-315 and NE85-378 being the warmest in this trial during this time period.

Net radiation data is presented for interpretation in conjunction with canopy temperature. Significant differences exist among varieties on many dates, however, overall there were no significant differences noted. A striking observation should be noted relative to NE84-315. On any given day when differences were noted, NE84-315 was always the lowest in NRAD reading (Table 3) and it was always the highest for canopy temperature (Table 2).

Table 2. Canopy temperatures (°C)of buffalograsses in the Dallas regional trial. Measurements were recorded during summer 1990.

Entry	13 Jun	21 Jun	29 Jun	03 Jul	27 Jul	29 Aug	05 Sep	Mean	PS
				Temperature (°C)					
Prairie	36.7a	38.9a	40.4a	45.0a	45.8a	47.7a	51.4a	43.7	7
Texoka	38.0a	39.9a	40.4a	46.3	45.4a	46.6a	52.9	44.2	5
84-609	36.2a	39.4a	39.8a	43.2a	43.8a	47.4a	50.8a	42.9	7
84-409	37.2a	40.5a	41.2a	44.0a	45.4a	47.8a	52.0a	44.0	7
84-304	36.4a	39.9a	40.4a	44.0a	44.9a	47.2a	51.2a	43.4	7
84-315	36.8a	42.7	42.8a	47.9	47.6	49.4a	54.9	46.0	3
85-378	39.6a	41.7	42.1a	46.9	46.4	49.1a	54.5	45.7	3
MSD[1]	n.s.	1.9	n.s.	2.6	2.2	n.s.	1.9	0.7	
Avg temp	37.3	40.4	41.0	45.3	45.6	47.9	52.5	(MSD = 0.7)	

[1] MSD = Minimum Significant Difference for comparison of means within columns based on Waller-Duncan k-ratio t test (k-ratio = 100).

Table 3. Net Radiation (NRAD) readings for the buffalograss regional trial by varietal entry during the summer of 1990. Dates correspond to the simultaneous canopy temperatures in previous table.

Entry	13 Jun	21 Jun	29 Jun	03 Jul	27 Jul	29 Aug	05 Sep	Mean
				Net Radiation				
Prairie	533.0	641.3	605.7	577.7a	585.3a	409.0a	439.7a	541.7
Texoka	612.0	614.3	602.3	570.7a	584.0a	407.7a	434.0a	546.4
84-609	612.7	641.0	609.0	584.7a	589.7a	410.7a	441.7a	555.6
84-409	626.3	637.3	594.3	572.0a	581.7a	408.0a	435.7a	550.8
84-304	563.7	635.3	606.0	580.0a	581.7a	401.3a	435.7a	543.4
84-315	487.7	631.3	576.7	560.0	574.3	398.7	427.7	522.3
85-378	638.0	620.7	603.3	574.3a	586.7a	404.3a	434.7a	551.7
MSD[1]	n.s.	n.s.	n.s.	22.8	11.7	13.2	10.2	n.s.
Avg Daily NRAD	581.9	631.6	599.6	574.2	583.3	405.7	435.6	(MSD = 23.2)

[1] MSD = Minimum Significant Difference for comparison of means within columns based on Waller-Duncan k-ratio t test (k-ratio = 100).

Zoysiagrass (*Zoysia* spp.) Cultivar Characterizations for 1989 and 1990: College Station

R. L. Green, J. B. Beard, and M. H. Hall

Introduction

Zoysiagrasses (*Zoysia* spp.) are warm-season, perennial turfgrasses that produce a dense, highly wear-resistant sod by both rhizomes and stolons. Among the commonly used warm-season turfgrasses, *Zoysia japonica* tolerates the widest range of high and low temperatures. Zoysiagrasses are best adapted to full sun, but will tolerate some shade. Their greatest cultural limitation is a very slow rate of establishment. Many cultivars require up to two growing seasons to establish a full turf cover when planted vegetatively from sprigs, even in a favorable climate.

The six Zoysia cultivars being characterized include four *Z. japonica* (Belair, El Toro, Korean Common, and Meyer), one *Z. matrella* (FC-13521), and one *Z. japonica* x *Z. tenuifolia* hybrid (Emerald). Two cultivars included in this study were more recently developed. El Toro was developed by the University of California at Riverside and Belair was developed by the USDA-ARS in Beltsville, Maryland.

Data from all six cultivars included in this study have been collected since 1984. Typically, a minimum of 5 years of assessments is required to obtain complete, reliable field evaluations of turfgrass cultivars and experimentals. Preliminary conclusions concerning the overall adaptation and performance of these zoysiagrass cultivars in the warm, humid climate at College Station, Texas are presented in this report. The reader also is referred to another report in this publication, "Comparative Characterizations of Four Commercially Available Cultivars and Four Experimental Selections of Zoysiagrass (*Zoysia* spp.) for 1990, College Station, Texas," in which data are presented for Belair, El Toro, Emerald, Meyer, and four experimental selections.

Materials and Methods

Three standard commercially available cultivars were included in this study: Emerald, FC-13521, and Meyer. They were planted by sprigging in August of 1979. El Toro was planted by sprigging in June of 1983, with Korean Common and Belair being planted by seed and sprigging, respectively, in July of 1984. The root zone was a well-drained, 10-inch (250-mm) deep modified loamy sand, with a subsurface drainage system. The experimental site was located at the Texas A&M Turfgrass Field Research and Teaching Laboratory in College Station, Texas. The plot size was 5 x 15 feet (1.5 x 4.5 m), with 18-inch (0.45-m) alleyways, arranged in a randomized complete block design with three replications.

The turfs were mowed twice weekly with a triplex reel mower at a 1-inch (25-mm) cutting height, with the clippings removed. Subplot fertility treatments were superimposed across each plot at rates of 0.25, 0.5, and 0.75 lb N/1000 sq ft per growing month (0.12, 0.25, and 0.37 kg N are^{-1} per growing month). Phosphorus and potassium were applied as needed based on an annual soil test. Sulfur was applied at a rate of 3 lbs S/1000 sq ft (1.5 kg S are^{-1}) per growing month to maintain the soil pH below 8.0. Irrigation was applied as needed to prevent visual wilt.

The cultivars were evaluated for turfgrass quality during the spring transition in 1989. The visual quality estimates were based primarily on a composite of two components: (a) uniformity of appearance and (b) shoot density. A visual quality rating of 5 or higher, on a scale of 1 to 9, represented an acceptable turf for lawns. Cultivar subplots did not respond to N differentials in terms of turfgrass quality in 1989, so no data were collected from the subplots.

The cultivars were evaluated for turfgrass quality at regular intervals during 1990. Cultivar subplots did respond to N differentials in 1990, but there was no cultivar x N level interaction. Thus, quality data are presented as the means of three N levels. No disease or insect problems were visually evident in terms of turf thinning in either 1989 or 1990.

Results

Comparisons of turfgrass visual quality during the spring transition, plus the fall low temperature color retention, among six zoysiagrass cultivars in 1989 are shown in Table 1. Emerald ranked highest for quality during the spring transition, while FC-13521 and Emerald ranked highest for fall low temperature color retention.

Data of turfgrass quality and spring greenup rate among the six zoysiagrass cultivars in 1990 are shown in Table 2. The seasonal quality means showed that all cultivars produced acceptable turf in 1990. Korean Common and Meyer had the fastest spring greenup rate among the cultivars in 1990.

A summary of the annual mean turfgrass quality ratings for the six zoysiagrass cultivars in College Station is shown in Table 3. Under the conditions in College Station, Texas, Emerald, FC-13521, Meyer, and El Toro have produced an acceptable lawn turf with differences in turf quality among the four cultivars being small. Belair and Korean Common have ranked the poorest in turf performance.

Table 1. 1989 comparisons of turfgrass quality ratings during the spring transition, plus the fall low temperature color retention ratings, among six zoysiagrass cultivars, College Station, Texas.

Zoysiagrass cultivar	Visual estimates of turfgrass quality during spring transition[1]				Fall low temperature color retention[2]
	3/29	4/19	5/9	Mean	12/6
Emerald	4.0 a[3]	5.3 a	6.0 a	5.1 a	8.0 a
Meyer	3.7 a	4.0 ab	5.0 ab	4.2 ab	2.7 c
FC-13521	3.3 ab	4.0 ab	4.7 ab	4.0 abc	9.0 a
El Toro	3.7 a	4.0 ab	4.3 b	4.0 abc	5.0 b
Korean Common	2.7 bc	3.7 ab	4.3 b	3.6 bc	0.0 d
Belair	2.3 c	3.3 b	3.5 b	3.0 c	2.7 c
Mean[4]	3.3 C	4.1 B	4.7 A		

[1] Visual turfgrass quality ratings based on a 1 to 9 scale: 1 = poorest and 9 = best; with 5 = the minimum acceptable turfgrass quality for lawns.
[2] Fall color retention ratings based on a 0 to 9 scale: 0 = dormant and 9 = green.
[3] Means followed by the same letter within the same column are not significantly different, LSD T Test, alpha = 0.05.
[4] Means over cultivars by date. Means followed by the same capital letter in this row are not significantly different, LSD T Test, alpha = 0.05.

Table 2. 1990 seasonal comparisons of turfgrass quality among six zoysiagrass cultivars, College Station, Texas.

Zoysiagrass cultivar	Visual estimates of turfgrass quality[1]						Spring greenup[2] (%)		
	6/27	7/16	7/30	8/25	9/14	Seasonal mean	3/6	4/2	Mean
FC-13521	7.3 a[3]	6.3 ab	6.4 a	6.8 a	6.9 ab	6.8 a	33.3 b	53.3 b	43.3 b
Emerald	7.3 a	6.4 a	6.3 ab	6.6 a	7.0 a	6.7 a	36.7 b	60.0 b	48.3 b
Meyer	7.3 a	6.4 a	6.3 ab	6.6 a	7.0 a	6.7 a	55.0 ab	65.0 ab	60.0 ab
El Toro	6.6 ab	5.2 abc	5.8 ab	6.2 ab	6.0 bc	6.0 ab	43.3 b	53.3 b	48.3 b
Korean Common	6.3 ab	5.1 bc	5.3 bc	5.7 b	5.6 cd	5.6 b	70.0 a	85.0 a	77.5 a
Belair	5.8 b	4.8 c	4.7 c	5.5 b	5.0 d	5.2 b	45.0 ab	65.0 ab	55.0 ab
Mean[4]	6.8 A	5.8 C	5.9 C	6.3 B	6.3 B				

[1] Visual turfgrass quality ratings based on a 1 to 9 scale: 1 = poorest and 9 = best; with 5 = the minimum acceptable turfgrass quality for lawns.
[2] Spring greenup ratings based on percent green shoot cover.
[3] Means followed by the same letter within the same column are not significantly different, LSD T Test, alpha = 0.05.
[4] Mean over cultivars by date. Means followed by the same capital letter in this row are not significantly different, LSD T Test, alpha = 0.05

Table 3. Summary of annual mean turfgrass quality ratings for six zoysiagrass cultivars from 1981 through 1990, College Station, Texas.

Zoysiagrass cultivar	Annual mean visual turfgrass quality ratings[1]							
	1981	1983	1984	1985	1986	1987	1988	1990
Emerald	5.7 a[2]	7.5 a	6.8 a	5.9 a	5.5 b	6.4 ab	7.1 a	6.7 a
FC-13521	16.6 a	7.3 a	6.2 ab	5.8 ab	4.7 c	6.6 a	6.1 ab	6.8 a
Meyer	5.3 b	6.4 b	7.0 a	5.2 abc	5.6 b	6.7 a	5.4 b	6.7 a
El Toro[3]	—	—	5.8 b	4.9 c	6.6 a	6.7 a	5.4 bc	6.0 ab
Korean Common[4]	—	—	—	5.0 c	5.1 bc	5.6 bc	4.1 cd	5.6 b
Belair[4]	—	—	—	5.1 ab	4.7 c	5.1 c	3.3 d	5.2 d

[1] Turfgrass quality means were averaged over three replications and multiple rating dates; based on a 1 to 9 scale: 1 = poorest and 9 = best; with 5 = minimum acceptable turfgrass quality for lawns.
[2] Means followed by the same letter within the same column are not significantly different. Duncan's multiple range test, alpha = 0.05.
[3] Established June, 1983.

Acknowledgment

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PR-4889

Centipedegrass (*Eremochloa ophuiroides*) Cultivar and Selection Characterizations for 1990: College Station

R. L. Green and J. B. Beard

Introduction

Centipedegrass (*Eremochloa ophuiroides* [Munro.] Hack.) was introduced into the United States in 1916 from China. It is a medium-textured, stoloniferous, warm-season, perennial grass with a prostrate growth habit and slow vertical shoot growth rate. Centipedegrass has good heat hardiness, with cold hardiness ranking intermediate among the bermudagrasses. It requires a low cultural intensity and has only fair recuperative potential. Centipedegrass is best adapted to full sun, but will tolerate some shade. Typically, it is found in moist, acid soils of low fertility. However, studies at Texas A&M University have shown that satisfactory turfs of centipedegrass can be grown on soil pH's up to 8.4 (1, 2, 3, 4, 5, 6).

Interest in minimal maintenance turfgrasses, such as centipedegrass, has been increasing. Georgia Common, Oklawn, and Tennessee Hardy centipedegrasses have been evaluated at the Texas A&M Turfgrass Field Research and Teaching Laboratory in College Station, Texas since 1979. Three experimental centipedegrasses from Auburn University were added to the study in 1983 and were fully established in 1984. One of these experimentals, AC-17, was officially released by the Alabama Agricultural Experiment Station in 1983 as AU Centennial. Typically, a minimum of 5 years of assessments at several locations is required to obtain complete, reliable field evaluations of turfgrasses. Preliminary conclusions concerning the overall adaptation and performance of these centipedegrass cultivars and selections at College Station are made in this report.

Materials and Methods

Three commercially available centipedegrass cultivars were planted in September of 1979. Tennessee Hardy and Oklawn were sprigged, while Georgia Common was seeded. Three vegetatively propagated selections from Auburn University were added to this study in 1983: AC-26, AC-44, and AC-17 (AU Centennial). The cultivars and selections were planted on a 10-inch (250-mm) deep, modified, loamy sand root zone with a subsurface drain system. Three replications of each grass were planted in a randomized complete block design. Plot size was 5 x 8 ft (1.4 x 2.4 m) with 18-inch (0.45-m) alleyways.

The turfs were mowed twice weekly with a rotary mower at a 1.5 inch (38 mm) cutting height, with the clippings removed. During 1990, the pH was maintained in the range of 7.9 to 8.2 via timely applications of sulfur. Nitrogen was applied once in the spring at a rate of 0.5 lb/1000 sq ft (0.25 kg are^{-1}). Phosphorus and potassium were applied as needed based on annual soil tests. Irrigation water was applied as needed to prevent visual wilt. No pesticides were applied in 1990.

Visual turfgrass quality ratings were made by two scientists during the growing season. The quality estimates were based on a composite of two primary components: (1) uniformity of appearance and (b) shoot density. These ratings were based on a 1 to 9 scale with 1 being poorest, and 9 being best; with 5 or higher being an acceptable lawn turf. No significant disease, insect, or weed problems were observed on the centipedegrass turfs during 1990.

Results

A summary of the 1990 seasonal visual turfgrass quality ratings and spring greenup rates for the four cultivars and two selections of centipedegrass is shown in Table 1. As a group, the quality ratings in 1990 were as low as they ever have been since the ratings were initiated in 1983 (Table 2). In 1990, the grasses had similar visual quality, with the possible exception of AU Centennial which had the lowest seasonal average. AU Centennial also ranked lowest in 1988. In general terms, all centipedegrasses have had acceptable visual turfgrass quality ratings at College Station since 1983, with the exception of AU Centennial. Visual turfgrass quality differences among the top five cultivars have been minimal.

In 1990, the grasses had similar spring greenup rates (Table 1). These findings are consistent with data collected in 1986 (4).

Table 1.1990 seasonal comparisons of turfgrass quality ratings among four cultivars and two selections of centipedegrass, College Station, Texas.

Centipedegrass cultivar or selection	Visual estimate of turfgrass quality[1] 6/27	7/16	7/30	8/25	9/14	Seasonal average	Spring greenup[2] 2/14
Georgia Common	5.3 a[3]	4.7 a	4.7 a	5.7 a	4.3 a	4.9 a	3.7 a
Oklawn	4.7 ab	4.3 ab	4.3 ab	5.0 a	4.3 a	4.5 a	3.3 a
AC-44	4.7 ab	4.3 ab	4.3 ab	5.0 a	4.0 a	4.5 a	3.7 a
AC-26	4.7 ab	3.7 ab	4.0 b	5.3 a	4.3 a	4.4 ab	3.7 a
Tennessee Hardy	4.0 ab	4.0 ab	4.0 b	5.0 a	4.5 a	4.3 ab	4.3 a
AU Centennial	3.3 b	3.3 b	3.3 c	4.0 b	4.0 a	3.6 b	4.7 a
Average	4.5 B[4]	4.1 C	4.1 C	5.0 A	4.2 BC		

[1] Visual estimates of turfgrass quality based on a 1 to 9 scale: 1 = poorest and 9 = best; with 5 = minimum acceptable turfgrass quality for lawns.
[2] Visual estimates of spring greenup rate based on a 1 to 9 scale: 1 = brown and 9 = totally green.
[3] Means followed by the same letter within the same column are not significantly different. LSD T TEST, alpha = 0.05.
[4] Average over cultivars and selections by date. Means followed by the same capital letter in this row are not significantly different. LSD T TEST, alpha = 0.05.

Table 2. Summary of annual mean turfgrass quality ratings for four cultivars and two selections of centipedegrass from 1983 to 1990, College Station, Texas.

Centipedegrass cultivar or selection	Annual mean turfgrass quality ratings[1] 1983	1984	1985	1986	1987	1988	1990
Georgia Common	4.7 a[2]	5.9 a	5.4 a	5.7 a	5.3 a	5.1 ab	4.9 a
Oklawn	4.5 a	6.0 a	5.6 a	4.7 a	5.1 a	5.7 a	4.5 a
AC-44	—	—	5.2 a	5.2 a	5.0 a	5.5 a	4.5 a
AC-26	—	—	5.5 a	5.3 a	4.7 a	5.3 ab	4.4 ab
Tennessee Hardy	4.7 a	5.9 a	5.4 a	5.7 a	5.3 a	5.1 ab	4.3 ab
AU Centennial	—	—	5.7 a	5.0 a	4.7 a	3.3 b	3.6 b

[1] Turfgrass quality means were averaged over three replications and multiple rating dates; based on a 1 to 9 scale: 1 = poorest and 9 = best; with 5 = minimum acceptable turfgrass quality for lawns.
[2] Means followed by the same letter within the same column are not significantly different. Duncan's Multiple Range Test, alpha = 0.05.

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PR-4890

1991 Update on Performance of Zoysiagrass Cultivars and Elite DALZ Lines Under Linear Gradient Irrigation

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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. More specifically, to: 1) determine the minimum amount of supplemental irrigation required to maintain turf for soil and water conservation and stabilization, and 2) determine the minimum amount of water required for acceptable turf performance. Numerous opportunities arise to also address other performance characters.

Progress

A total of 26 different zoysiagrasses (*Zoysia* Spp.) were planted to LGIS during 1987. A randomized complete block with four replications, two on either side of the line irrigation source were used. Plots were 1.5m x 20m wide 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 and to encourage full turf coverage, which was achieved by fall 1988. The experimental area receives a yearly total of 0.98 kg N are^{-1} and is maintained at a 2.54 cm mowing height.

Gradient irrigation was initiated in mid-July 1989 and is continual regardless of season to create a moisture stress gradient and to determine the volume of irrigation required to maintain ground cover, prevent drought stress, maintain acceptable turf quality, and maintain at least 50 percent 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. 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 (Fig. 1). Data for 1991 is through July 24, 1991. Total rainfall in 1990 was 135.6 cm., and through June 30, 1991, 54.2 cm . Turf performance is measured throughout the year.

Objectives

The objectives of the winter study were to evaluate the fall color, winter green color retention, frost injury, and ability of the grasses to maintain a monoculture stand. Objectives of the summer study were to evaluate the green cover retention and turf quality of the grass under drought conditions. Winter and spring turf quality were noted.

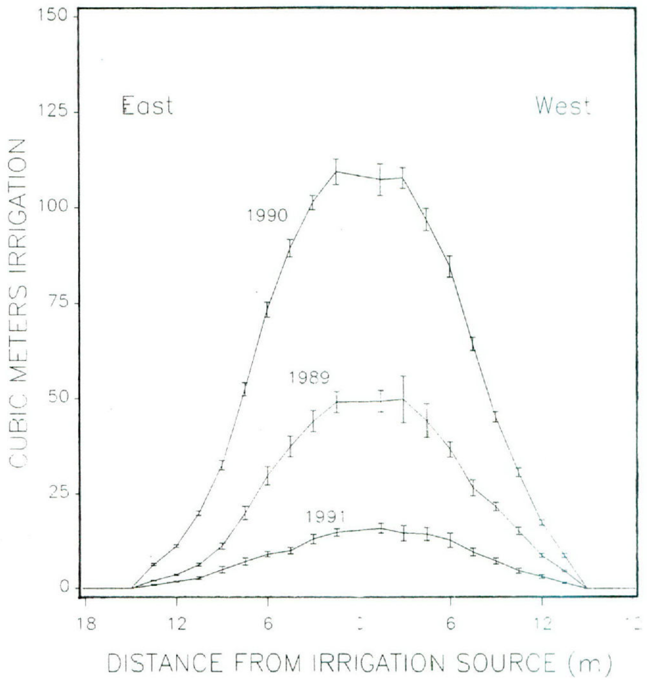


Figure 1. Irrigation distribution for the Linear Gradient Irrigation System at TAES-Dallas during 1989, 1990, and January 1 through July 29, 1991. Means plus standard errors are plotted east and west of the line irrigation source, respectively.

Results

Retention of Green Active Growth

Seasonal turf performance differed over time, across the irrigation gradient and across varieties. The turf varieties ability to retain green active growing plant material across a moisture gradient and under stress , and to recover from stress were significantly different. In late summer 1990, the percent of green turf color was measured during a period of stress (September 5) and 7 days following termination of stress by rainfall (September 15). Prior to stress DALZ8512 had the highest green turf plot cover under no irrigation (Table 1). Other grasses which had good green turf cover under high and moderate irrigation, but failed to maintain adequate cover under no irrigation were Belair, Emerald, El Toro, Korean Common, FC13521, DALZ8507, DALZ8508, DALZ8510, and DALZ8514. DALZ8522 and DALZ8523 had poor green turf coverage under all irrigations.

Table 1. Mean percentage green turf cover during stress (5 September) and 7 days after termination of stress (15 September) by rainfall for three levels of irrigation on LGIS zoysiagrasses at TAES-Dallas, Texas in 1990.

	5 September			15 September		
Entry	High[1]	Inter.	None	High	Inter.	None
Belair	93	87	36	93	85	70
Cashmere	78	48	8	83	52	10
Emerald	95	82	20	95	84	66
El Toro	93	90	35	95	90	77
K. common	96	76	13	96	78	39
Meyer	96	73	13	95	80	40
FC13521	95	78	16	93	81	52
DALZ8501	89	64	16	89	64	19
DALZ8502	90	74	20	90	81	41
DALZ8503	96	67	8	96	69	14
DALZ8504	91	54	7	94	64	17
DALZ8505	89	66	5	94	66	13
DALZ8506	94	67	18	95	74	33
DALZ8507	96	82	25	97	87	67
DALZ8508	95	76	17	96	80	35
DALZ8510	96	76	21	95	81	58
DALZ8511	96	68	15	93	72	27
DALZ8512	92	89	45	94	93	80
DALZ8513	83	67	21	82	70	45
DALZ8514	94	88	35	94	92	78
DALZ8515	94	65	9	94	68	13
DALZ8516	90	73	22	91	76	41
DALZ8517	94	70	10	95	80	30
DALZ8522	25	6	1	25	13	2
DALZ8523	56	31	11	49	34	18
DALZ8524	84	68	23	85	74	29
MSD[2]	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] Minimum significant difference for comparison of entry means within columns based on the Waller-Duncan k ratio test where k=100.

By September 15 (following stress) DALZ8512 still maintained highest green plot cover under all irrigations, but all grasses recovered greatly, and in particular DALZ8514. Recovery was greater under no irrigation than in moderate or high irrigation. Nonirrigated Cashmere, DALZ8501, DALZ8503, DALZ8504, DALZ8505, DALZ8515, DALZ8522, and DALZ8523 had less than 20 percent green plot cover following stress, and could be considered as slow to recover.

Fall and Winter Color

Cashmere, Emerald, FC13521, DALZ8502, DALZ8506, DALZ8507, DALZ8508, DALZ8510, DALZ8512, DALZ8513, DALZ8515, DALZ8516, DALZ8523, and DALZ8524 had best green color on November 13 across all irrigations (Table 2). DALZ8501 and DALZ8505 had equally good color at intermediate and no irrigation, but were less green under high irrigation. The poorest performers at this date were Korean Common, Meyer, DALZ8503, DALZ8504, DALZ8511, and DALZ8514. DALZ8522 received a 0 color quality rating under no irrigation, indicating that none of the planted variety was present. There were no significant differences among varieties at the November 29 sampling date. Gross fall color pigmentation is indicated for each of the lines. Several experimentals have considerable red pigmentation with possible ornamental appeal, including DALZ8503, DALZ8508, DALZ8512, and DALZ8514.

As of December 10, Cashmere, DALZ8501, and DALZ8502 had good color under all irrigations, while FC13521, DALZ8503, DALZ8506, DALZ8507, DALZ8508, DALZ8510, DALZ8512, DALZ8516, DALZ8517, and DALZ8524 had acceptable color under reduced irrigation only (Table 3). Lowest color ratings observed on this date were for Belair, El Toro, Korean Common, Meyer, DALZ8504, DALZ8505, DALZ8511, DALZ8514, DALZ8515, DALZ8522, and DALZ8523. DALZ8502 was the only selection which maintained significant green color into February. Of those varieties and lines which lost their green canopies, gold and grey were the predominant winter colors. Golden canopies were observed for Korean Common, Meyer, DALZ8511, and DALZ8512, and grey canopies were common for Cashmere (TAES3477), DALZ8508, and DALZ8516.

Winter Color Retention

As of November 29, Belair, Emerald, El Toro, FC13521, DALZ8507, and DALZ8512 had the highest green plot cover under all irrigations (Table 4). Cashmere, DALZ8501, DALZ8502, DALZ8503, DALZ8504, DALZ8506, DALZ8508, DALZ8510, DALZ8511, DALZ8513, DALZ8514, DALZ8515, DALZ8516, and DALZ8517 had good to acceptable green cover under high and moderate irrigation, but dropped to unacceptable levels under no irrigation. Korean Common and DALZ8523 had very low green plot cover overall. El Toro, DALZ8512, and DALZ8514 had best green cover on December 10. DALZ8501, DALZ8502, DALZ8508, DALZ8516, and DALZ8517 had acceptable turf cover under high and moderate irrigation, but had lower levels under no irrigation. All varieties retained succulent stolons and some emerging green leaves beneath their canopies during this winter.

Spring Green Up

Spring green cover developed fastest for El Toro, Emerald, FC13521, Meyer, DALZ8504, DALZ8506, DALZ8508, DALZ8512, DALZ8516, DALZ8517, and DALZ8524, with 70 to 90 percent green cover by April 13, 1991 (Table 5). DALZ8522, DALZ8523, and DALZ8513 produced only 25 to 40 percent green cover by this same date. The commercial varieties, Belair, El Toro, Emerald, Korean Common, and Meyer, greened up at comparable rates to each other and to most experimental lines, but were slightly slower than the top-ranked experimental lines. Plants in nonirrigated zones were slower to green up than irrigated plants. Six zoysiagrass lines including Meyer, DALZ8501, and DALZ8511, had green up rates at least 1.6 times slower when not irrigated than when irrigated. Belair, El Toro,

Table 2. Fall color quality ratings (1-9: 9 = darkest green and 5 = acceptable) for three levels of irrigation, and secondary color (G = green, GR = green-red, RG = red-green, and GY = green-yellow) averaged over irrigation, on LGIS zoysiagrasses at TAES, Dallas, Texas in 1990.

	13 November				29 November			
Entry	High[1]	Inter.	None	2nd Col.	High	Inter.	None	2nd Col.
Belair	5.0	6.5	7.5	RG	5.0	5.0	6.5	RG
Cashmere	8.5	8.0	8.5	G	8.0	8.5	7.5	G
Emerald	6.5	6.5	7.0	RG	6.5	6.5	6.5	G
El Toro	6.5	6.5	5.0	RG	5.5	6.0	7.0	RG
K. common	4.0	5.0	5.5	GY	6.0	4.5	5.0	GR
Meyer	4.0	4.5	4.0	GY	5.5	5.0	5.0	G
FC13521	7.0	6.5	7.5	GR	6.5	7.0	7.5	G
DALZ8501	5.0	7.0	7.0	RG	7.0	8.0	6.5	G
DALZ8502	6.5	8.0	7.5	G	7.0	8.0	7.0	G
DALZ8503	5.5	5.5	5.0	RG	5.0	6.0	6.5	RG
DALZ8504	2.5	3.0	5.0	GY	5.5	6.0	7.5	G
DALZ8505	4.0	6.0	7.0	GR	5.5	6.5	5.5	G
DALZ8506	6.0	6.5	7.5	RG	7.0	6.5	6.5	G
DALZ8507	6.5	7.0	7.5	RG	6.0	6.0	8.0	G
DALZ8508	6.0	7.5	8.0	RG	6.0	6.5	7.5	RG
DALZ8510	6.0	7.0	7.5	RG	6.0	6.0	7.5	G
DALZ8511	4.5	3.0	4.5	RG	4.5	5.5	5.5	G
DALZ8512	6.0	6.5	7.0	RG	5.0	5.0	6.5	RG
DALZ8513	6.5	6.5	7.0	GR	6.5	6.5	7.5	G
DALZ8514	4.5	4.5	5.0	RG	6.0	5.5	6.5	RG
DALZ8515	6.5	7.5	3.0	RG	6.0	5.5	7.5	G
DALZ8516	7.0	7.5	8.0	RG	7.0	7.0	8.0	G
DALZ8517	6.5	6.5	7.0	RG	5.5	6.5	7.0	G
DALZ8522	7.0	7.0	0.0	G	6.0	4.5	7.0	G
DALZ8523	7.0	6.5	7.5	RG	4.0	3.5	4.0	GR
DALZ8524	5.5	8.0	7.5	RG	6.5	7.0	8.0	G
MSD entry[2]	2.7	2.5	2.9		ns	ns	ns	

[1]Irrigation levels of high, intermediate, and none are equivalent to 87, 29, and 0 percent of the irrigation volume at the line source, respectively.
[2]MSD entry = Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

Table 3. Winter color ratings (1-9: 9 = darkest green and 5 = acceptable) for three levels of irrigation on LGIS zoysiagrasses at TAES, Dallas, Texas in 1990-1991.

	10 December			2 February		
Entry	High[1]	Inter.	None	High	Inter.	None
Belair	3.0	3.3	3.8	1.5	1.5	1.0
Cashmere	6.8	7.0	7.0	1.0	1.0	1.0
Emerald	5.0	5.3	5.0	1.8	1.8	1.5
El Toro	3.5	3.0	3.8	1.8	1.5	1.0
K. common	4.0	3.5	3.0	2.0	1.8	2.0
Meyer	3.8	3.0	3.3	2.0	2.0	1.5
FC13521	5.3	5.0	6.3	1.8	1.5	1.0
DALZ8501	6.8	7.0	7.3	1.0	1.0	1.0
DALZ8502	7.3	7.3	6.0	4.0	4.0	2.0
DALZ8503	3.8	4.0	6.0	1.8	1.8	1.5
DALZ8504	3.5	4.0	4.5	2.0	1.3	1.3
DALZ8505	4.5	4.3	5.0	1.8	1.8	1.5
DALZ8506	5.5	6.3	7.0	1.5	1.5	1.3
DALZ8507	5.3	5.3	5.8	2.0	1.3	1.0
DALZ8508	4.0	3.8	6.0	1.0	1.0	1.0
DALZ8510	5.8	5.5	6.8	1.8	1.8	1.5
DALZ8511	4.3	4.3	4.8	2.0	1.8	1.8
DALZ8512	4.0	4.3	6.0	2.0	1.5	1.8
DALZ8513	5.8	5.5	6.5	1.0	1.0	1.0
DALZ8514	3.8	3.5	4.3	1.8	1.5	1.5
DALZ8515	3.5	3.8	4.0	2.0	1.8	1.0
DALZ8516	3.3	3.5	5.3	1.0	1.0	1.0
DALZ8517	4.8	5.3	6.8	1.8	1.5	1.5
DALZ8522	4.5	5.3	2.5	1.3	1.0	1.3
DALZ8523	4.5	4.8	4.5	1.0	1.0	1.0
DALZ8524	4.3	5.0	6.0	1.0	1.3	1.0
MSD entry[2]	1.5	1.4	2.2	0.4	0.6	1.1

[1] Irrigation levels of high, intermediate, and none are equivalent to 87, 29, and 0 percent of the irrigation volume at the line source, respectively.
[2] MSD entry = Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

Table 4. Mean percentage green turf cover during fall and winter for three levels of irrigation on LGIS zoysiagrasses at TAES, Dallas, Texas in 1990-1991.

	13 November			29 November			10 December		
Entry	High[1]	Inter.	None	High	Inter.	None	High	Inter	None
Belair	100.0	100.0	97.5	75.5	44.5	68.5	55.3	46.0	56.5
Cashmere	100.0	95.0	42.5	76.5	89.0	23.5	18.8	18.3	3.3
Emerald	100.0	100.0	82.5	85.0	77.0	55.0	39.3	49.0	19.0
El Toro	100.0	100.0	100.0	84.5	78.5	72.0	66.5	74.3	62.3
K. common	100.0	95.5	55.0	22.5	11.0	14.5	5.8	5.8	7.5
Meyer	100.0	87.5	45.0	57.5	38.5	24.5	5.3	5.3	6.3
FC13521	100.0	100.0	77.5	67.0	67.5	52.5	30.5	36.3	23.5
DALZ8501	100.0	95.0	47.5	54.0	62.0	18.1	58.8	62.8	8.5
DALZ8502	100.0	100.0	75.0	57.0	51.0	31.0	67.8	66.5	28.0
DALZ8503	95.0	90.0	25.0	85.5	64.5	8.0	33.0	27.5	2.5
DALZ8504	95.0	92.5	35.0	71.0	49.0	7.5	14.3	25.3	5.0
DALZ8505	95.0	97.5	55.0	38.0	74.0	5.0	16.0	32.5	3.8
DALZ8506	100.0	100.0	50.0	57.5	58.5	26.5	34.3	42.3	16.3
DALZ8507	100.0	100.0	85.0	75.0	75.0	53.5	34.0	38.3	35.8
DALZ8508	92.5	100.0	52.5	79.0	77.5	35.5	58.3	64.8	12.3
DALZ8510	100.0	100.0	87.5	85.0	89.0	47.5	26.8	50.8	29.5
DALZ8511	97.5	95.0	67.5	51.5	44.5	23.0	5.8	11.5	8.8
DALZ8512	100.0	100.0	100.0	74.0	81.0	77.5	56.8	65.5	64.5
DALZ8513	100.0	100.0	92.5	47.0	56.5	5.0	12.8	17.8	17.8
DALZ8514	100.0	100.0	95.0	81.0	83.0	48.0	61.8	73.0	58.3
DALZ8515	100.0	100.0	47.5	66.5	44.5	2.0	29.5	13.5	3.8
DALZ8516	95.0	95.0	65.0	59.5	51.0	35.0	52.5	45.3	19.5
DALZ8517	100.0	100.0	60.0	68.0	75.0	14.0	40.3	63.0	8.8
DALZ8522	62.5	72.5	0.0	31.5	32.5	3.0	4.3	8.5	0.8
DALZ8523	85.0	90.0	72.5	7.5	1.0	7.5	13.5	12.0	12.8
DALZ8524	95.0	100.0	52.5	47.5	37.0	10.5	16.5	30.5	12.0
MSD entry[2]	19.9	ns	20.7	39.2	58.1	28.0	20.1	20.8	13.0

[1] Irrigation levels of high, intermediate, and none are equivalent to 87, 29, and 0% of the irrigation volume at the line source, respectively.
[2] MSD entry = Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

Emerald, FC13521, DALZ8506, DALZ8507, DALZ8516, DALZ8517, and DALZ8521 wre among the fastest to green up when cultured without supplemental irigation. Slowest to achieve green plot cover were Cashmere, DALZ8513, DALZ8515, DALZ8522, and DALZ8523.

Summer 1990 Turf Quality

DALZ8507, DALZ8512, and DALZ8514 had the best turf quality in the non-irrigated zone on September 5 (Table 6). There was no improvement in turf quality following stress, except for moderate improvement in the zone receiving no irrigation. In this zone, Belair, El Toro, DALZ8507, DALZ8512, and DALZ8514 had the greatest increase in turf quality.

Winter Turf Quality

During the winter, turf quality was highest under all irrigations for DALZ8502 (Table 7). Turf quality was at an acceptable level under high and moderate irrigation, but dropped to an unacceptable level (<5) under no irrigation. No other grass had acceptable turf quality under any irrigation. In general, winter quality was best in high irrigation zones and worst in nonirrigated zones.

All components of turf quality contributed to the moderate turf quality of DALZ8502, but density was primarily responsible, particularly in nonirrigated plots (Table 8). Winter color canopy uniformity had negative influences on turf quality of DALZ8502 in nonirrigated plots (Table 3). DALZ8522 and DALZ8523 were poor in all turf quality components. DALZ8507 and DALZ8510

Table 5. Mean spring green turf cover by April 3, 1991 of zoysiagrasses planted to LGIS at TAES, Dallas, Texas.

	Green turf cover		
Entry	High[1]	Inter.	None
Belair	81.3a	65.0	75.0a
Cashmere	32.5	35.0	11.3
Emerald	71.3	73.8a	82.5a
El Toro	78.8a	72.5	73.8a
K. common	72.5	76.3a	60.0a
Meyer	81.3a	83.8a	43.8
FC13521	82.5a	78.8a	71.3a
DALZ8501	65.1	76.3a	46.3
DALZ8502	70.0	72.5	51.3
DALZ8503	67.5	71.3	62.5a
DALZ8504	67.5	70.0	63.8a
DALZ8505	68.8	75.0a	46.3
DALZ8506	71.3	73.8a	72.5a
DALZ8507	71.3	77.5a	82.5a
DALZ8508	90.8a	88.0a	72.5a
DALZ8510	66.3	76.3a	81.3a
DALZ8511	78.8a	77.5a	50.0
DALZ8512	71.3	67.5	72.5a
DALZ8513	42.5	40.3	32.5
DALZ8514	73.8	68.8	70.0a
DALZ8515	62.5	60.0	28.8
DALZ8516	90.0a	88.8a	80.0a
DALZ8517	81.3a	80.0a	70.0a
DALZ8522	25.0	22.5	5.0
DALZ8523	38.8	37.5	31.3
DALZ8524	70.0	75.0a	72.5a
MSD entry[2]	14.1	16.0	23.8

[1] Irrigation levels of high, intermediate, and none are equivalent to 87, 29, and 0% of the irrigation volume at the line source, respectively.
[2] MSD entry = Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

Table 6. Mean zoysiagrass turf quality during stress (5 September) and 7 days after termination of stress (15 September) by rainfall for three levels of irrigation on LGIS at TAES-Dallas, Texas in 1990.

Entry	5 September			15 September		
	High[1]	Inter.	None	High	Inter.	None
Belair	4.6	4.1	2.2a	4.5	4.1	3.2
Cashmere	2.6	1.9	1.0	2.7	2.1	1.0
Emerald	5.4	4.0	1.8	5.3	4.0	2.7
El Toro	5.3	4.3a	2.1	5.2	4.4	3.6
K. common	5.5	3.2	1.4	5.0	3.4	2.0
Meyer	5.8	3.8	1.7	5.7	4.1	2.1
FC13521	5.3	4.4a	1.8	5.5	3.9	2.1
DALZ8501	3.9	2.9	1.1	3.7	2.9	1.5
DALZ8502	4.7	4.1	1.5	4.9	4.0	1.9
DALZ8503	5.7	3.8	1.1	5.5	3.6	1.3
DALZ8504	4.7	2.8	1.0	4.8	3.2	1.3
DALZ8505	4.8	3.5	1.0	4.4	3.4	1.2
DALZ8506	5.4	4.2a	1.6	5.9a	4.0	1.8
DALZ8507	6.6a	5.0a	2.2a	6.4a	5.4a	2.9
DALZ8508	5.7	4.0	1.5	5.8a	3.9	2.0
DALZ8510	6.0a	4.9a	1.9	5.7	4.5	2.9
DALZ8511	5.6	3.4	1.6	5.6	3.4	1.9
DALZ8512	5.0	4.4a	2.4a	5.0	4.9a	3.9a
DALZ8513	3.3	2.7	1.4	2.9	2.6	1.8
DALZ8514	5.2	4.5a	2.3a	5.0	4.5	3.4
DALZ8515	5.4	3.4	1.0	5.2	3.5	1.4
DALZ8516	3.8	2.9	1.3	3.9	3.1	2.0
DALZ8517	5.1	3.4	1.3	5.1	3.8	1.8
DALZ8522	1.3	1.0	1.0	1.4	1.2	1.0
DALZ8523	2.6	1.9	1.3	2.0	1.9	1.4
DALZ8524	3.1	2.9	1.1	2.7	2.7	1.7
MSD[2]	0.6	0.8	0.2	0.6	0.7	0.2

[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] Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k ratio test where k=100.

Table 7. Winter and spring turf quality ratings (1-9: 9 = highest quality and 5 = acceptable) for three levels of irrigation on LGIS zoysiagrasses at TAES, Dallas, Texas in 1990-1991.

Entry	6 February			24 April		
	High[1]	Inter.	None	High	Inter	None
Belair	3.8	3.8	3.3	5.0a	4.8	4.8a
Cashmere	4.3	3.8	3.0	4.8	4.5	1.8
Emerald	4.3	4.3	3.5	5.5a	5.8a	4.8a
El Toro	4.0	4.0	3.5	5.3a	4.8	4.5a
K. common	4.5	4.0	3.5	5.0a	5.3	2.5
Meyer	4.3	4.0	3.3	6.0a	6.3a	3.0
FC13521	4.3	3.8	3.3	5.3a	5.8a	4.0a
DALZ8501	4.0	4.0	3.3	4.8	5.0	2.2
DALZ8502	6.0a	5.8a	4.5a	5.8a	6.3a	3.8
DALZ8503	4.5	4.0	3.0	5.5a	5.3	3.3
DALZ8504	4.5	3.5	3.0	5.5a	6.0a	2.8
DALZ8505	4.0	3.8	3.0	4.8	6.0a	2.0
DALZ8506	4.0	4.0	3.3	5.5a	5.5a	3.8
DALZ8507	4.5	4.3	3.8a	5.8a	6.5a	5.0a
DALZ8508	4.0	3.3	3.0	6.0a	6.3a	3.5
DALZ8510	4.0	4.0	3.8a	5.3a	6.0a	4.8a
DALZ8511	4.5	4.0	3.5	5.8a	5.8a	2.8
DALZ8512	4.3	3.8	3.8a	5.0a	5.5a	4.8a
DALZ8513	3.5	3.5	3.3	4.0	3.8	2.0
DALZ8514	3.8	4.0	3.8a	4.8	5.0	4.8a
DALZ8515	4.3	4.0	3.0	5.3a	6.0a	1.3
DALZ8516	4.0	3.5	3.3	5.0a	5.5a	3.5
DALZ8517	4.0	4.0	3.3	5.3a	6.0a	3.5
DALZ8522	3.0	3.3	1.8	1.8	2.3	0.8
DALZ8523	3.5	3.3	3.5	4.3	4.3	2.3
DALZ8524	4.0	4.0	3.8a	4.8	5.8a	3.8
MSD entry[2]	0.7	0.8	0.9	1.0	1.1	1.1

[1] Irrigation levels of high, intermediate, and none are equivalent to 87, 29, and 0% of the irrigation volume at the line source, respectively.
[2] MSD entry = Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

had relatively high ratings for turf quality components, but had unacceptable overall quality due to poor color (Table 3). Uniformity and density of all grasses declined with decreasing irrigation.

Spring Turf Quality

By spring a number of grasses had improved in overall quality, particularly at high and intermediate irrigation levels (Table 7). Under no irrigation, only Belair, Emerald, El Toro, FC13521, DALZ8507, DALZ8510, DALZ8512, and DALZ8514 had relatively acceptable turf quality. DALZ8522 continued to have the poorest quality of the varieties and at all irrigation levels evaluated (mean quality at all irrigations = 1.63). Plants in moderately irrigated zones gained quality as spring progressed, yet nonirrigated zones were still of relatively poor quality.

Frost Injury

Frost injury became evident by November 13, 1990 (Table 9). Meyer, Emerald, FC13521, DALZ8507, DALZ8510, DALZ8511, DALZ8515, DALZ8517, and DALZ8524 were among the most injured, which contrasts greatly with DALZ8501 and DALZ8516, which showed less than 25 percent frost damage. All other varieties and lines tested showed at least 40 percent damage overall. Just 2 weeks later, DALZ8516 had maintained a moderate frost injury (<40 percent injury), while all but two of the other 25 lines had at least 60 percent frost damage. El Toro was the least frost damaged of the commercial varieties, yet was over 70 percent damaged by December 10. Frost injury was generally lower for nonirrigated plants than for plants maintained at either moderate or high irrigation levels.

Weed Cover

Since being planted in summer 1987 and 1988, LGIS zoysiagrasses have been competing with the more aggressive neighboring LGIS zoysiagrasses, and with some of the native and naturalized North Texas flora. Varieties exhibiting the lowest overall weed cover include El Toro, DALZ8507, DALZ8508, DALZ8512, and DALZ8514 (Table 10). These are varieties which have shown excellent drought tolerance in past summers, and which have completely established turf cover. Weeds have invaded experimental lines which have not established good turf cover, such as DALZ8513, DALZ8522, and DALZ8523 (weed cover > 30 percent and plot green cover <50 percent). Commercial varieties which exhibit higher weed cover are Korean Common and Meyer, and also have moderate turf coverage (60 to 75 percent). Generally, weed cover is significantly higher in the nonirrigated zone than in the highly or moderately irrigated zones evaluated for the zoysia varietal plots.

Table 8. Canopy density (9 = densest, 5 = lowest acceptable density, and 0 = none of the variety is present), canopy uniformity (1 = uniform canopy, 0 = patchy canopy distribution), and canopy evenness (1 = even height, 0 = undulated canopy) at Februrary 6, 1991, for three levels of irrigation on LGIS zoysiagrasses at TAES, Dallas.

	Density			Uniformity			Evenness		
Entry	High[1]	Inter.	None	High	Inter.	None	High	Inter.	None
Belair	4.8	4.8	4.5	0.0	0.3	0.5	0.5	0.8	0.3
Cashmere	6.0	5.5	4.3	0.5	0.0	0.0	0.8	0.3	0.8
Emerald	5.3	5.0	4.5	0.3	0.0	0.3	0.5	0.0	0.5
El Toro	4.8	4.3	4.0	0.3	0.8	0.8	0.8	1.0	0.8
K. common	5.3	4.3	3.5	0.8	0.5	0.0	0.5	0.8	0.8
Meyer	5.5	4.8	3.8	0.8	0.8	0.3	0.0	0.3	0.8
FC13521	5.3	4.5	4.0	0.8	0.5	0.5	0.3	0.5	0.8
DALZ8501	5.3	5.3	4.0	0.3	0.3	0.3	0.8	0.8	1.0
DALZ8502	6.0	5.3	5.3	0.8	0.8	0.3	1.0	0.8	0.8
DALZ8503	6.0	5.0	3.0	0.8	0.8	0.3	0.0	0.0	0.3
DALZ8504	5.5	4.5	3.5	0.8	0.8	0.0	0.3	0.0	0.5
DALZ8505	4.3	4.5	3.3	0.5	0.5	0.3	0.8	0.5	0.5
DALZ8506	5.5	5.3	3.8	0.5	0.8	0.0	0.3	0.0	1.0
DALZ8507	5.5	5.3	4.8	0.5	1.0	0.0	0.5	0.5	0.8
DALZ8508	5.0	4.8	4.0	1.0	0.3	0.0	0.0	0.3	0.5
DALZ8510	5.0	4.8	5.3	0.5	0.5	0.5	0.3	0.8	0.0
DALZ8511	5.5	4.8	3.8	0.8	1.0	0.8	0.3	0.0	0.5
DALZ8512	4.3	4.5	4.0	1.0	0.5	0.8	1.0	0.8	0.8
DALZ8513	4.8	5.0	4.8	0.5	0.3	0.0	0.3	0.5	0.3
DALZ8514	4.8	4.8	4.3	0.5	0.3	0.3	0.5	1.0	1.0
DALZ8515	5.3	5.0	3.8	0.8	0.5	0.0	0.3	0.5	0.8
DALZ8516	5.5	4.8	4.8	0.5	0.3	0.3	0.5	0.5	0.3
DALZ8517	5.0	5.0	4.0	0.8	0.8	0.0	0.3	0.5	1.0
DALZ8522	3.8	3.8	2.0	0.0	0.3	0.0	0.8	1.3	0.3
DALZ8523	4.8	4.8	4.8	0.0	0.0	0.0	0.8	0.5	0.8
DALZ8524	5.3	5.0	4.5	0.5	0.0	0.0	0.8	1.0	1.0
MSD entry[2]	1.0	ns	1.1	0.9	0.8	ns	ns	0.8	ns

[1] Irrigation levels of high, intermediate, and none are equivalent to 87, 29, and 0% of the irrigation volume at the line source, respectively.
[2] MSD entry = Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

Table 9. Percent of turf injured by frost for three levels of irrigation on LGIS zoysiagrasses at TAES, Dallas, Texas in 1990-1991.

	13 November			29 November			10 December		
Entry	High[1]	Inter.	None	High	Inter.	None	High	Inter.	None
Belair	57.5	65.0	37.5	75.0	80.0	75.0	77.5	88.3	82.5
Cashmere	90.0	85.0	47.5	85.0	77.5	77.5	97.8	95.8	92.5
Emerald	92.5	82.5	80.0	87.5	85.0	85.0	95.8	95.8	97.0
El Toro	45.0	52.5	37.5	47.5	67.5	27.5	76.3	71.3	72.5
K. common	95.0	95.0	67.5	87.5	87.5	87.5	99.0	99.3	95.8
Meyer	99.0	97.5	95.0	95.0	95.0	90.0	99.0	99.0	97.0
FC13521	85.0	85.0	80.0	85.0	87.5	85.0	95.8	95.3	95.0
DALZ8501	20.0	10.0	7.5	52.5	57.5	77.5	76.3	77.3	88.8
DALZ8502	60.0	42.5	45.0	67.5	40.0	77.5	72.5	73.8	85.0
DALZ8503	57.5	80.0	50.0	90.0	90.0	87.5	89.3	90.8	96.8
DALZ8504	90.0	60.0	30.0	92.5	90.0	87.5	98.0	96.5	91.3
DALZ8505	87.5	90.0	42.5	85.0	87.5	72.5	96.5	93.3	88.8
DALZ8506	85.0	80.0	45.0	85.0	87.5	85.0	97.3	94.0	93.3
DALZ8507	85.0	82.5	85.0	87.5	90.0	72.5	96.0	95.8	94.0
DALZ8508	80.0	70.0	25.0	82.5	75.0	70.0	71.0	78.8	94.8
DALZ8510	87.5	85.0	87.5	87.5	82.5	80.0	97.5	92.5	93.3
DALZ8511	92.5	95.0	75.0	92.5	87.5	92.5	97.8	96.3	93.5
DALZ8512	40.0	82.5	45.0	80.0	77.5	75.0	83.8	87.5	81.3
DALZ8513	70.0	82.5	45.0	77.5	80.0	35.0	96.0	94.5	93.3
DALZ8514	40.0	45.0	47.5	67.5	57.5	60.0	66.3	63.8	70.0
DALZ8515	90.0	95.0	75.0	90.0	92.6	85.0	96.5	96.8	70.8
DALZ8516	20.0	17.5	12.5	35.0	30.0	32.5	65.0	72.5	73.3
DALZ8517	87.5	77.5	80.0	87.5	80.0	75.0	92.3	90.0	91.3
DALZ8522	87.5	37.5	0.0	92.5	80.0	65.0	97.5	97.5	48.5
DALZ8523	80.0	85.0	40.0	35.0	35.0	35.0	70.0	70.8	69.5
DALZ8524	90.0	72.5	85.0	90.0	87.5	87.5	97.8	96.0	91.3
MSD entry[2]	46.2	36.7	57.5	29.9	26.3	36.8	22.3	21.5	44.2

[1] Irrigation levels of high, intermediate, and none are equivalent to 87, 29, and 0% of the irrigation volume at the line source, respectively.
[2] MSD entry = Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

Table 10. Percentage of the plot that is weed cover (not of the variety planted) for March 29, 1991, on LGIS zoysiagrasses at TAES, Dallas, Texas.

Entry	High[1]	Inter.	None
Belair	6.8	15.5	13.8
Cashmere	10.5	13.5	38.8
Emerald	22.3	12.5	11.8
El Toro	8.3	7.5	10.3
K. common	8.5	31.3	37.5
Meyer	15.8	18.5	31.3
FC13521	16.3	15.0	21.3
DALZ8501	12.5	14.3	36.3
DALZ8502	14.8	18.8	30.0
DALZ8503	12.5	18.3	48.8
DALZ8504	9.6	23.3	52.5
DALZ8505	21.0	15.5	61.3
DALZ8506	18.8	12.3	32.5
DALZ8507	9.3	7.3	12.3
DALZ8508	8.3	7.8	15.5
DALZ8510	7.5	6.3	19.3
DALZ8511	6.5	13.0	24.3
DALZ8512	6.5	5.5	15.8
DALZ8513	40.0	26.3	41.3
DALZ8514	10.8	8.5	13.0
DALZ8515	16.8	36.3	53.8
DALZ8516	16.8	18.5	22.5
DALZ8517	9.0	8.0	40.0
DALZ8522	32.5	31.3	31.3
DALZ8523	41.3	58.8	46.3
DALZ8524	27.5	25.5	27.3
MSD entry[2]	22.4	23.3	22.0

[1] Irrigation levels of high, intermediate, and none are equivalent to 87, 29, and 0% of the irrigation volume at the line source, respectively.
[2] MSD entry = Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

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.

PR-4891

Creeping Bentgrass Shoot Hydration Environmental Stress Response and Heritability

V.G. Lehman and M.C. Engelke

Introduction

Genetic improvement for adaptation to stress is dependent on identification of physiological attributes directly or indirectly associated with improved plant performance in the field or stress environment. Selection criteria must be developed to effectively assess large populations with a sizeable number of samples for heritable prediction attributes (Blum 1988). Genetic improvement of creeping bentgrass dehydration and supraoptimal temperature stress resistance would enhance its use in warmer areas of the transition zone.

Duff and Beard (1974) examined creeping bentgrass (*Agrostis stolonifera* L.) at five day-night temperature regimes of 20-10, 25-15, 30-20, 35-25, and 40-30 °C, and they found a 67 percent increase in dry weight of leaf blade tissue between the 20-10 and 40-30 °C regime. A large decrease in total dry weight of leaves occurred at 35-25 and 40-30 °C. Sub-irrigated bentgrass plants with roots in soil zones with supraoptimal moisture content did not incur wilt during heat stress periods, while sprinkler irrigated plants required cooling by syringing (Krans and Johnson 1974). Krans and Johnson suggested plants with more extensive root systems avoided the secondary, heat-induced dehydration stress. Becwar et al. (1983) used electrolyte leakage to determine the effect of water stress (imposed by polyethylene glycol (PEG)) on heat tolerance in seedlings of four turfgrass species. They determined that water stress did not increase in vitro heat tolerance of the turfgrasses, including creeping bentgrass.

Maintenance of water content has been associated with improved drought resistance in wheat (*Triticum aestivum* L.) where it was found to be a heritable character (Dedio 1975). Tischler and Voigt (1990) explored water content of 19 weeping lovegrass (*Eragrostis curvula* Schrad.) genotypes, and found with the exception of one subgroup, boer lovegrass (*Eragrostis curvula* Nees), that a higher water content was associated with a slower rate of leaf rolling. Blum and Ebercon (1981) compared the dehydration and heat tolerances of 66 wheat cultivars in 1978 and 77 cultivars in 1979 by measurement of electrolyte leakage. No significant correlation was found between injury by heat and injury by dehydration in wheat. Maximum separation in percent injury occurred under favorable moisture conditions.

The objectives of these studies were to: 1) determine if increased shoot hydration was associated with creeping bentgrass survival in response to elevated soil temperatures; 2) determine the relationship in plant stress response between soil dehydration and elevated soil temperatures as measured by shoot hydration; 3) estimate the heritability of shoot hydration in creeping bentgrass.

Materials and Methods

Glasshouse - In 1985, a population of 'Seaside' creeping bentgrass was exposed to supraoptimal soil temperatures as a selection pressure at the Texas Agricultural Experiment Station (TAES) Dallas, Texas. Seaside,a highly heterogeneous population of plants was released by the Oregon Agricultural Experiment Station, in 1936. Eighty plants which survived soil temperatures in excess of 39 °C for over 21 days (Engelke et al. 1985) were designated as Population A.

Rooted plugs of Population A and of randomly selected plants from Seaside, approximately 1 cm in diameter, were planted in 9 x 9 x 8 cm square plastic cups in a media composed by volume of 80 percent fine, washed, noncalcarious sand (97percent which passed US. sieve size no. 30) and 20 percent peat-vermiculite soil mix. The plants were trimmed to 3.8 cm height every 2 weeks prior to exposure to elevated soil temperatures. The plants were fertilized with 49, 6, and 26 kg ha^{-1} of N, P, and K, respectively, each month using 28-8-18 fertilizer, split into two applications.

Hydration determinations were made in replicate studies over time: 8 November 1988, 7 February 1989, 14 April 1989, 12 June 1989, 19 June 1989, 3 August 1989, and 14 August 1989. The study conducted in November contained six clones of Population A and seven of Seaside. The other studies included 12 clones of Population A and Seaside, randomly selected for each study from the population of 80 plants of Seaside and Population A. Each study was conducted as a randomized complete block design with four replications. The data were combined for analysis across studies to estimate population performance across environments, with the analysis of variance conducted with all factors random (McIntosh 1983). To determine that assumptions underlying the analysis of variance were not violated, residuals were plotted against predicted values (Draper and Smith 1981).

The clones were arranged on a glasshouse bench for 28 days of elevated soil temperatures. An insulated lead heat cable was used to maintain elevated soil temperatures. The cable was covered with 5 cm of sand in the bottom of a bench with the pots placed on the sand. Soil temperatures were elevated by 5 °C each day for up to 7 days to reach the desired temperature. Soil temperatures were determined at eight random locations 5 days per week at approximately 0830 h at 8 cm soil depth with a digital thermometer. The mean soil temperature was determined for each study (Table 1). Two tensiometers were placed in pots of similar plant material, which were not evaluated for hydration, and monitored daily. The plants and soil were drenched daily with tap water, and exhibited no visual signs of moisture stress. Ambient temperatures were monitored with a recording thermograph (Table 1). After 4 weeks of elevated soil temperatures, lengths of the three longest stolons per plant from each replication were determined. Three leaves from different stolons, third youngest from the tip, were measured with digital calipers for blade width and length. Width was determined at the widest portion of the leaf blade, and length was measured from the collar to the leaf tip. Approximate 0.2 g samples of fresh tissue were cut from the shoot system of each plant (including leaf, sheath, and stem tissues), weighed, oven dried at 50 °C for 48 hours, and weighed again. Hydration was calculated as ([wet weight-dry weight]/dry weight).

Ten parental clones were placed in pollination isolation in Tangent, Oregon in 1987, with half-sib seed harvested by maternal parent in 1988. Seeds were germinated to develop progeny plants of each maternal parent. In February 1990, stolon cuttings of the parental clones and the progeny were propagated in the sand, peat-vermiculite soil in 1.8 x 1.8 x 2.6 cm containers. Each replication contained two pots of a parental clone and five half-sib, maternal progeny of each of the 10 parents. The plants were arranged in a randomized complete block design with four replications. On 10 April prior to heat stress, samples were obtained from the parents and progeny and evaluated for hydration as above, and repeated after 2 and 4 weeks of soil temperature stress. Mean soil temperature was 35.0 °C at approximately 0830 h for the course of the study. Mean ambient temperatures were 21.0, 25.8, and 21.9 °C at 0800 h, daytime maximum, and 2400 h, respectively.

Table 1. Mean ambient and soil temperatures of seven separate glasshouse studies conducted in 1988-89 (Max. = maximum temperature for the day), averaged across days for each study.

Study	Temperature			
	Soil	Ambient		
	°C			
		h 0800	Max.	h 2400
8 Nov.	29.3	18.4	29.1	21.0
7 Feb.	34.1	18.6	26.4	16.8
14 Apr.	34.5	18.4	24.4	17.9
12 June	37.5	20.7	28.7	21.1
19 June	34.5	20.6	28.9	21.1
3 Aug.	36.6	22.1	31.7	23.1
14 Aug.	34.5	21.0	31.1	22.6

Sampled at approximately 0830 h daily, close to mean low ambient air temperature.

This study was repeated in August-September with the same parents and a different set of half-sib progeny, and with temperature stress extended for 6 weeks. Mean soil temperature was 35.4 °C at approximately 0830 h for the course of the study. Mean ambient temperatures were 26.5, 36.6 and 25.3 °C at 0800 h, daytime maximum, and 2400 h, respectively.

Growth Chamber - The 10 parental clones of creeping bentgrass, used in the parent-progeny studies, were established by stolon cuttings in pots filled with fritted clay. Three g of a slow-release, plastic-coated fertilizer (20-10-17 N, P, and K, respectively) were mixed with approximately 900 g of fritted clay. The media was placed in plastic pots, 16.5 x 12.7 cm in size, drenched with water, and planted with vegetative sprigs during 20-21 August 1989. The plants, maintained in a glasshouse prior to the study, were trimmed twice weekly to 1.3 cm, with clippings removed, and watered as needed to promote growth. The plants were fertilized at a rate of 25, 3, and 26 kg ha^{-1} for N, P, and K, respectively, using a soluble 20-10-17 formulation every 2 weeks. Experimental design was a randomized complete block design with four replications. The study was conducted with a 12 h photoperiod in a growth chamber illuminated with a coated metal arc lamp suspended 1.5 m from bench height. A pan of water was placed beneath the bench to maintain a mean relative humidity of 58.7 percent. Plants were placed in the growth chamber for 3 days prior to treatment. The plants were watered to soil saturation, with water dripping freely from the pot bottom, drained for 4 hours to eliminate free water, sealed with waterproof tape for moisture retention, and weighed to the nearest 1 g. Starting on 18 November 1989, canopy temperatures were recorded with an infrared gun (Everest Scientific Model 210, Everest Scientific, Tustin, California) for 17 days. The gun was mounted on a standard so the target measurement was approximately 15 cm diameter. Daily mean canopy temperatures were determined by averaging 12 observations per pot per day. On 28 November after visually observing severe dehydration stress, the pots were refilled to 95 percent (±2 percent) of the original combined weight of the pot, plant, water, and fritted clay for a second drydown period.

Results and Discussion

Glasshouse - Elevated soil temperatures generated selection pressure on Seaside, as evidenced by comparing Population A to Seaside (Table 2). Population A, selected for soil temperature stress resistance, contained 10 percent more water per g of dry tissue weight than Seaside. This suggests that the plants from Population A were either accumulating more moisture, or were more efficient at maintaining higher water content. Maintenance of water content may be effected by a dehydration avoidance mechanism such as increased water uptake via an extensive root system (Sullivan and

Table 2. Mean stolon lengths, leaf widths and lengths, and hydration of two glasshouse grown creeping bentgrass populations, averaged across seven studies.

	Character			
	Stolon	Leaf Blade		
Population	Length	Width	Length	Hydration
	mm			g
A	138.6	2.05	44.1	2.79*
Seaside	150.2	2.02	43.6	2.53

*Mean population values are significantly different using least-square means (p<=0.05).

Ross 1979), or by closing of stomata to conserve water (Levitt 1980). The creeping bentgrasses in our studies were grown specifically in containers which would prohibit rooting depth advantages between plants with genetically increased root length, documented as present in Population A (Lehman 1990). No major shift in plant size or shoot morphology that could contribute to survival, such as increased leaf blade width or length, was distinguished (Table 2).

When 10 creeping bentgrass parents and their half-sib progeny were compared for hydration, there was no significant relationship between parents and progeny until the plants were placed under soil temperature stress (Tables 3 and 4). Parent and progeny hydration was significantly correlated after 2 and 4 weeks of elevated soil temperatures (Tables 3 and 4). When Asay et al. (1974) examined tall fescue clones under two levels of moisture stress, there was not a significant correlation between clonal means at the two water stress levels. Asay et al. concluded that selection should be practiced under a range of conditions to which the resultant variety is most likely to be subjected. Selection for improved bentgrass shoot hydration should be conducted under high soil temperature stress.

The regression of offspring on parent hydration was estimated to be 0.49 (Fig. 1) in the April-May study. The narrow-sense heritability, determined by multiplying the slope by 2 (Becker, 1985) with limits between 0 and 1, was estimated at 0.98 and 1.0 in the April-May study and the August-September study (Fig. 2), respectively for creeping bentgrass shoot hydration in these studies. Dedio (1975) was effective in selecting for percent water content in wheat, with a significant increase in the fourth generation of 0.71 percent moisture content in the selected plants over the non-selected hybrids, illustrating the heritability of water content in wheat.

Hydration of the 10 parental clones, measured at 4 weeks in each of the studies, was significantly rank correlated (r(s)=0.68, p<=0.05), suggesting stability of the character across environments. Stability of character across environments may hasten progress that may be made through a breeding effort. In the August-September 1989 study, there was no significant correlation between parent and progeny hydration after 6 weeks of stress. By visual observation, the plants were showing a lack of growth, suggesting the soil temperatures may have pushed the plants beyond any levels of discernable stress resistance.

Growth Chamber - Significant differences existed in mean canopy temperatures among the creeping bentgrass clones when held under soil moisture stress (Table 5). A significant rank correlation (r(s)=0.65,

Table 3. Hydration of 10 parental (Par) creeping bentgrass clones and their half-sib progeny (Prog) under 0, 2, and 4 weeks soil temperature stress, April-May 1990.

	Hydration Number Weeks Stress					
	0		2		4	
Clone	Par	Prog	Par	Prog	Par	Prog
	g water/g dry shoot tissue					
404A	3.71	3.15	3.55	3.05	2.90	2.68
204R	3.60	3.05	3.38	2.95	3.05	2.78
703A	3.51	3.46	3.25	3.30	3.29	3.15
505A	3.49	3.15	3.40	2.97	2.92	2.64
401R	3.46	2.96	2.70	2.75	2.04	2.53
604R	3.40	2.89	3.13	2.71	2.56	2.43
307A	3.29	3.31	3.17	2.90	2.54	2.58
503A	3.24	2.98	3.31	3.02	2.51	2.64
304R	3.20	2.95	3.08	2.76	2.47	2.55
2735	3.45	3.05	3.33	3.09	2.19	2.28
LSD+	0.47	0.21	0.44	0.23	0.34	0.17
r(s)	0.45ns		0.65*		0.78*	

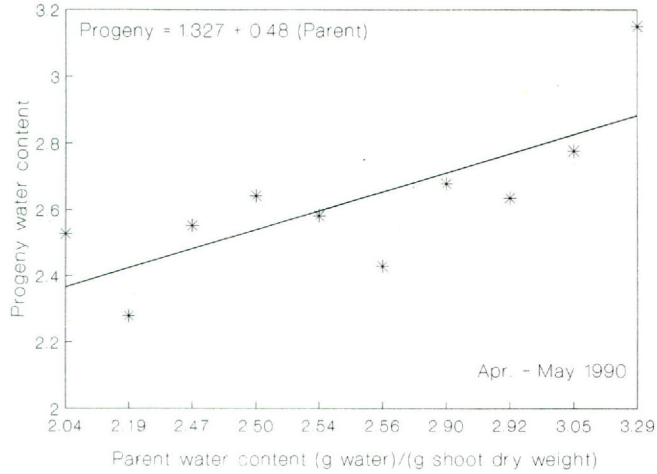
+F protected LSD (p<=0.05).
r(s) Spearman rank correlation coefficients for line ranks between parent and progeny hydration, ns=non-significant.
*Significance at the 0.05 level.

Table 4. Shoot hydration of 10 parental (Par) creeping bentgrass clones and their half-sib progeny (Prog) under 0, 2, 4, and 6 weeks soil temperature stress, July - August 1990.

	Hydration Number Weeks Stress							
	0		2		4		6	
Clone	Par	Prog	Par	Prog	Par	Prog	Par	Prog
	g water/g dry shoot tissue							
404A	3.14	2.45	2.41	1.87	2.52	2.23	2.46	2.09
204R	2.70	2.19	2.16	1.68	2.02	1.83	2.32	1.75
703A	2.67	2.29	2.05	1.69	2.18	1.86	2.08	2.03
505A	3.04	2.42	2.24	1.96	2.02	2.09	2.38	2.22
401R	2.24	2.19	2.00	1.63	1.84	1.87	2.08	1.91
604R	1.98	1.86	1.86	1.57	1.81	1.59	1.94	1.85
307A	2.64	2.18	2.33	1.95	2.11	2.14	2.22	2.26
503A	2.47	2.42	1.87	1.71	1.72	1.81	1.93	1.93
304R	2.19	2.20	1.89	1.70	1.89	2.00	2.21	2.15
2735	2.32	2.12	1.70	1.66	1.61	1.62	1.78	1.90
LSD+	0.23	0.26	0.26	0.19	0.29	0.10	0.28	0.20
r(s)++	0.44ns		0.68*		0.72*		0.46ns	

+F protected LSD (p<=0.05).
r(s)++ Spearman rank correlation coefficients for line ranks between parent and progeny hydration, ns=non-significant.
*Significance at the 0.05 level.

p<=0.05) was found between hydration of parental clones under soil moisture stress and soil temperature stress from the April-May study. This is in contrast to Blum and Ebercon's (1981) work with wheat where no correlation was found between dehydration and heat tolerance. This suggests that in creeping bentgrass, the response to temperature stress is related to hydration, with avoidance of heat stress by maintenance of water content.



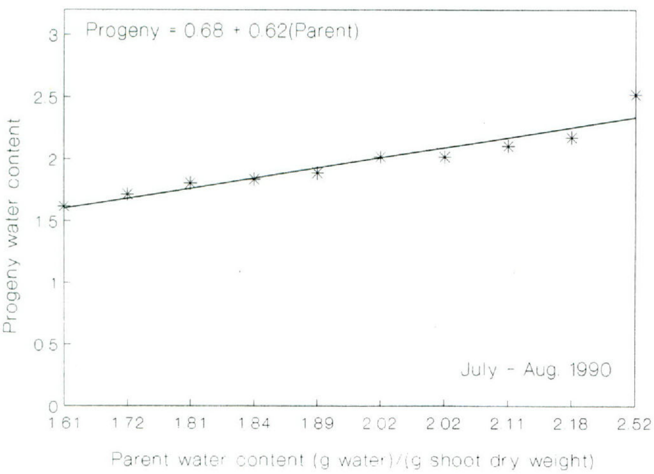


Figure 1. Hydration of parental creeping bentgrass clones and 20 progeny of each measured in two glasshouse studies.

Table 5. Correlation of creeping bentgrass shoot canopy temperatures under soil dehydration and shoot hydration under soil temperature stress, April-May, 1990.

Clone	Canopy Temperature		4 Week Hydration
	°C	rank	
307A	39.2	10	6
2735	29.2	9	9
304R	29.1	8	8
505A	29.1	7	3
503A	29.0	6	7
401R	29.0	5	10
404A	28.8	4	4
604R	28.8	3	5
703A	28.6	2	1
204R	28.4	1	2
LSD+	0.6		
r(s)++			0.65*

+F protected LSD (p<=0.05).
r(s)++ Spearman rank correlation coefficients for line ranks between canopy temperatures and shoot hydration at 4 weeks (April-May 1990 study).
*Significance at the 0.05 level.

Shoot hydration was positively associated with increased survival of creeping bentgrass plants under soil temperature stress in these studies. Hydration was determined to be a highly heritable trait in this population of bentgrass. As one mechanism of stress resistance in creeping bentgrass, screening for shoot hydration could be integrated into a breeding program for improved plant performance. The technique of determining hydration is sufficiently rapid to permit examination of large numbers of plants, necessary in a breeding program.

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Performance of Four Warm-season Turfgrass Genera Cultured in Dense Shade I. *Buchloe dactyloides* and *Eremochloa ophiuroides*

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

Introduction

Buffalograss (*Buchloe dactyloides*) and centipedegrass (*Eremochloa ophiuroides*) are commonly used in sunny, dry locations in the Great Plains states and in the southeastern United States, respectively. They are not normally grown in shaded conditions, but the advent of new varieties of these species increases the likelihood of one of these varieties being adapted to shade culture. This report, the first in a series of three on the performance of warm-season turfgrasses cultured in shade (Morton, et al. 1992a, 1992b), concerns such an evaluation.

Materials and Methods

In cooperation with the City of Richardson, Texas, Parks and Recreation Department, the evaluation trial was planted on May 24, 1990, at Cottonwood Park. The planting site was in dense shade created by a stand of live oaks and cedar elms (only about 15 percent of full sunlight was available under the tree canopy). Seven buffalograss lines and seven centipedegrass lines were planted as 10 cm plugs on 0.6 m centers in a randomized complete block design with four replications. The seven buffalograsses included five experimental Nebraska lines, a seeded variety, 'Texoka', and the Dallas-developed 'Prairie'. Among the seven centipedegrasses were commercial cultivars 'Tennessee Hardy' and 'Centennial'. Irrigation was provided as needed to prevent drought stress.

Turfgrass canopy density was estimated by scoring plants on a one to nine scale with nine equalling most dense (minimal interfoliar air space). Color was evaluated on the same numbering scale, in which nine indicated dark green, and five was the lowest acceptable green quality. Spread was determined by measuring the longest stolon length beyond the perimeter of the original plug.

ANOVA was used to find differences between the varieties within a genus. Where the ANOVA indicated $P<0.05$, Waller-Duncan mean separation tests were performed, and the minimum significant difference (MSD) for the data set was calculated. Where the ANOVA indicated $P>0.05$, no minimum significant difference was calculated.

Results

For all buffalograss entries, good density during summer was observed most frequently in early summer (Table 1). Experimental line NEB84315 maintained

Table 1. Mean canopy density[1] for buffalograss and centipedegrass lines cultured under dense shade in Richardson, Texas during summer 1990.

	Canopy Density								
Entry	14 June	27 June	18 July	1 Aug.	21 Aug.	6 Sept.	21 Sept.	Avg.	PS[2]
Buchloë									
Prairie	3.5a	3.0	2.8	2.5	4.3	3.3	3.7	3.2	1
Texoka	5.0a	5.0a	4.5a	4.5a	4.3	4.8a	4.0	4.6a	6
NEB84304	5.0a	5.3a	4.3a	4.5a	4.3	4.0	3.5	4.4a	5
NEB84315	5.0a	5.0a	5.0a	4.3a	4.8	5.8a	4.0	4.8a	6
NEB84409	2.8a	3.6	3.5	3.5	4.3	3.0	3.5	3.4	1
NEB84609	4.3a	4.0a	4.8a	5.0a	4.0	4.3a	3.3	4.2	5
NEB85378	2.3	2.8	3.3	3.5	3.0	4.3a	2.8	3.1	1
MSD entry[3]	2.3	1.3	1.4	1.4	n.s.	1.6	n.s.	0.5	
Avg	4.0	4.0	4.0	4.0	4.1	4.2	3.5	4.0	
Eremochloa									
AC44	2.5	2.5	2.8	2.5	2.8	3.3	2.5	2.7	0
Centennial	2.0	1.8	2.8	2.5	2.0	1.5	2.5	2.1	0
Common	2.3	2.3	3.5	3.5	3.3	3.0	2.5	2.9	0
TennesseeHardy	2.3	2.0	3.3	3.0	2.0	2.5	2.3	2.5	0
CG8501	3.0	2.8	3.5	4.0	4.0	4.5	3.5	3.6a	1
CG8502	2.3	2.3	3.0	3.3	2.8	3.5	3.0	2.9	0
CG8503	2.3	2.0	3.3	3.5	2.5	2.5	2.3	2.7	0
MSD entry	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.5	
Avg	2.4	2.2	3.1	3.2	2.8	3.0	2.7	2.8	

[1] Turfgrass canopy density was estimated by scoring plants on a one to nine scale with nine equalling most dense (minimal interfoliar air space), and five is the lowest acceptable density.

[2] PS is the phenotypic stability indicating the number of times the entry ranked in the highest statistically significant group.

[3] MSD is the Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

good density longer than other entries. All seven entries maintained their density over the growing season, with some slight thinning in NEB84304 and NEB84315. Density was poor quality for most entries at all dates noted.

Centipedegrass canopy density was poor for all entries (Table 1). Experimental line CG8501 was observed to have the best density of the centipedegrass entries, which was only marginal quality. This peak was observed during late summer.

Table 2. Mean color quality[1] for buffalograss and centipedegrass lines cultured under dense shade in Richardson, Texas during summer 1990. Ratings were noted September 21, 1990, after the first fall rain and 4 months after planting.

	Color quality		
Entry	21 Sept.	Entry	21 Sept.
Buchloë		*Eremochloa*	
Prairie	7.7	AC44	7.8
Texoka	6.5	Centennial	5.0
NEB84304	8.8	Common	7.8
NEB84315	6.5	Tennessee Hardy	7.3
NEB84409	7.3	CG8501	8.0
NEB84609	8.3	CG8502	7.3
NEB85378	7.0	CG8503	7.7
MSD entry[2]	1.0	MSD entry	n.s.
Avg	7.4	Avg	7.4

[1] Color was evaluated on a one to nine scale, in which nine indicated dark green, and five was the lowest acceptable green quality.
[2] MSD is the Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

The color at the final note date (September 21, 1990) was good to excellent for all buffalograss and centipedegrass entries except the centipedegrass standard variety, 'Centennial', which had marginal color quality (Table 2).

Four of the seven buffalograss entries produced stolons, of which NEB84304 and NEB84409 produced the longest stolons (Table 3). Among centipedegrass entries, two experimental lines, CG8501 and CG8502, and one commercial line, AC44, produced stolons. The longest buffalograss stolon was 20.6 cm by NEB84304, and the longest centipedegrass stolon was 7.6 cm by AC44, both of which are short when compared to stolon lengths generated by St. Augustinegrasses, yet show the positive potential of selected lines of these genera to spread when cultured in the shade.

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2. Morton, S.J., M.C. Engelke, and R.H. White. 1992b. Performance of four warm-season turfgrass genera cultured in dense shade. III. *Zoysia* spp. Texas Turfgrass Research-1991. Texas Agric. Exp. Sta. PR-4894. pp. 51-52.

Table 3. Vegetative spread, as represented by the average longest stolon (cm), for each of the buffalograss and centipedegrass lines cultured under dense shade in Richardson, Texas during summer 1990.

	Length, cm								
Entry	14 June	27 June	18 July	1 Aug.	21 Aug.	6 Sept.	21 Sept.	Avg.	PS[2]
Buchloë									
Prairie	0.0	3.2	2.5	4.8	4.8	5.1	6.7	3.9a	1
Texoka	2.2	1.9	0.0	4.8	5.4	6.0	6.4	3.8a	1
NEB84304	0.0	0.0	0.0	0.0	9.2	8.9	20.6	5.5a	1
NEB84315	0.6	0.0	0.0	0.0	1.0	0.0	0.0	0.2	0
NEB84409	1.9	2.3	3.5	5.1	10.2	7.0	18.1	6.7a	1
NEB84609	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.3	0
NEB85378	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
MSD entry	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	3.7	
Avg	0.7	1.1	0.2	2.1	4.4	3.9	7.7	2.9	
Eremochloa									
AC44	2.5	0.6	0.0	0.0	0.0	5.7	7.6	2.4a	1
Centennial	2.2	0.0	2.2	0.0	0.0	0.0	0.0	0.6	0
Common	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0
Tennessee Hardy	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.5	0
CG8501	2.2	2.5	3.2	3.8	5.1	4.8	6.0	3.9a	1
CG8502	2.5	2.2	0.0	1.3	3.5	1.9	3.8	2.2a	0
CG8503	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
MSD entry	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	2.2	
Avg	1.4	0.8	0.0	0.7	1.2	2.3	2.5	1.4	

[1] MSD is the Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).
[2] PS is the phenotypic stability indicating the number of times the entry ranked in the highest statistically significant group.

Performance of Four Warm-season Turfgrass Genera Cultured in Dense Shade II. *Stenotaphrum secundatum*

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

Introduction

St. Augustinegrass (*Stenotaphrum secundatum*) varieties are popular as shade-grown turfgrass in much of the southern United States. As a part of the National Turfgrass Evaluation Program, this study was designed to identify the relative shade tolerance of commercial and elite experimental varieties of St. Augustinegrass. This report is the second in a series of three reports on warm-season turfgrass performance under shade (Morton, et al., 1992a, 1992b).

Materials and Methods

The location, protocol, and data collection method has been previously described (Morton, et al. 1992a). Planted were the 26 entries of the 1989 NTEP St. Augustinegrass trial and two additional Dallas developed experimental lines. The NTEP entries included commercial cultivars 'Raleigh', 'Sunclipse', 'Bitterblue', and 'Floratam'.

Results

Acceptable turf canopy density was observed for six experimental lines, including Dallas developed DALSA8402, but none of the commercial lines produced acceptable canopy density during the summer growing season (Table 1). Commercial line Jade had nearly acceptable canopy density by late summer. Three of the other five experimental lines exhibiting acceptable turf canopy density, FX313, FX33, and M1 showed increases in density during the experiment, and by late summer had the best densities of the St. Augustinegrass varieties tested.

Foliar color quality improved during the growing season for four commercial varieties and seven experimental lines of St. Augustinegrass (data not shown). Most improved of these was S67-72-107, which was rated at 6.8 upon planting, and was rated at 8.8 at the end of the study. By the end of the growing season, and the end of the

Table 1. Mean canopy density[1] for St. Augustinegrasses cultured under dense shade in Richardson, Texas during summer 1990.

	Canopy Density								
Entry	14 June	27 June	18 July	1 Aug.	21 Aug.	6 Sept.	21 Sept.	Avg.	PS[2]
Bitterblue	2.0	2.3	2.5	3.3	2.8	3.3	3.0	2.7	0
Dalsa8401	2.5	3.0	4.3a	4.0a	3.8a	4.8a	4.0	3.8	4
Dalsa8402	5.8a	5.5a	4.6a	5.5a	4.5a	4.6a	4.8a	5.0a	8
Dalsa8403	4.0	4.3a	5.0a	5.3a	4.5a	3.8	4.0	4.4	4
Delmar	2.3	2.5	4.0a	3.8a	3.3	4.3a	3.5	3.3	3
Floralawn	2.0	2.3	3.3	3.3	3.0	3.0	3.3	2.9	0
Floratam	2.5	1.8	2.8	3.3	3.0	3.0	2.8	2.7	0
FX10	2.8	2.5	2.8	3.3	3.8a	4.0	3.8	3.3	1
FX261	2.8	2.8	3.3	3.3	3.5a	4.0	3.5	3.3	1
FX313	3.0	3.0	4.3a	5.0a	5.0a	6.3a	6.0a	4.6a	6
FX33	3.3	3.8	4.3a	5.0a	4.0a	5.3a	4.8a	4.3	5
FX332	2.8	2.5	2.3	3.3	3.5a	4.0	3.5	3.1	1
Jade	1.3	1.8	2.8	3.3	3.4	4.8a	4.5	3.1	1
Mercedes	2.0	2.0	3.0	3.3	3.3	4.3a	3.5	3.0	1
M1	2.5	2.8	3.5	3.8a	4.5a	5.5a	5.0a	3.9	4
MSA2	2.5	2.8	2.8	2.3	2.8	3.8	3.5	2.9	1
MSA11	2.3	2.0	3.0	3.3	3.8a	4.3a	3.5	3.2	2
MSA20	2.8	2.0	3.5	3.8a	4.3a	3.7	3.5	3.3	2
Raleigh	2.5	2.8	3.0	2.5	2.5	3.5	2.5	2.8	0
Seville	1.5	2.0	2.3	2.5	2.8	4.0	3.8	2.7	0
Sunclipse	2.3	2.0	3.0	3.3	3.5a	4.3a	4.0	3.2	2
S671138	2.5	2.5	3.0	2.8	3.0	4.0	2.8	2.9	0
S6772107	2.8	2.5	3.5	3.5a	3.8a	5.0a	4.0	3.6	3
S712090	1.8	2.0	2.8	2.7	3.5a	3.5	3.3	2.8	1
S71770	2.3	2.3	2.5	4.0a	3.0	3.3	3.3	2.9	1
TR610	2.5	2.5	3.0	4.0a	4.3a	5.0a	4.0	3.6	3
TR63	3.0	2.3	3.0	4.3a	3.8a	4.7a	4.0	3.5	3
MSD entry[3]	1.2	1.3	1.3	2.0	1.4	2.1	1.3	0.5	
Avg.	2.6	2.6	3.2	3.6	3.5	4.2	3.8	3.4	

[1]Turfgrass canopy density was estimated by scoring plants on a one to nine scale with nine equalling most dense (minimal interfoliar air space), and five is the lowest acceptable density.

[2]PS is the phenotypic stability indicating the number of times the entry ranked in the highest statistically significant group.

[3]MSD is the Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

Table 2. Mean color quality[1] for St. Augustinegrasses cultured under dense shade in Richardson, Texas during summer 1990. Ratings were noted September 21, 1990, after the first fall rain and 4 months after planting.

	Color quality		
Entry	21 Sept.	Entry	21 Sept.
Bitterblue	8.0	Mercedes	8.0
Dalsa8401	7.8	M1	8.0
Dalsa8402	8.0	MSA2	8.0
Dalsa8403	7.7	MSA11	7.8
Delmar	8.3a	MSA20	7.5
Floralawn	7.0	Raleigh	7.3
Floratam	6.8	Seville	8.0
FX10	7.0	Sunclipse	8.0
FX261	8.3a	S671138	8.3a
FX313	9.0a	S6772107	8.8a
FX33	7.3	S712090	7.8
FX332	8.0	S71770	8.3a
Jade	8.5a	TR610	8.3a
		TR63	8.3a
		MSD entry[2]	0.8
		Avg	7.9

[1] Color was evaluated on a one to nine scale, in which nine indicated dark green, and five was the lowest acceptable green quality.
[2] MSD is the Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

experiment, excellent color quality was observed of seven experimental lines, including FX313, S67-72-107, and of two commercial varieties, 'Delmar' and 'Jade' (Table 2).

Generally, St. Augustinegrasses spread quickly and extensively. At the end of the experiment, on September 21, 1990, eight of the 27 St. Augustinegrasses had stolons at least 30 cm long, of which 'Sunclipse' had the longest stolons (= 60 cm) (Table 3). Five of these eight were commercial lines and three were experimental lines, which of the latter included S71770, TR610, and MSA11. The poorest development was observed for FX33, FX10, and the commercially available 'Bitterblue'.

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2. Morton, S.J., M.C. Engelke, and R.H. White. 1992b. Performance of four warm-season turfgrass genera cultured in dense shade. III. *Zoysia* spp. Texas Turfgrass Research-1991. Texas Agric. Exp. Sta. PR-4894. pp. 51-52.

Table 3. Vegetative spread, as represented by the average longest stolon (cm), for each of the St. Augustinegrass lines cultured under dense shade in Richardson, Texas during summer 1990.

	Length, cm								
Entry	14 June	27 June	18 July	1 Aug.	21 Aug.	6 Sept.	21 Sept.	Avg.	PS[2]
Bitterblue	5.1	1.9	1.0	0.0	2.5	5.1	5.4	3.0	0
Dalsa8401	9.2a	4.4	5.7	6.4a	2.9	11.4	10.8	7.4	2
Dalsa8402	5.1	3.5	3.8	6.4a	8.3	34.0	20.0	12.1	1
Dalsa8403	1.3	0.0	0.6	7.0a	3.4	12.4	7.9	4.7	1
Delmar	8.3a	6.7a	15.9a	21.9a	15.6a	32.7	31.8	19.0	5
Floralawn	13.0a	8.3a	9.8a	8.9a	12.4a	24.8	15.2	13.2	5
Floratam	11.7a	2.9	8.6a	3.8a	1.0	4.5	1.9	4.9	3
FX10	4.8	1.3	1.0	0.0	1.3	0.0	0.0	1.2	0
FX261	10.8a	15.6a	22.9a	14.4a	26.4a	33.3	23.2	21.2	5
FX313	7.0a	4.8	7.3a	6.0a	12.4a	19.7	21.9	11.3	4
FX33	4.1	1.0	1.6	0.0	0.0	1.9	4.1	1.2	0
FX332	12.4a	12.4a	3.2	3.2a	11.1	17.2	21.6	11.6	3
Jade	8.3a	8.3a	14.9a	27.6a	40.9a	44.1	49.5	28.1a	6
Mercedes	7.3a	9.8a	19.7a	25.1a	27.9a	39.1	34.3	23.3a	6
M1	8.3a	9.2a	8.6a	15.6a	15.9a	21.9	25.7	15.0	5
MSA2	7.6a	9.5a	8.6a	5.1a	6.4	16.2	22.9	11.1	4
MSA11	6.4	8.3a	17.8a	17.4a	23.5a	33.0	32.4	20.0	4
MSA20	8.3a	7.0a	12.1a	19.4a	33.0a	24.1	29.5	18.9	5
Raleigh	7.0a	8.3a	24.1a	26.0a	33.7a	32.4	53.7	26.4a	6
Seville	7.3a	4.1	4.8	7.6a	9.5	11.1	13.0	8.2	2
Sunclipse	13.7a	15.6a	19.1a	28.3a	33.0a	47.9	60.0	31.1a	6
S671138	7.9a	8.6a	8.3a	10.8a	19.7a	27.6	28.6	15.9	5
S6772107	7.6a	7.0a	14.6a	17.2a	21.0a	25.4	28.3	17.3	5
S712090	7.3a	3.5	9.5a	16.9a	8.9	15.6	23.5	12.0	3
S71770	9.8a	11.4a	23.8a	30.2a	34.6a	52.4	54.6	31.0a	6
TR610	5.7	6.4	6.7	12.4a	20.0a	28.9	37.5	16.8	2
TR63	12.4a	11.7a	11.7a	10.8a	16.2a	3.4	15.6	12.0	5
MSD entry[1]	7.1	9.0	16.8	28.8	29.2	n.s.	n.s.	8.9	
Avg	8.1	7.1	3.8	12.8	16.8	23.1	24.9	14.8	

[1] MSD is the Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).
[2] PS is the phenotypic stability indicating the number of times the entry ranked in the highest statistically significant group.

Performance of Four Warm-season Turfgrass Genera Cultured in Dense Shade III. *Zoysia* spp.

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

Introduction

Typically tall fescue (*Festuca arundinacea*) and St. Augustinegrass (*Stenotaphrum secundatum*) are cultured as shade-grown turfgrass in Dallas, Texas, and much of the central southern United States. Interest has begun in increasing the variety of shade tolerant grass genera available to landscapers and homeowners, among which zoysiagrass (*Zoysia* spp.) has entered the market. Zoysiagrasses are considered intermediate among warm season grasses in their ability to persist under heavily shaded conditions. The objective of the study was to identify the relative shade tolerance of commercial and elite experimental lines of zoysiagrass. This report concludes a series of three reports on warm-season turfgrass performance under shade (Morton, et al. 1992a, 1992b).

Materials and Methods

The location, protocol, and data collection methods have been previously described (Morton, et al. 1992a). Twenty elite DALZ lines and commercial zoysiagrasses, including 'Meyer', 'Emerald', 'El Toro', 'FC13521', 'Korean Common', and 'Belair', and two accessions designated TAES3372 and 'Cashmere' were planted.

Results

Turf density scores provide a good indication of turfgrass shade tolerance (Table 1). DALZ8501, DALZ8503, DALZ8506, DALZ8507, DALZ8524, and Emerald had similar high mean turf density scores. Whereas, four of the commercially available entries, such as Korean Common and Meyer, and six of the experimental lines, including DALZ8505 and DALZ8522, had low mean turf density scores. The zoysiagrasses maintained higher mean turf density scores than the other warm-season turfgrass species overall.

Spread, as indicated by longest stolon length (Table 3), 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,

Table 1. Mean canopy density[1] for Zoysiagrass lines cultured under dense shade in Richardson, Texas during summer 1990.

	Canopy Density								
Entry	14 June	27 June	18 July	1 Aug.	21 Aug.	6 Sept.	21 Sept.	Avg.	PS[2]
Belair	6.3a	5.5	4.3	4.5	3.3	4.3	5.3a	4.8	1
Cashmere	6.0a	5.0	4.5	4.8	3.3	4.3	4.5	4.6	1
El Toro	6.0a	6.3	4.5	4.8	3.5a	4.0	4.5	4.7	2
Emerald	7.6a	7.5a	6.0	6.3a	4.5a	6.5a	6.3a	6.4a	7
FC13521	5.8a	6.0	4.3	5.0	3.8a	5.0a	4.5	4.9	3
Korean Common	5.0a	6.3	4.8	4.8	3.0	4.3	3.5	4.5	1
Meyer	7.0a	6.5	5.0	4.8	3.3	4.3	4.0	5.0	1
DALZ8501	7.3a	7.5a	5.5	6.8a	4.5a	6.5a	6.0a	6.3a	7
DALZ8502	6.6a	7.3a	5.0	5.0	4.3a	6.5a	5.0a	5.7	5
DALZ8503	7.3a	7.5a	6.3	6.5a	4.0a	6.3a	5.5a	6.2a	7
DALZ8504	7.3a	7.3a	5.8	6.0a	3.7a	4.5	4.5	5.6	4
DALZ8505	5.0a	5.8	4.3	4.5	2.8	4.0	3.5	4.3	1
DALZ8506	6.8a	7.5a	5.5	6.3a	4.5a	6.0a	6.0a	6.1a	7
DALZ8507	7.0a	7.3a	5.3	6.5a	4.5a	6.5a	5.5a	6.0a	7
DALZ8508	4.0	3.8	4.7	6.5a	4.0a	3.5	6.5a	4.4	3
DALZ8510	6.2a	6.8a	5.0	5.5	4.3a	5.0a	4.8	5.4	4
DALZ8511	5.8a	6.3	4.5	5.0	4.0a	4.8	4.3	4.9	2
DALZ8512	5.3a	4.3	3.8	4.0	3.2	4.3	4.5	4.1	1
DALZ8513	4.5a	4.0	3.5	4.3	3.0	4.0	4.5	4.0	1
DALZ8514	5.3a	5.5	5.0	5.7a	4.0a	4.8	5.3a	5.1	4
DALZ8515	7.3a	7.5a	5.5	5.5	3.5a	5.5a	5.0a	5.7	5
DALZ8516	7.0a	6.0	4.8	5.3	3.0	5.8a	4.5	5.2	2
DALZ8517	7.3a	7.3a	5.0	5.8a	4.6a	6.5a	4.5	5.8a	6
DALZ8522	3.8	2.8	3.3	3.3	2.3	2.5	2.8	3.0	0
DALZ8523	6.0a	5.3	4.3	4.5	3.5a	4.8	4.5	4.7	2
DALZ8524	7.4a	7.0a	5.8	5.8a	4.5a	6.3a	5.3a	6.1a	7
DALZ8701	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0
TAES3372	3.8	4.0	3.5	4.0	3.0	4.8	4.0	3.9	0
MSD entry[3]	3.2	1.8	2.0	1.2	1.2	1.6	1.5	0.7	
Avg	5.9	5.8	4.8	5.2	3.7	4.8	4.7	5.0	

[1] Turfgrass canopy density was estimated by scoring plants on a one to nine scale with nine equalling most dense (minimal interfoliar air space), and five is the lowest acceptable density.

[2] PS is the phenotypic stability indicating the number of times the entry ranked in the highest statistically significant group.

[3] MSD is the Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

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.

Table 2. Mean color quality[1] for Zoysiagrass lines cultured under dense shade in Richardson, Texas during summer 1990. Ratings were noted September 21, 1990, after the first fall rain and 4 months after planting.

	Color quality		
Entry	21 Sept.	Entry	21 Sept.
Belair	7.8	DALZ8508	8.0a
Cashmere	7.5	DALZ8510	7.5
El Toro	7.8	DALZ8511	7.0
Emerald	7.8	DALZ8512	7.5
FC13521	8.3a	DALZ8513	7.0
Korean Common	6.5	DALZ8514	8.0a
Meyer	6.8	DALZ8515	6.8
DALZ8501	8.0a	DALZ8516	8.8a
DALZ8502	8.0a	DALZ8517	7.8
DALZ8503	7.0	DALZ8522	7.0
DALZ8504	7.0	DALZ8523	8.0a
DALZ8505	6.5	DALZ8524	8.0a
DALZ8506	7.8	DALZ8701	0.0
DALZ8507	8.0a	TAES3372	8.0a
		MSD entry[2]	0.9
		Avg	7.5

[1] Color was evaluated on a scale of one to nine, in which nine indicated dark green, and five was the lowest acceptable green quality.
[2] MSD is the Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).

Four Species Comparison

An overall comparison of the four species reported in this report and Morton et al. (1992a, 1992b), shows St. Augustinegrass to have the best overall color and zoysia the poorest, although the average zoysia exhibited good green color when grown in the shade. St. Augustinegrass also had the best spread during the 3-month growing season. The other three generally did not extend beyond the initial crowns, yet these three exhibited the better canopy density than the average St. Augustine variety.

Future work will continue to explore the relative shade tolerance of zoysiagrasses grown perennially. Shade tolerance trials of the 1991 NTEP zoysiagrass and 1991 NTEP buffalograss trials will be established in late July 1992.

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2. Morton, S.J., M.C. Engelke, and R.H. White. 1992b. Performance of four warm-season turfgrass genera cultured in dense shade. II. *Stenotaphrum secondatum*. Texas Turfgrass Research-1991. Texas Agric. Exp. Sta. PR-4893. pp. 49-50.

Table 3. Vegetative spread, as represented by the average longest stolon (cm), for each of the Zoysiagrass lines cultured under dense shade in Richardson, Texas during summer 1990.

	Length, cm								
Entry	14 June	27 June	18 July	1 Aug.	21 Aug.	6 Sept.	21 Sept.	Avg.	PS[2]
Belair	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Cashmere	1.3	2.2	0.0	1.9a	0.0	0.0	0.0	0.8	1
El Toro	3.8	2.9	0.0	0.0	0.0	0.0	0.0	0.8	0
Emerald	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
FC13521	0.6	2.2	1.0	1.0a	0.0	0.0	0.0	0.7	1
Korean Common	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Meyer	0.0	1.3	0.6	1.3a	0.0	0.0	0.0	0.4	1
DALZ8501	3.0	2.9	0.0	1.0a	0.0	0.0	0.0	0.9	1
DALZ8502	2.5	3.2	2.2	1.3a	0.0	0.0	4.4	2.0	1
DALZ8503	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0
DALZ8504	3.0	3.2	2.5	1.0a	0.0	0.0	1.9	1.7	1
DALZ8505	1.3	1.3	0.0	0.0	0.0	0.0	0.0	0.4	0
DALZ8506	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0
DALZ8507	3.0	2.9	1.6	2.2a	0.0	0.0	0.0	1.3	1
DALZ8508	0.6	4.1	3.2	5.7a	3.5	3.2	3.5	3.2a	2
DALZ8510	3.6	4.8	2.2	3.2a	2.2	0.0	0.0	2.3	1
DALZ8511	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
DALZ8512	2.1	1.3	0.0	0.0	0.0	0.0	0.0	0.5	0
DALZ8513	4.8	7.0	6.7	4.8a	0.0	1.9	0.0	3.6a	2
DALZ8514	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0
DALZ8515	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
DALZ8516	0.6	1.3	0.0	0.0	0.0	0.0	0.0	0.3	0
DALZ8517	2.9	1.3	1.3	1.3a	0.0	0.0	0.0	0.9	1
DALZ8522	4.3	2.9	4.1	5.1a	0.0	0.0	0.0	2.4a	2
DALZ8523	2.9	2.5	0.6	0.0	0.0	0.0	0.0	0.9	0
DALZ8524	2.0	1.3	1.0	1.0a	1.3	0.0	0.0	1.0	1
DALZ8701	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0
TAES3372	2.5	1.9	1.0	1.9a	0.6	0.6	0.0	1.2	1
MSD entry[1]	n.s.	n.s.	n.s.	5.0	n.s.	n.s.	n.s.	1.2	
Avg.	1.8	1.8	0.3	1.1	0.3	0.2	0.4	0.9	

[1] MSD is the Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).
[2] PS is the phenotypic stability indicating the number of times the entry ranked in the highest statistically significant group.

Measuring Water Flow in Landscape Shrubs

J. L. Heilman and J. M. Ham

Introduction

Little research has been done to measure water use in landscape environments, due in part, to the difficulty of the measurements. The heat balance method of Sakuratani (1981) and its modification by Baker and Van Bavel (1987) provide a way for continuously measuring mass flow rate of water (sap) in the xylem, which may be useful for measuring water use in landscape plants.

With the heat balance method, a steady amount of heat is applied to a plant stem by a flexible heater that encircles the stem. Some of the heat is conducted axially up and down the stem, and radially outward from the stem, and the remainder is carried away by the sap. By measuring stem surface temperatures above and below the heater, the mass flow rate of water can be calculated. Sakuratani (1981), Baker and Van Bavel (1987) and Ham and Heilman (1990) demonstrated that sap flow rate in herbaceous plants could be estimated to within 10 percent of gravimetric measurements of transpiration. Steinberg et al. (1989) used this method to measure daily water use of small trees to within 4 percent. We conducted an experiment to test this method on wax leaf ligustrum (*Ligustrum japonicum*) in a growth chamber and in the field to evaluate its accuracy and its potential for measuring water use of shrubs in landscape environments. A complete description of methods and results can be found in Heilman and Ham (1990).

Materials and Methods

A stem flow gauge was attached to a ligustrum growing in a 11.3-l (3-gallon) pot containing fritted clay. The gauge was attached to the main stem between the soil surface and the lowest branch, and was wrapped in aluminum foil to minimize effects of radiation on the heat balance of the stem. The pot was wrapped in plastic to minimize soil evaporation and placed on a computer-controlled electronic balance in a growth chamber. Different rates of transpiration were produced in the chamber over a 12-hour period by creating three levels of radiation (115, 196 and 280 W m^{-2}) using a combination of incandescent and low-pressure sodium lamps. The air temperature was maintained between 26 and 29 °C (79-84 °F) and the relative humidity ranged from 31 to 38 percent. Transpiration was determined by automatically recording the weight loss at 15-min intervals. Signals from the stem flow gauge were measured at 15-sec intervals and averaged over 15-min periods.

Field measurements were conducted at the Texas A&M University Turfgrass Field Research and Teaching Laboratory in College Station, Texas. The same ligustrum as noted above was placed on the electronic balance that was read manually at 2-hr intervals to record the weight loss due to transpiration. Stem-flow gauge signals were measured at 15-sec intervals and averaged over 30-min periods. Solar radiation varied from 145 to 990 W m^{-2}, while air temperature and relative humidity ranged from 24 to 34 °C (75-93 °F) and 37 to 87 percent, respectively. Additional tests were done in which sap flow rates were measured on five ligustrum placed side-by-side in the field.

Results and Discussion

Sap flow rates measured in the single plant in the growth chamber and in the field were within 10 percent of the gravimetric measurements of transpiration, which is consistent with results reported by Sakuratani (1981) and Baker and Van Bavel (1987). We found no evidence of lags between transpiration and sap flow caused by plant capacitance.

Substantial differences in flow existed among the five ligustrums, due primarily to differences in leaf area. Cumulative flow from 0700 to 1800 hours ranged from 0.43 to 0.56 kg (0.95 to 1.23 lb) with a mean cumulative flow of 0.51 kg (1.12 lb) and a coefficient of variation of 10 percent. When sap flow was expressed on a unit leaf area basis, the coefficient of variation dropped to 4 percent. Field measurements under partly cloudy skies with fluctuating solar radiation showed that the heat balance method has the dynamic response necessary to react to changing environmental conditions.

Our study provided further evidence that the heat balance method is a useful tool for measuring plant water use. Our tests were limited to small shrubs with negligible capacitance. In large plants, where significant capacitance may exist, changes in sap flow may lag behind changes in transpiration which will prevent analysis of water use over short periods. However, as shown by Steinberg et al. (1988), accurate measurements of daily water use can be obtained by integrating sap flow over 24 hours.

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Water Use by Shrubs as Affected by Energy Exchange with Building Walls

J. L. Heilman, C. L. Brittin, and J. M. Zajicek

Introduction

Water use by vegetation is controlled by the physical environment, and plant response to that environment. In cities, plants must contend with an environment that is significantly different from rural areas (Landsberg 1981). These differences are caused by changes in the energy and water balances produced by buildings, roads, etc., by reductions in the amount of vegetation, and by combustion processes associated with automobiles and industry. Plants are routinely grown next to buildings, roads, and fences that are sources of radiation and sensible heat.

Urban vegetation may use more water per unit of vegetated area than in rural areas due to advected sensible heat from nonvegetated areas. Oke (1979) found that latent heat flux (evaporation) from an irrigated suburban lawn exceeded net radiation on both an hourly and a daily basis. Feldhake et al. (1983) found that advected energy accounted for 35 percent of the evaporation from turfgrass in cities.

Because of the complex nature of the urban environment, little research has been done to quantify effects of the urban environment on water use by vegetation or to determine water requirements for maintaining urban landscapes. We conducted a study to explore how instantaneous and daily water use of shrubs may be affected by energy exchange with adjacent building walls. A complete description of methods and results can be found in Heilman et al. (1989).

Materials and Methods

The study was conducted from mid-June to early July 1988 on a 1-ha (2.47-acre) plot of Tifway bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) at the Texas A&M Turfgrass Field Research and Teaching Laboratory in College Station, Texas. The grass was maintained at a cutting height of 0.03 m (1.3 inches) and was irrigated by sprinklers. A 4.9 m x 4.9 m (16- x 16-ft) building shell with 2.5 m (8.2 ft) high rough-cut pine walls and no roof was constructed in the bermudagrass plot. Interior surfaces of the walls were insulated with R5 foam board insulation. Walls were painted which produced an albedo of 0.17.

Three wax leaf ligustrum (*Ligustrum japonicum*) in 11.3-l (3-gallon) pots were placed in front of each wall at a distance of 0.5 m (1.6 ft) from the wall. The distance between plants was 1.2 m (4 ft). Pots were inserted into aluminum cylinders buried in the soil so that tops of the pots were flush with the soil surface. An additional three plants, 1.2 m (4 ft) apart, were inserted 10 m (33 ft) east of the building. Plants were watered daily, and pots wrapped in plastic to prevent soil evaporation. Leaf area was determined for each plant using measurements of leaf length and width. Stomatal resistance on upper leaves was measured at selected periods with a steady-state porometer.

Transpiration on the center plant at each wall, and on the center plant of the three positioned away from the building were measured using heat balance, stem-flow gauges (Sakuratani 1981; Ham and Heilman 1990) attached to the trunk between the soil surface and the lowest branch. Air temperatures adjacent to walls were measured with thermocouples at a distance of 0.5 m (1.6 ft) from the walls and an elevation of 1.5 m (5 ft) above the turfgrass, while wind speeds at the same locations were measured with cup anemometers. Air temperature, humidity, wind speed and direction, and solar radiation were measured at a portable weather station 10 m (33 ft) west of the building. Wall, ligustrum, and bermudagrass temperatures were measured with a hand-held infrared thermometer. The energy balance of the turfgrass was measured using the Bowen ratio method (Tanner 1960).

Results and Discussion

Weather conditions during the study were characterized by partly cloudy skies, high temperatures, and moderate wind speeds. Highest shrub transpiration rates occurred in plants adjacent to east and west walls, with peak flow occurring at mid-morning for the plant at the east wall, and in late afternoon for the plant at the west wall. Transpiration in the plant next to the south wall was lower than for plants next to east and west walls, and away from the building. Transpiration was lowest in the plant adjacent to the north wall. No differences in stomatal resistance were found among the plants.

Peak transpiration in plants adjacent to walls occurred when direct beam solar radiation and wall temperatures were at their maxima. Longwave radiation emitted by the walls was a major factor affecting transpiration while reflected radiation from walls was of secondary importance because of the low albedo of the walls. Cumulative transpiration was greatest in shrubs away from the influence of the building due to the absence of any shading by walls, and to wind speeds that were higher than those adjacent to the building. Plants adjacent to the building were generally 2 to 4 °C (3.6 to 7.2 °F) warmer than the air throughout the day.

Our study was conducted during a period when the solar declination was at a maximum, which at our latitude, resulted in high solar elevation angles at midday. As a result, the contribution of the south wall to the radiation balance of adjacent shrubs was relatively low compared to what would occur earlier and later in the season, and at higher latitudes. In a landscape, the magnitude of radiation exchange will vary not only with sun angle, but also with thermal and optical properties of the construction materials.

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PR-4897

Effects of Evaporation from Turfgrass on External Temperatures of Buildings

J. L. Heilman, R. W. Gesch, and J. B. Beard

Introduction

Studies of urban climate have shown that vegetation modifies both mesoscale and microscale climates by changing the surface energy balance (Myrup 1969). These modifications can affect human comfort and potentially reduce requirements for air conditioning in hot climates (Hutchison and Taylor 1983). Mechanisms by which vegetation affects building energy balance include shading, alteration of wind speed and direction, and evaporative cooling of vegetation and air. Shade and wind alteration operate at the microscale, and their effects on building temperatures have been well-documented (McPherson et al. 1988). Evaporative cooling of air has been thought of as a mesoscale process and to have little impact at the microscale level. However, recent studies by Huang et al. (1987) and McPherson et al. (1989) indicate that especially in arid regions, microscale effects of evaporative cooling may be as important as mesoscale effects.

When water shortages occur, the first action usually taken is to restrict or eliminate landscape irrigation. If water is withheld and evaporation reduced, a greater proportion of the net radiation will be used for heating the soil (soil heat flux) and heating the air (sensible heat flux). If evaporative cooling is effective at the microscale, such changes in landscape energy balances may affect the energy balance of buildings. Thus, we conducted an experiment to explore how external building temperatures may be affected by reducing irrigation of adjacent turfgrass and changing the surface energy balance of the grass. A complete description of methods and results from this experiment can be found in Heilman and Gesch (1991).

Materials and Methods

The study was conducted on a 1-ha (2.47-acre) plot of Tifgreen bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) at the Texas A&M University Turfgrass Field Research and Teaching Laboratory in College Station, Texas. The grass was maintained at a cutting height of 0.03 m (1.2 inches) and was irrigated by sprinklers. A 4.9 m x 4.9 m (16- x 16-ft) building shell with 2.5 m (8.2 ft) high rough-cut pine walls and no roof was constructed in the bermudagrass plot. Interior surfaces of the walls were insulated with R5 foam board insulation. Walls were painted which produced an albedo of 0.17.

Wall temperatures were continuously recorded with infrared thermometers aimed at the walls from a distance of 2 m (6.5 ft). Air temperatures adjacent to walls were measured with thermocouples at a distance of 0.5 m (1.6 ft) from the walls and an elevation of 1.5 m (5 ft) above the grass, while wind speeds at the same locations were measured with cup anemometers. Air temperature, humidity, wind speed and direction, and solar radiation were measured at a portable weather station 10 m (33 ft) west of the building. The energy balance of the grass was measured using the Bowen ratio method (Tanner 1960).

Irrigation water was withheld from the bermudagrass for two 7-day periods, 12 - 18 July (days 193 to 199) and 28 August to 3 September 1989 (days 242 to 248), to gradually reduce evaporation. Energy balance, wall temperature, and microclimate measurements were made during these drying cycles. Irrigation was resumed following the July measurement period to allow the bermudagrass to recover.

Results and Discussion

Skies were partly cloudy on most days during the study which led to differences in solar radiation within each drying cycle. Air temperatures were high and wind speeds were low to moderate. Winds were southerly except on days 246 through 248.

During the first drying cycle, latent heat flux (evaporation) decreased from 14.2 to 8.8 MJ m^{-2} while sensible heat flux increased from 2.9 to 7.3 MJ m^{-2}. Soil heat flux decreased slightly as the soil dried. At the beginning of the cycle, sensible heat was 16 percent of net radiation, while at the end, sensible heat accounted for 42 percent of net radiation. During the second drying cycle, latent heat flux decreased from a maximum of 12.5 MJ m^{-2} to 7.4 MJ^{-2} (82 percent to 44 percent of net radiation) while sensible heat increased from 1.0 to 7.6 MJ m^{-2} (8 to 46 percent of net radiation). In spite of substantial decreases in evaporation, no systematic increases in wall temperatures were observed. In addition, no systematic differences were found between air temperatures above the turfgrass and those at a nearby airport which supports the conclusion that evaporative cooling of air is mainly a mesoscale process. Our results do not preclude a small effect of evaporative cooling on wall temperatures, but other environmental factors were clearly more important.

The major factors affecting wall temperatures were solar radiation and wind speed. Changes in wind speed had the greatest effect on wall temperatures during periods of low average wind speed. When average wind speeds were high, changes in wind speed had relatively small effects on wall temperature.

Our results suggest that localized reductions in irrigation and evaporation are unlikely to affect building energy balances in many climatic regimes. They also suggest that water-conserving landscapes of turfgrasses, trees, and shrubs can be developed and installed without increasing building energy loads.

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PR-4898

Genetic Diversity in Low Temperature Hardiness Among 35 Major Warm-season Turfgrass Genotypes

J. B. Beard, S. I. Sifers, and S. D. Griggs

Introduction

The 1980's have been exceptional years for turfgrass culture in Texas. This is due to three years when serious direct low temperature kill of turfgrasses occurred with a severity, that in most cases, exceeded any cold stress experienced in the previous 50 years. Direct low temperature kill involves the death of turfgrasses as a result of ice crystal formation internally within the tissues. This is a distinctly different physiological phenomenon from that of chilling injury or chill stress which involves low temperature discoloration of warm-season turfgrasses at temperatures in the 55 to 60°F (13 to 16°C) range. This study addressed direct low temperature kill at temperatures below 32°F (0°C). It should be noted that it is not uncommon for those turfgrasses with superior direct low temperature stress hardiness to have an inverse relationship in terms of inferior chill stress tolerance.

Materials and Methods

To reliably evaluate the low temperature stress hardness of turfgrasses, a low temperature stress simulation chamber was constructed in which temperatures could be readily controlled (Figure 1). The chamber was made from a large chest-type freezer with interior dimensions of 66 x 24 x 50 inches (1.7 x 0.6 x 1.3 m) deep in which key modifications were accomplished (1, 3). Modifications included two expanded metal shelves elevated above the chamber base and shortened from the chamber ends to allow a mechanical air circulation system in the base to enhance temperature uniformity. The lower shelf was positioned 1 ft (300 mm) above the chamber base, with the upper shelf having a 1-ft (300 mm) vertical space above which accommodated 6 inches (150 mm) of air space and 6 inches (150 mm) for turfgrass shoots plus container. Temperature control was maintained by a rotary chart driven temperature recorder which was modified with a plastic cam that controlled the temperature regime in the chamber. The cam was programmed to slowly lower the chamber temperature from 30°F (-1°C) to -10°F (-23°C) in 5°F (2.8°C) intervals with an 8-hour hold period at each 5°F (2.8°C) level. The treatment temperatures chosen based on previous preliminary tests on the warm-season

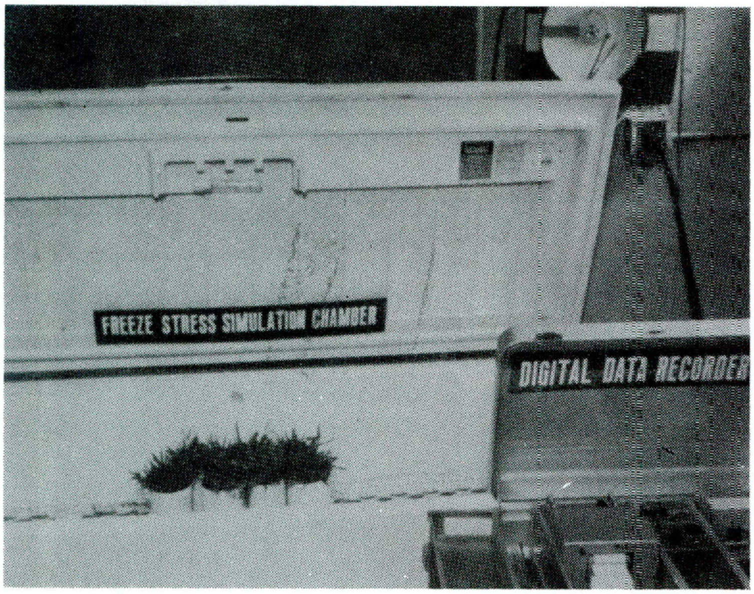

Figure 1. Low temperature stress simulation chamber, controller, and data recorder.

grasses included 30, 25, 20, 15, and 10 °F (-1.1, -3.9, -6.7, -9.4, and -12.3°C).

The turfs were allowed to completely cold harden in the field to full dormancy prior to the initiation of this study in January. The sampling time criteria also allowed for adequate soil drying in order to minimize micro-differentials in tissue hydration caused by standing water and/or variable surface soil drainage. Four-inch (100-mm) diameter by 3-inch (75-mm) deep turf plugs were collected from each of three replications of the 35 major warm-season turfgrass genotypes encompassing nine species. Six sets of three replicates for each genotype were collected, including a non-cold stressed check set. The turf plugs were subjected to the designated temperature range for 8 hours, after which the designated replicated sets were removed from the chamber, allowed to thaw for 24 hours in a shaded room maintained at 48 to 54°F (9 to 12°C), and then placed in the glasshouse to allow shoot regrowth. The individual turfs were evaluated for percent shoot survival at 15-, 30-, and 60-day intervals following the temperature stress treatments.

The turfgrasses evaluated included (a) 18 bermudagrass genotypes encompassing two species (*Cynodon dactylon* and *C. dactylon* x *C. transvaalensis*); (b) four buffalograss genotypes (*Buchloe dactyloides*); (e) three genotypes of centipedegrass (*Eremochloa ophoroides*); (d) one genotype of seashore paspalum (*Paspalum vaginatum*); (e) five genotypes of St. Augustinegrass (*Stenotaphrum secundatum*); and (f) three species of zoysiagrass encompassing five genotypes (*Zoysia japonica, Z. matrella, Z. tenuifolia*, and a *Z. japonica* x *Z. tenuifolia* hybrid). All turfs had been grown to a mature stage at the Texas A&M University Turfgrass Field Research and Teaching Laboratory in College Station, Texas prior to collecting the turf plugs for the low temperature hardiness assessments.

Results

In making low temperature stress assessments, it is important to note that the soil temperture rather than the air temperture is particularly critical. This is because the key meristematic survival sites on individual turfgrass plants, the nodes on crowns and/or stems, are typically located within or adjacent to the soil itself. The results of these extensive assessments are summarized in Table 1 in terms of relative rankings. Specific lethal temperatures are not shown as the actual killing temperature for a given genotype is not a finite number. Rather, the actual killing temperature varies greatly depending upon the rate of freezing, rate of thawing, number of times frozen, duration of freezing, and the hydration content of the tissue. The greater the tissue hydration level, the higher the killing temperature. Cultural practices that can adversely increase the hydration content of the meristematic tissue include excessive nitrogen and deficient potassium nutritional levels, plus poor surface and subsurface soil drainage characteristics. The specific temperature exposure level can also be affected by insulating factors such as a higher height of cut and greater thatch accumulation.

The warm-season turfgrasses adapted to the transitional climatic region that ranked highest in low temperature hardiness include the four buffalograss genotypes, plus two genotypes of *Zoysia japonica*, Midwest and Meyer. Ranking next in cold hardiness were three zoysiagrasses and four bermudagrass genotypes: U-3, Midiron, Midway, and Texturf 1F. Note the broad range in relative low temperature hardiness among the bermudagrasses being distributed across six of the nine ranking levels. This emphasizes the importance of selecting the appropriate cultivar of bermudagrass in relation to the severity of low temperature stress anticipated.

Ranking next in low temperature hardiness along with five bermudagrass genotypes were two centipedegrass genotypes plus Adalayd seashore paspalum. Lowest ranked in cold hardiness of the warm-season turfgrass was St. Augustinegrass, with Floratam and Floralawn being extremely poor in terms of low temperature hardiness.

These results demonstrate the importance of selecting a specific cultivar in addition to the individual warm-season turfgrass species for those locations where low temperature stress may occur periodically.

Table 1. Comparative rankings* for direct low temperature or cold hardiness of 35 major warm-season turfgrass genotypes encompassing nine species.

Relative ranking	Buffalograss	Zoysiagrass	Bermudagrass	Seashore paspalum	Centipedegrass	St. Augustinegrass
1	Oklahoma Common Commanche Texoka					
2	Sharp's Improved	Midwest Meyer				
3		Emerald FC13521 Tenufolia	U-3 Midiron Midway Texturf 1F			
4			Tifdwarf Pee Dee Tiflawn Texturf 10 Bayshore	Adalayd	Tennessee Hardy Oklawn	
5			Everglades Tifway Santa Ana		Georgia Common	
6			Tiffine Tifgreen Ormond FB119			
7			Sunturf			Texas Common Raleigh
8			Arizona Common			Seville
9						Floratam Floralawn

*These rankings are on the optimum cultural system for each species for quality lawns, sports fields, and golf fairways. Any cultural practices that impose a stress on the turfgrass plant would result in decreased cold hardiness. For example, a closely mowed, high nitrogen fertility bermudagrass green.

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PR-4899

Comparative Wear Tolerances of Tall Fescue (*Festuca arundinacea*) Genotypes Grown Under Post Oak Tree Shade in a Warm-Humid Climate

S. I. Sifers, J. B. Beard, and M. H. Hall

Introduction

Tall fescue (*Festuca arundinacea* Schreb.) is well adapted to the transitional climatic regions of the United States. It is one of the most wear tolerant, heat hardy, and drought resistant of the cool-season turfgrasses. With improvements in heat hardiness, tall fescue could become better adapted to the cooler portions of the warm-humid climatic regions of the South. Almondares and Beard (1, 2) reported in 1977 that tall fescue could be grown successfully under tree shade in the warm-humid gulf coast climate. Since tall fescue has good shade adaptation and is established by seeding, it is well suited to rapid turf renovation and repair under shade stress conditions. Thus, the interest in tall fescue increased substantially in the Northern and Eastern portions of Texas, especially as the newer turf-type tall fescue cultivars became available.

The characterization of 14 tall fescue cultivars under post oak (*Quercus stellata* Wang) tree shade is 10 years old (1, 2, 3, 5, 7, 8, 9, 10). Typically, a minimum of 6 years of assessments is required to obtain reliable field evaluations of turfgrass cultivars. Reasonable and reliable conclusions concerning the overall adaptation and performance of these tall fescue cultivars under tree shade in a warm-humid climate can be made now.

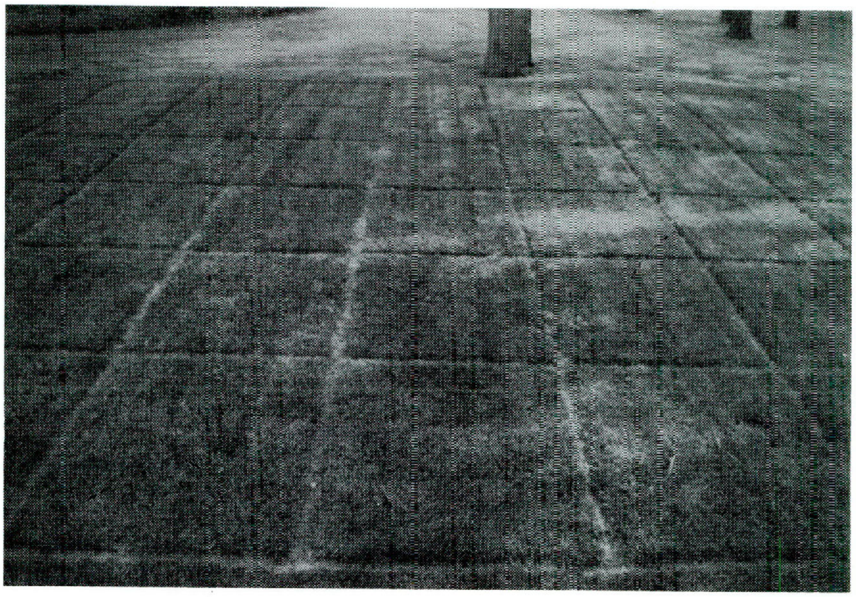

Figure 1. Tall fescue shade assessment area at Texas A&M Turfgrass Field Laboratory.

In summary, these characterizations show that under post oak tree shade conditions with adequate moisture, including irrigation as needed, 11 of the 14 tall fescue cultivars included in this study produced an acceptable turf cover for lawns. The best turfgrass quality across the tall fescues was observed during May and June. Brookston, Galway, and Kenwell were lowest in turfgrass quality and were the only cultivars rated less than acceptable for lawns.

People tend to seek the cooler environs of a tree shade. They concentrate recreational activites, such as swings and picnic tables, in these shaded areas; thereby imposing severe traffic stress. This study was conducted to compare the relative wear tolerances of 14 tall fescue genotypes under post oak tree shade during May and June, the period of prime turf quality.

Materials and Methods

All cultivars were planted in November of 1982, by seeding at a rate of 9 lbs/1,000 sq ft (4.5 kg are^{-1}) on a modified Lufkin fine sandy loam. A randomized complete block design of three replications was used, with a plot size of 5 x 7 ft (1.5 x 2.1 m). The study site was positioned in a grove of post oak trees at the Texas A&M Turfgrass Research and Teaching Laboratory in College Station, Texas. The trees had average diameters of 24 inches (600 mm) providing 80 percent shade, except for the direct radiation in the form of sunflects which diurnally moved across the plot area (Figure 1).

The turfs were mowed weekly with a rotary mower at a 2-inch (50-mm) cutting height, with the clippings removed. The soil pH was maintained between 7.5 and 8.0 based on an annual soil test. Nitrogen was applied at a rate of 1 lb N/1,000 sq ft (0.5 kg are^{-1}) per growing month from October through March. Potassium was applied once in early spring and again in early fall at a rate of 1 lb K/1,000 sq ft (0.5 kg are^{-1}), based on soil tests. Phosphorus was not needed based on annual soil tests. Irrigation water was applied as needed to prevent visual wilt. Pesticides were not applied during the growing season nor were any disease or insect damage symptoms observed, except for a severe Pythium blight attack in late summer 1983.

Turfgrass wear was imposed in May 1989 via a mechanical wear simulator constructed for small plot use and described by Shearman et al. (12) (Figure 2). This simulator was developed for use on experimental plots as small as one square meter. The wear simulator is operated by an electric motor and is constructed to rotate around a pivotal point with an adjustable diameter that was fixed at 5 ft (1.5 m) for this study. The unit weighs 104 lb (47.2 kg) with the weight of the rotating unit supported by a 4- x 8-inch (10 x 20 mm) pneumatic tire supplying a pressure of 1 lb per square inch (7.2 kg dm^{2}) on the turf. The tire simulates wear aspects similar to golf carts and maintenance equipment. The unit is chain driven with the number of revolutions recorded on a counting device.

A wear endpoint was selected during preliminary trials and was determined by the number of revolutions required to reach a point when all leaf blades were shredded from the sheath and only stems and bare soil remained. The initial number of revolutions was to be 500 based on data from Shearman et al. (11) and Beard et al. (16). The apparatus was centered at the intersection of four plots so four different genotypes were wear stressed at each placement. Following imposition of wear, the device was moved to another intersection and the wear treated areas were irrigated. Seventy-two hours after wear had been imposed, four 4-inch (0.25 dm^{-2}) plugs were pulled from the wear track and from an adjacent non-wear area for analyses of shoot density, shoot fresh weight, and shoot dry weight. This procedure was repeated until all three replications of 14

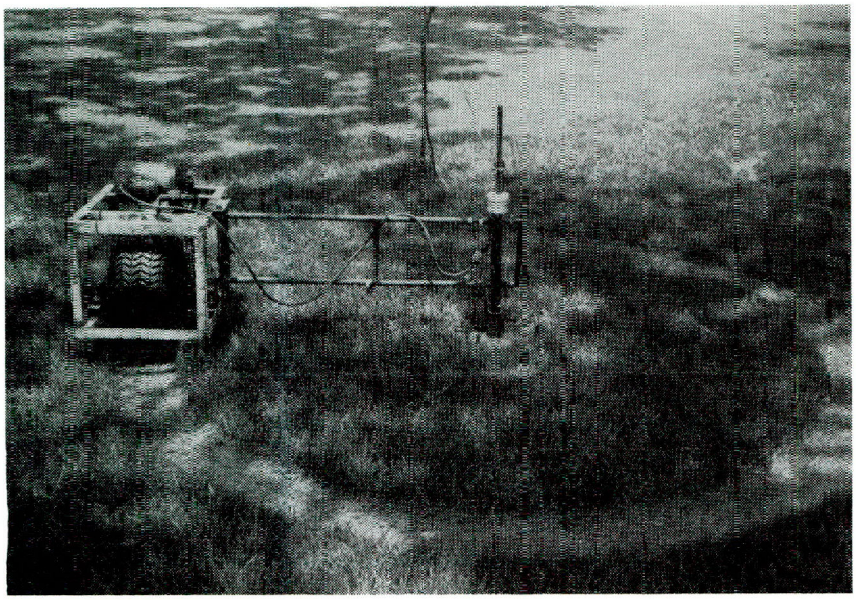

Figure 2. Turfgrass Mechanical Wear Simulator at Texas A&M Turfgrass Field Laboratory, College Station, Texas.

genotypes had received the wear stress treatment. Recovery was monitored weekly via visual estimates.

Results

The target number of wear revolutions was 500. However, following 400 revolutions of the wear wheel at the first placement, the wear endpoint had been reached on all four plots. Thus, the wheel wear action was terminated. Subsequently, the apparatus was moved following 400 revolutions at each placement. The relative genotype rankings for wear tolerance are shown in Table 1. Jaguar and Falcon turfs had improved wear tolerance based on dry weight biomass

Table 1. Relative wear tolerance of 14 tall fescue genotypes growing under Post Oak tree shade in a warm-humid climate, College Station, Texas.

Relative ranking[1]	Wear tolerance
Excellent	Jaguar
Good	Falcon
Medium	Kentucky 31 Olympic Marathon Houndog Kenwell Rebel
Fair	Brookston Mustang Clemfine
Poor	Adventure Alta Galway

[1] Ranking comparisons are made only within Festuca arundinacea, with no relationship to other genera or species.

remaining after wear stress treatment. Galway, Alta, and Adventure ranked the poorest for wear tolerance. There were no statistical differences among cultivars in terms of shoot fresh weight before wear. Also, the shoot dry weights corresponded closely with the fresh weights of each genotype.

Significant genotype differences in shoot density between wear and non-wear stressed turfs occurred as a result of the wear stress treatment. Jaguar, Falcon, Kentucky 31, Olympic, Marathon, and Houndog had very small losses in shoot density; while Alta, Adventure, Clemfine, and Mustang lost from 14 to 28 percent in shoot density. All turfs subsequently recovered fully. There were statistically significant intraspecies differences in shoot densities within the wear and non-wear categories. Most cultivars had shoot densities above 40 shoots per dm^{-2} before wear, with only Kenwell and Galway below this number. This lower shoot number may have contributed to the less than acceptable turfgrass quality ratings for these two cultivars.

The wear data indicate that there are tall fescue cultivars with more wear tolerance than others for use on lawn in shaded sites in warm-humid climates. Selection of these more wear tolerant cultivars for shaded, high traffic planting sites would be prudent.

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PR-4900

Evapotranspiration Rates of 24 Bermudagrass, 10 St. Augustinegrass, and 11 Zoysiagrass Genotypes Under Well-watered, Field Conditions

R. L. Green, S. I. Sifers, J. B. Beard, and C. E. Atkins

Introduction

Bermudagrasses (*Cynodon* spp.), St. Augustinegrasses [*Stenotaphrum secundatum* (Walt.) Kuntze], and zoysiagrasses (*Zoysia* spp.) are commonly used for turf purposes throughout much of the southern United States. The production of quality, functional turfs normally requires supplemental irrigation to prevent leaves from turning brown from low-moisture stress. Since water conservation is an important concern, a combination of cultural practices are needed to conserve irrigation water. One cultural approach is the selection of turfgrass species and cultivars with low evapotranspiration (ET) rates (Beard 1985). Results from prior studies suggested a potential for water savings based on species and cultivar selection of warm-season turfgrasses (Kim and Beard 1988), perennial ryegrass (*Lolium perenne* L.) (Shearman 1989), Kentucky bluegrass (*Poa pratensis* L.) (Shearman 1986), and tall fescue (*Festuca arundinacea* Schreb.) (Kopec et al. 1988).

Identification of rapid, simply-assessed morphological traits that are associated with low ET rates may aid breeders in the selection of water-conserving turfgrasses. Kim and Beard (1988) reported that turfgrass species with comparatively lower ET rates under well-watered conditions were generally characterized by (a) a high canopy resistance, including a high shoot density and/or relatively horizontal leaf orientation, and (b) a low leaf area, including a slow vertical leaf extension rate and/or a narrow leaf texture. They also reported that the individual morphological traits affect the ET rate in varying degrees and combinations, depending on both the species and the cultivar.

The primary objective of this research was to compare ET rates among 24 bermudagrass, 10 St. Augustinegrass, and 11 zoysiagrass genotypes under well-watered, field conditions. A secondary objective was to correlate the ET rate to potential, rapidly-assessed plant predictors of the ET rate. Leaf extension rates were measured as an indicator of leaf area and shoot densities were measured as an indicator of canopy resistance. This report summarizes the major findings of three separate studies (Atkins et al. 1991; Beard et al. 1991; Green et al. 1991).

Materials and Methods

The turfgrass cultivars and experimental selections evaluated in this investigation are shown in Table 1. Three replicate plugs, 8.25-inch (210-mm) diameter, of each grass were collected from mature turf plots, located at the Texas A&M Turfgrass Field Research Laboratory on the Texas A&M University campus at College Station, Texas. Roots were severed from each plug and the soil removed by washing. Plugs were individually transplanted onto a growth medium of fritted clay (Van Bavel et al. 1978) contained in black plastic minilysimeter pots (Johns et al. 1983), measuring 8.25 inches (210 mm) in diameter and 8.25 inches (210 mm) deep. They were rooted under glasshouse conditions for at least 3 months prior to ET rate evaluations. Turfs were fertilized biweekly with a nutrient solution (20.0N-8.8P-16.6K plus micronutrients) at 1 lb N/1,000 ft^2 (5.0 g N m^{-2}) per month. Bermudagrasses, St. Augustinegrasses, and zoysiagrasses were mowed weekly at a 1-inch (25-mm), 2-inch (51-mm), and 1-inch (25-mm) cutting height, respectively, using a reel mower with clippings removed. They were watered to prevent visual wilt symptoms during the rooting phase and during the subsequent studies.

Table 1. Turfgrass cultivars and experimental selections evaluated for ET rates and leaf extension rates under well-watered, field conditions.

Bermudagrass	St. Augustinegrass	Zoysiagrass
A-22	Floralawn	Belair
A-29	Floratam	El Toro
Arizona Common	PI 410356	Emerald
Bayshore	PI 410364	FC-13521
Everglades	Raleigh	KLS-05
FB-119	Texas Common	KLS-11
Midiron	TX 106	KLS-13
Midway	TXSA 8202	Korean Common
Ormond	TXSA 8208	Meyer
Pee Dee	TXSA 8218	PI 231146
Santa Ana		41-21-5
Sunturf		
Texturf 1F		
Texturf 10		
Tifdwarf		
Tiffine		
Tifgreen		
Tifgreen II		
Tiflawn		
Tifway		
Tifway II		
Tufcote		
U-3		
Vamont		

The same minilysimeters were used for all measurements during 3 consecutive years so they were maintained in the field during May through October and in a glasshouse during November through April. They received 1 lb N/1,000 ft^2 (5.0 g N m^{-2}) per month as biweekly applications of a granular fertilizer (21.0N-0.0P-0.0K) when in the field and as biweekly applications of a nutrient solution (20.0N-8.8P-16.6K plus micronutrients) when in the glasshouse. There was no noticeable shoot thinning, disease or insect problems for the duration of the study. A visual inspection following completion of the study indicated no objectional nor significant root mass at the bottom or sides of the minilysimeters.

Evaluations of ET rates and leaf extension rates were conducted in selected summer months in each of the 3 consecutive years. Three or four measurements (subsamples) of ET rate and leaf extension rate were taken each year. A measurement consisted of determining the ET rate, by the water-balance method (Johns et al. 1983), between the 24th and 48th hour following mowing and saturation with water; with the leaf extension rate determined during the 48 hours following mowing and saturation with water and then converted to a 24-hour basis. Evapotranspiration rates were evaluated under well-watered conditions to minimize ET rate confounding caused by possible genotypic differences in rooting and thus the capability to extract moisture from the soil. The minilysimeters were placed in individual, mature turfed field plots. Field plots were arranged in three complete blocks. The field-plot construction (Kim and Beard, 1988) allowed for each lysimeter turf canopy to be contiguous with the surrounding turf canopy of the field plot. The procedure for determining leaf extension rates involved measuring the height of 10 leaf blades per minilysimeter immediately following mowing and 48 hours later. The number of live shoots were counted from within a frame (1.97 x 3.94 inch) (50 x 100 mm); counts were converted to a per square decimeter basis (one square decimeter = 15.5 square inch). Daily maximum and minimum air temperatures at 4.9 feet (1.5 m) above the soil surface, pan evaporation, windspeed at one foot (0.3 m) above the soil surface, and solar radiation at 9.8 feet (3.0 m) above the soil surface were measured during ET rate measurements at a class A National Weather Service Station located on the field research laboratory.

Analysis of variance was made on ET rate and leaf extension rate subsample means for individual years using a randomized complete block design with three replications and for overall years using a repeated-measures design with genotypes as main plots and years as the repeated-measures factor. Pearson correlation coefficients were calculated between ET and leaf extension rates for individual and overall years. Also, correlation coefficients were calculated between overall ET rates and shoot densities.

Results

ET and Leaf Extension Rates

A summary of the overall ET rates is shown in Table 2. ET rates were significantly different among the 24 bermudagrasses, but not among the 10 St. Augustinegrasses nor 11 zoysiagrasses. These data, which were collected under well-watered conditions, may indicate a potential for water savings based on bermudagrass cultivar selection that was comparable to the potential water savings based on warm-season turfgrass species selection reported by Kim and Beard (1988). Shearman (1989) made similar conclusions concerning water savings based on cultivar selections of 12 well-watered perennial ryegrasses. Significant intraspecific ET rate variations also have been reported among 20 well-watered Kentucky bluegrass cultivars (Shearman, 1986) and six tall fescue cultivars (Kopec et al., 1988) which also would indicate potential water savings by cultivar selection.

Significant ET rate differences among the St. Augustinegrasses and zoysiagrasses may exist at soil moisture levels lower than well watered conditions. Traits increasing internal resistance to moisture loss from leaf tissue, such as leaf wax formation and early stomatal closure would influence ET rates to a greater

Table 2. Summary of ET rates of three warm-season turfgrass genera evaluated under well-watered, field conditions.

ET rate (mm·day^{-1})[1]	Bermudagrass[2]		St. Augustinegrass[3]		Zoysiagrass[3]	
3.8-4.2	A-29				Belair	El Toro
	A-22				FC-13521	KLS-05
	Tufcote				Emerald	KLS-13
					Korean Common	PI 231146
4.3-4.6	Arizona Common	Texturf 10	Floratam		Meyer	
	FB-119	Tifgreen II	Texas Common		41-21-5	
	Tifdwarf	Bayshore	PI 410356			
	Midway	Vamont				
		TXSA 8202				
4.7-5.2	Tifway	Everglades	Floralawn	TX106	KLS-11	
	U-3	Midiron	Raleigh	TXSA 8262		
	Tifgreen	Pee Dee	Pi 410364	TXSA 8218		
	Sunturf	Tifway II				
	Tiffine	Ormond				
	Tiflawn	Texturf 1F				
		Santa Ana				

[1] ET rates are the average of 9 to 12 subsamples taken during selected summer months during three consecutive years. Comparisons between genera are not advisable since each genera was separately evaluated during different summer months having different environmental conditions. Also, cutting heights were different among the genera.
[2] ET rates were significantly different among the grasses within this genera.
[3] ET rates were not significantly different among the grasses within this genera. This information is provided only to indicate the range.

extent under drier soil moisture conditions than under well-watered conditions (Johns, 1980; Johns et al., 1983). Kim (1987) evaluated the ET rates of the major warm-season turfgrass species grown under field conditions and subjected to a progressive drought. He reported that genotypic differences in early stomatal closure and leaf wax formation during progressive drought contributed to significant ET rate differences among the turfgrasses.

A summary of the overall leaf extension rates is shown in Table 3. Leaf extension rates were significantly different among the 24 bermudagrasses, 10 St. Augustinegrasses, and 11 zoysiagrasses. Variations in leaf extension rates among the grasses within each of the three genera would cause different mowing frequency requirements.

Plant Morphological Traits Affecting the ET Rate

There is a need to identify simple, rapidly-assessed plant parameters for the prediction of ET rates within turfgrasses. Thus, one of our objectives was to correlate ET rates to leaf extension rates and shoot densities. Kim and Beard (1988) reported that turfgrasses with comparatively lower ET rates under well-watered conditions were generally characterized with a low leaf area, including a slow leaf extension rate and a narrow leaf texture, and a high canopy resistance, including a high shoot density. We found no correlations between ET rates and leaf extension rates nor shoot densities in any of our studies. In other field studies, Shearman (1989) reported significant correlations between ET rates and leaf extension rates ($r = 0.93$) and verdure dry weight ($r = -0.89$) among 12 well-watered perennial ryegrasses.

Higher turfgrass ET rates have been associated with higher amounts of shoot growth caused by either higher heights of cut (Biran et al., 1981; Feldhake et al., 1983; Madison and Hagan, 1962; Parr et al., 1984; Shearman and Beard, 1973) or higher rates of nitrogen fertilization (Feldhake et al., 1983; Krogman, 1967). Conversely, lower turfgrass ET rates or water consumption have been associated with lower amounts of shoot growth induced by applications of plant growth regulators that suppress shoot growth (Devitt and Morris, 1989; Doyle and Shearman, 1985; Green et al., 1990; Johns and Beard, 1982; Mathias et al., 1971).

Though water usage has been positively correlated with the amount of shoot growth, our data suggest that measurement of leaf extension rates, though easily taken, was not a reliable predictor of total leaf area as it influences the ET rate of certain warm-season turfgrass species. More laborious, time consuming measurements, such as leaf area or clipping dry weight, may be required, though they may not be practical for rapid evaluations of a large number of genotypes. Johns (1980) demonstrated that ET rates from a well-watered St. Augustinegrass turf increased with passage of time following mowing. Measurements of leaf area showed that leaf area indices also increased with increases in days after mowing. Bowman and Macaulay (1991) reported a significant correlation ($r = 0.82$) between ET rates and clipping dry weights among 20 well-watered tall fescue cultivars.

Table 3. Summary of leaf extension rates of three warm-season turfgrass genera evaluated under well-watered, field conditions.

Leaf extension rate (mm·day^{-1})[1]	Bermudagrass[2]		St. Augustinegrass[2]		Zoysiagrass[2]	
2.0-4.0	Ormond Tifdwarf U-3 Tifgreen Tifway Texturf 10 Pee Dee Sunturf Tiflawn	Tiffine A-29 Tufcote Tifgreen II Bayshore Vamont Tifway II Texturf II Santa Ana	Texas Common PI 410356 TX106			
4.1-7.0	FB-119 Arizona Common Midway	Midiron Everglades A-22	Raleigh Floratam Floralawn	TXSA 8202 PI 410364 TXSA 8262		
7.1-10.0				TXSA 8218	Emerald Meyer El Toro KLS-13 FC-13521 Korean Common	KLS-11 41-21-5 Belair KLS-05 PI 231146

[1] Leaf extension rates are the average of 9 to 12 subsamples taken during selected summer months during 3 consecutive years. Comparisons between genera are not advisable since each genera was separately evaluated during different summer months having different environmental conditions. Also, cutting heights were different among the genera.

[2] Leaf extension rates were significantly different among the grasses within this genera.

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Performance of Buffalograsses (*Buchloe dactyloides* [Nutt.] Engelm.) Under Linear Gradient Irrigation

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Introduction

Limitations on resources and environmental concerns dictate that future turfgrass cultivars have high tolerance to environmental stresses and produce good turf quality with minimal cultural imputs. The linear gradient irrigation system (LGIS) at TAES-Dallas (White, et al., 1990) was developed specifically to determine water requirements of newly developed turfgrasses under field conditions. A primary objective of this project is the development of new turfgrasses which will significantly reduce the amount of water required to maintain quality turf. The performance of newly developed turfgrasses is being evaluated with a full gradient of supplemental irrigation to determine the minimum amount of water required to sustain a turf that will persist and stabilize the soil and the optimum amount of water required to maintain actively growing turf with acceptable quality.

Materials and Methods

Construction of the LGIS system was initiated in the spring of 1986. Three buffalograsses, including Prairie buffalograss, which was released in 1990, the Texas experimental variety DALBD8202, and Texoka, were planted to LGIS during 1987. Plots were planted as sprigs using a 1:35 planting ratio. Each plot is 1.5 m wide by 20 m perpendicular to the line irrigation source. The field design is a randomized complete block with two replications on either side of a center trench for a total of four replications. The area received uniform fertilization and irrigation as needed in 1987 and 1988 to prevent stress. Full turf coverage was achieved by fall 1988. Currently the experimental area receives a yearly total of 0.98 kg N are^{-1} and is maintained at a 2.54 cm mowing height.

Gradient irrigation was imposed mid-July 1989 to create a moisture stress gradient and to determine the amount of irrigation required to prevent drought stress and to maintain green actively growing turf. Average annual rainfall for Dallas is about 71 cm, but was 124 and 110 cm for 1989 and 1990, respectively. Irrigation water distribution for the gradient is determined by measuring irrigation water collected in rain guages positioned at 1.5 m increments from the irrigation line source. Total irrigation applied in 1991 up to July 24 was 34.6 cm on plots receiving high supplemental irrigation (adjacent to center trench), 6.8 cm on plots receiving moderate supplemental irrigation (midway along irrigation gradient) and 3.1 cm on plots receiving low supplemental irrigation (furthest from center trench).

Canopy temperature and net radiation readings were taken during the summer of 1990. Canopy temperatures were taken by a Everest Interscience, Inc. infrared thermometer which was mounted on a stand 2 ft above the turf canopy and at an angle of 45 degrees. Net radiation readings were taken by a Micromet Systems net rediometer model 3032, which was mounted on the same stand 3 ft above the turf canopy. The net radiometer measures the difference between incoming photosynthetically active radiation and outgoing (reflected and transmitted) radiation from the turf canopy. The stand was slowly moved in a 15 degree arc across the plot canopy while the readings were taken.

Growth characteristics for the grasses were evaluated periodically by estimating total coverage, spring greenup, summer green cover, and overall turf quality.

Results

Canopy temperature was lower for Prairie and DALBD8202 than for Texoka (Table 1). This indicates that transpriational cooling was less for Texoka, and therefore that Texoka was under greater drought stress (Table 1). In addition, net radiation readings were higher for Prairie and DALBD8202 than for Texoka under low and moderate irrigation, indicating a higher rate of net photosynthesis for these two grasses under water deficit.

Spring greenup tended to be fastest for Prairie across all irrigations, followed by DALBD8202, with Texoka laging significantly behind as of Februrary 12 (Table 2). By Februrary 28 the same trend was evident, with only Prairie averaging greater than 50 percent green cover. By March 24 Texoka had largely caught up with DALBD8202, but was still behind Prairie in green turf color.

Total turf ground cover (including dead cover) was significantly higher for Prairie and DALBD8202 than for Texoka at Februrary 12 on plots receiving high

Table 1. Canopy temperature (°C) and net radiation (W m^{-2}) at high, moderate, and low supplemental irrigation on June 20, 1991.

	Temperature			Net Radiation		
Entry	Low	Mod.	High	Low	Mod.	High
Prairie	40.7	40.7a	40.6a	653.8a	654.8a	643.3
DALBD8202	40.7	40.9a	41.8a	650.8a	653.5a	651.8
Texoka	42.4	42.8	43.6	639.3	643.5	646.5
MSD[1]	n.s.	1.7	2.7	6.6	4.5	n.s.

[1] MSD, Minimum Significant Difference for comparison of means based on the Duncan/Waller k ratio test where k = 100.

irrigation (Table 3). There was no significant difference for total turf cover at the Februrary 28 measuring date. By April 25 Prairie had the highest total turf cover over all irrigations.

There were no significant differences between grasses in total turf cover or green turf cover during the summer measuring date of July 25 (Table 4). However, Prairie tended to have higher total turf cover and green cover than the other grasses over all irrigation treatments.

Turf quality was significantly better for Prairie than the other grasses across all irrigations on April 3, and under high irrigation on July 25 (Table 5). However, Prairie tended to have better quality over all irrigation treatments over all dates measured. Only Prairie had average turf qualities of greater than 5 (the minimum acceptable quality rating) for each measuring date.

Table 2. Percent green turf cover at high, moderate, and low supplemental irrigation during spring (Februrary 12, Februrary 28, and March 24), 1991.

	Feb. 12			Feb. 28			Mar. 24		
	Irrigation Amount								
Entry	Low	Mod.	High	Low	Mod.	High	Low	Mod.	High
Prairie	43.8a	46.3a	35.0a	63.8	65.0a	53.8a	86.3	88.8a	83.8
DALBD8202	25.0a	35.0	31.3a	43.8	51.3	46.3a	77.5	83.8a	68.8
Texoka	7.8	3.8	1.8	28.8	28.8	25.0	78.8	78.8	65.0
MSD[1]	19.9	6.5	7.7	n.s.	11.7	15.4	n.s.	5.9	n.s.

[1] MSD, Minimum Significant Difference for comparison of means based on the Duncan/Waller k ratio test where k = 100.

Table 3. Percent total turf ground cover at high, moderate, and low supplemental irrigation during spring (Februrary 12, Februrary 28, and March 24), 1991.

	Feb. 12			Feb. 28			Mar. 24		
	Irrigation Amount								
Entry	Low	Mod.	High	Low	Mod.	High	Low	Mod.	High
Prairie	93.3	94.5	91.3a	92.5	98.0	80.0	85.3	89.5a	72.5a
DALBD8202	81.3	86.3	66.3a	76.3	88.0	68.8	63.8	81.3	61.3a
Texoka	80.5	88.8	48.8	77.3	86.3	45.0	67.5	77.5	35.0
MSD[1]	n.s.	n.s.	29.2	n.s.	n.s.	n.s.	n.s.	7.6	20.4

[1] MSD, Minimum Significant Difference for comparison of means based on the Duncan/Waller k ratio test where k = 100.

Table 4. Percent total turf ground cover (TCVR) and percent green turf cover (GCVR) at high, moderate, and low supplemental irrigation on July 25, 1990.

	% TCVR			% GCVR		
Entry	Low	Mod.	High	Low	Mod.	High
Prairie	96.8	92.5	72.5	72.5	76.3	92.5
DALBD8202	92.8	80.0	48.8	60.0	76.3	85.0
Texoka	78.3	81.3	47.5	58.8	73.6	88.9
MSD[1]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

[1] MSD, Minimum Significant Difference for comparison of means based on the Duncan/Waller k ratio test where k = 100.

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Table 5. Turf quality (1-9, 5 = minimum acceptable quality) at high, moderate, and low supplemental irrigation during spring (April 3 and April 25) and summer (July 25), 1990.

	April 3			April 25			July 25		
	Irrigation Amount								
Entry	Low	Mod.	High	Low	Mod.	High	Low	Mod.	High
Prairie	7.0a	7.5a	5.8a	6.3	5.8	4.3	5.3	5.8	6.0a
DALBD8202	4.0	5.5	3.5	6.0	5.3	3.0	4.5	4.5	4.5
Texoka	5.0	5.0	3.0	6.0	5.3	3.0	4.0	4.8	4.3
MSD[1]	1.5	0.8	1.3	n.s.	n.s.	n.s.	n.s.	n.s.	1.2

[1] MSD, Minimum Significant Difference for comparison of means based on the Duncan/Waller k ratio test where k = 100.

PR-4902

Efficacy of Fungicides for Controlling Gray Leaf Spot on St. Augustinegrass[1]

P.F. Colbaugh

Abstract

Field plots of 'Raleigh' St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze] were used to determine efficacy of fungicide sprays for controlling the Gray Leaf Spot disease. Fungicide treatments were initiated on 25 September 1990, and continued over a 7-week period on intensively watered and fertilized plots. Symptoms of Gray Leaf Spot were observed 3 weeks after initiation of the study, and leaf spot severity data were taken after 30 days. Of 28 fungicide treatments tested on St. Augustinegrass, the highest disease ratings on replicate plots were on the untreated control plots (31%). Field plots treated with Daconil 2787® 4F (4 oz), Vorlan® + Fungo® 25W (1 oz + 1 oz), Chipco 26019® 50W (2 oz), ASC66518-c 82.5 FG (4 oz), Fungo Flo® 46.2 E (2 oz), and ASC66900 (4 and 8 oz) or ASC66608 (5 and 7.5 oz) sustained 0-10 percent leaf spot disease symptoms.

Introduction

The Gray leaf spot disease is a common and damaging disease on all popular varieties of St Augustinegrass. The causal agent of gray leaf spot, *Pyricularia grisea*, is closely related to *P. oryzae* that causes severe foliar blighting of rice (Atkins 1974). St. Augustinegrass, annual ryegrass, crabgrass, spurge, smartweed, rice, oats, wheat, millet, and corn are considered to be susceptible to the disease, however, among cultivated turfgrasses, only St. Augustinegrass (Freeman 1964) and annual ryegrass (Trevathan 1982) are damaged extensively by the disease.

Characteristic symptoms of gray leaf spot are round to oblong leaf lesions that have a brown to ash color with purple to brown margins. Under prolonged periods of warm temperatures with excessive moisture, the pathogen sporulates profusely on infected leaf blades. Gray leafspot is commonly observed during the transition seasons of spring and fall.

The gray leafspot field study during 1990 was conducted on 'Raleigh' St. Augustinegrass at the Texas A&M Research Center in Dallas, Texas. The purpose of the study was to determine product efficacy for controlling the leafspot disease. Field applications of the fungicide treatments continued over a 7-week period beginning in late September. Application rates and the number of sprays for each of the treatments were established by the manufacturers.

Methods and Procedures

The St. Augustinegrass plots received 36 individual treatments with four replications each in a randomized complete block design. Spray applications for each fungicide treatment was made with a CO_2 pressurized spray rig delivering 30 psi. Fungicide formulations were applied in 1,800 ml tap water to four replicate 50-ft² (1.6 x 3.15 m) field plots.

Fungicides used in the field test were as follows: Banner® 1.1 E (propiconazol) Ciba-Geigy Corp., Greensboro, North Carolina; Chipco 26019® (iprodione) Rhone Poulenc Chemical Co., Monmouth Junction, New Jersey; Daconil 2787® and ASC66518-66900 (chlorothalonil) Fermenta ASC Plant Protection Co., Painesville, Ohio; Fungo® (thiophanatemethyl) and Vorlan® (vinclozolin) Grace Sierra Chemical Co., Milpitas, California; G-696 (metsulfovax), Terraguard® (triflumizole) UniRoyal Chemical Co., Raleigh, North Carolina; Mon 24000 (chemistry not available) Monsanto Chemical Co. St. Louis, Missouri; and Prostar R (flutolanil) NorAm Chemical Co. Wilmington, Delaware (Table 1).

Disease assessments were made 30 days after the initiation of spray applications to the field plots. The number of elongate lesions on leaf blades was determined within a 285 cm² circular ring which was constructed of plastic tubing. The rings were randomly placed on the four replicate field plots to determine lesion count data for each fungicide treatment. Lesion data were subjected to statistical analysis to separate treatment means using the Duncan's multiple range test P=0.05.

Results and Discussion

Symptoms of Gray leafspot were uniformly distributed on the field block, and the severity of disease symptoms was in the moderate range. Thirty days after the initiation of the test, the untreated plots had a mean of 31 lesions per unit area (285 cm²) observed. This lesion count can be extrapolated to 1,100 lesions/m².

Several standard fungicide products were used in the field test to establish base level of control for the disease pressure at hand. Standard fungicides used in the test were Chipco 26019 50WP, Banner 1.1E, Daconil 2787 4F, and Fungo Flo 46E. Among the labeled fungicide treatments tested, Daconil (4 oz) on a 10-day spray schedule or Chipco 26019 (2 oz) and Fungo Flo (2 oz) gave significant levels of disease control after 30 days (Table 1).

[1] This publication reports research involving pesticides. It does not imply that the uses discussed here have been registered.

Table 1. Efficacy of fungicides for controlling gray leafspot on 'Raleigh' St. Augustinegrass 30 days after initiating field sprays.[1]

Treatment	Freq./Rate per 1,000 ft²		Mean Lesion[2] Count	
Not Treated		—	31.00	a
Chipco 26019 50WP	14d	2 oz	9.25	d-e
Banner 1.1E	14d	2 oz	19.50	a-d
Vorlan+Fungo 25W	14d	1 oz + 1 oz	11.25	d-e
Vorlan+Fungo 25W	14d	2 oz + 2 oz	11.25	c-e
Vorlan Flo 41.3E	14d	2 oz + 2 oz	12.50	c-e
Fungo Flo 46.2E	14d	2 oz	9.50	d-e
Daconil 2787 4F	10d	4 oz	9.75	d-e
ASC66518a 82.5 FG	10d	4 oz	11.25	c-e
ASC66518b 82.5 FG	10d	4 oz	10.25	d-e
ASC66518c 82.5 FG	10d	4 oz	9.00	d-e
ASC66900 82.5 FG	10d	8 oz	3.50	e
ASC66791 82.5 FG	10d	4 oz	10.50	d-e
ASC66791 82.5 FG	10d	6 oz	18.25	a-e
ASC66608 82.5 FG	10d	5 oz	5.50	d-e
ASC66608 82.5 FG	10d	7.5 oz	6.25	d-e
ASC66900 82.5 FG	10d	4 oz	7.75	d-e
Prostar 50WP	28d	2 oz	18.00	a-e
Prostar 70DG	28d	2 oz	17.75	b-e
Prostar 70DG	28d	1.25 oz	11.50	c-e
Prostar 50WP	14d	1 oz	18.00	a-e
Prostar 50WP	28d	1.50 oz	17.75	a-e
Terraguard50W	10d	8 oz	15.25	b-e
MON-24000 4F	14d	0.12 oz	26.25	a-c
MON-24000 4F	14d	0.25 oz	21.50	a-c
MON-24000 4F	28d	0.25 oz	17.50	a-e
MON-24000 4F	28d	0.50 oz	19.00	a-d
MON-24000 4F	28d	1 oz	15.50	b-e
G 696 4F	28d	8 oz	19.75	a-d

[1] Grey leafspot data are number of lesions in a 285 cm² tubing ring. Treatment plots were 50 ft² each.

[2] Means followed by the same letter could not be separated by DMRT 0.5%.

Results of disease ratings for Gray leafspot indicated little or no control for the disease with Terraguard 50W or G-696 4F (Table 1). Observations on the Prostar treated field plots gave little indication of effectiveness with the exception of the highest rate (1.25 oz) on a 14-day spray schedule (Table 1).

Gray leafspot control with Fungo Flo was only slightly better than with Vorlan Flo or combinations of the two fungicides (Table 1). Results with Fungo Flo (2 oz) were slightly better than with Daconil 2787 (4 oz) which is a standard product for controlling this disease.

Of the chemical treatments rated for Gray leafspot control, the Daconil and ASC/Daconil formulations ranked among the best treatments. The most effective treatments were ASC66900 and ASC66608 of all the treatments tested and this included good results obtained with Daconil 2787 4F (Table 1).

Monsanto's Mon-24000 4F was used on St. Augustinegrass at 14-, 28- and 42-day intervals at rates varying from 0.12 - 1.0 oz. Results with MON-24000 were generally poor for gray leafspot control.

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PR-4903

Evaluation of Fungicides for Controlling *Rhizoctonia* Blight of St. Augustinegrass[1]

P.F. Colbaugh

Abstract

Field plots of 'Raleigh' St. Augustinegrass [*Stenotahrum secundatum* (Walt.) Kuntze] were used to determine efficacy of fungicide products for controlling *Rhizoctonia* blight. Applications of the fungicides were initiated three days after inoculating with *R. solani* on 25 September and the study continued for 7 weeks on intensively watered and fertilized field plots. Initial symptoms of *Rhizoctonia* blight were observed 2 weeks after inoculations were made. Of 36 chemical treatments tested, the highest disease ratings during the sixth week were on untreated plots (18%). No disease was observed on plots treated with Prostar 50W® (1.5 oz), Mon 24000 4F (.25 oz), and Daconil 2787® 4F, ASC66518-b or ASC66518-c 82.5 FG at the 4 oz rate.

[1] This publication reports research involving pesticides. It does not imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate state and federal agencies before they can be recommended.

Introduction

Rhizoctonia brown patch is known to occur on most turfgrass species throughout the world and has been the subject of numerous research reports (2). Four species of *Rhizoctonia* occur on turfgrasses, however, *R. solani* AG2-2 is widely distributed in Texas and is thought to be responsible for most of the *Rhizoctonia*-incited turfgrass diseases (1). Rhizoctonia blight is a recurring and damaging disease on St. Augustinegrass and particularly during the fall season.

The purpose of this study was to determine fungicide efficacy of labeled and experimental products for Rhizoctonia blight control. Field applications of fungicides were made at varying application frequencies and concentrations during a 7-week period beginning in late September. Application rates and the frequency of sprays for the treatments were established by the fungicide manufacturers.

Methods and Procedures

The Brown Patch Field Study was conducted on 'Raleigh' St. Augustinegrass field plots located at the Texas A&M Research and Extension Center in Dallas, Texas. The field plot nursery consisted of 140 separate plots which were used to evaluate 36 fungicide treatments. Treatments were arranged in a randomized complete block design with four replicates per treatment. Each plot consisted of a 5- x 10-ft. (1.57m x 3.15m) area. Field plots were inoculated on 25 September 1990, by spreading *Rhizoctonia solani* (isolate #25) infested rye grain (approximately 3 kernels/ft^2) over the plot. Following inoculation, the plot area was irrigated thoroughly to initiate growth of the pathogen.

Spray applications for fungicide treatments were made with a CO_2 pressurized spray rig delivering 30 psi. Fungicide treatments were applied in 1800 ml tap water on four replicate 50 ft^2 field plots. Concentrations of the fungicides tested were according to the manufacturers recommendations (Table 1). Disease assessments on the field plots were recorded after 42 days as percentage of plot area showing typical disease symptoms. Evaluations of visible symptoms of residue and of phytotoxicity were also made at the termination of the study.

Fungicides used in the field test were as follows: Banner® 1.1 E (propiconazol) from Ciba-Geigy Corp., Greensboro, North Carolina; Chipco 26019® (iprodione) Rhone Poulenc Chemical Co., Monmouth Junction, New Jersey; Daconil 2787® and ASC66518-ASC66900 (chlorothalonil) Fermenta ASC Plant Protection Co., Painesville, Ohio; Fungo® (thiophanate-methyl) and Vorlan® (vinclozolin) Grace Sierra Chemical Co., Milpitas, California; G-69 (metsulfovax), PCNB® (terraclor), Terraguard® (triflumizole) UniRoyal Chemi-

Table 1. Rhizoctonia brown patch on Raleigh St. Augustinegrass field plots 42 days after the application of fungicide spray treatments. TAMU Dallas REC 1991.

Treatment	Freq.	Rate (P) /1,000 ft^2	Brown Patch[a] mean %	Residue[b] (0-3max)	Phytotox[c] (0-3max)
Not treated	—	—	18.2 a	0	0
Terraclor 75W	28 d	0.45 kg	0.5 b	0	0
Terraclor 50DF	28 d	24 oz	2.5 b	0.75	0
Terraguard 50W	28 d	4 oz	0.7 b	0	0
Terraguard 50W	14 d	8 oz	0.7 b	0.03	0
G 696 4F	28 d	8 oz	14.5 ab	0	0
Prostar 50W	28 d	2 oz	3.8 b	0	0
Prostar 70DG	28 d	2 oz	2.5 b	0	0
Prostar 70DG	28 d	1.25 oz	0.5 b	0	0
Prostar 50WP	14 d	1 oz	3.8 b	0	0
Prostar 50WP	28 d	1.50 oz	0 b	0	0
Mon-24000 4F	14 d	0.12 oz	0.5 b	0	0
Mon-24000 4F	14 d	0.25 oz	0 b	0	0
Mon-24000 4F	28 d	0.25 oz	0.5 b	0	0
Mon-24000 4F	28 d	0.50 oz	0.5 b	0	0
Mon-24000 4F	42 d	0.25 oz	6.7 ab	0	0
Mon-24000 4F	42 d	0.50 oz	0 b	0	0
Mon-24000 4F	42 d	1 oz	0 b	0	0
Chipco (50WP)	14 d	2 oz	3.2 b	0.25	0
Banner 1.1E	14 d	2 oz	9.7 ab	0	2.3
Vorlan+Fungo 25W	14 d	1 oz + 1 oz	9.5 ab	0	0
Vorlan+Fungo 25W	14 d	2 oz + 2 oz	3.5 b	0	0.25
Vorlan Flo 41.3E	14 d	2 oz	8.2 b	0	0.25
Fungo Flo 46.2E	14 d	2 oz	4.2 b	0	0
Daconil 2787 4F	10 d	4 oz	0 b	1.5	0
ASC66518a 80FG	10 d	4 oz	2.7 b	0.75	0
ASC66518b 80FG	10 d	4 oz	0 b	2.0	0
ASC66518c 80FG	10 d	4 oz	0 b	2.0	0
ASC66900 80FG	10 d	8 oz	6.3 ab	3.0	0.63
ASC66791 0.65F	10 d	4 oz	0.7 b	1.3	0
ASC66791 0.65F	10 d	6 oz	0 b	1.5	0
ASC66608 0.65F	10 d	5 oz	4.5 ab	1.0	0
ASC66608 0.65F	10 d	7.5 oz	10.5 ab	0.75	0
ASC66900 0.65F	10 d	4 oz	8.2 ab	2.5	0
ASC66811 0.65F	10 d	0.06 oz	10.0 ab	0	0

[a] Brown patch data are % area infected, means of four replicate treatment plots of 50 ft^2 each. Means followed by the same letter could not be separated by DMRT P=0.5%.

[b] Residue data using a residue index (0-3max).

[c] Phytotoxicity data using a phytotoxicity index (0-3max).

cal Co., Raleigh, North Carolina; Mon 24000 (chemistry not available) Monsanto Chemical Co. St. Louis, Missouri; and Prostar® (flutolanil) NorAm Chemical Co. Wilmington, Delware (Table 1).

Results and Discussion

Field plot disease data on St. Augustinegrass was fairly uniform; however, a low level of disease was observed in spite of the inoculations with *R solani*. The uniform but low level of disease symptoms on the plots suggested that the inoculations were successful but the weather conditions did not support heavy disease activity.

Several standard fungicides were used in the field test in order to establish a base line for the level of control under the existing disease pressures. Standards were Chipco 26019 (50WP), Banner 2E, Daconil 2787 4F and Terraclor 75W (Table 1). The level of control of Rhizoctonia blight was excellent for Chipco 26019 (2 oz), Terraclor (0.45 kg), and Daconil 2787 (4 oz); however, the level of control by Banner (2 oz) was among the mid range of treatment results. Banner treated field plots also showed signs of phytotoxicity (red coloration) following three applications at the 2 oz rate.

Rhizoctonia blight control with Terraclor 50 DF was very good (Table 1). Results were also very good with Terraguard 50W (4 oz) which was among the best of products tested. Rhizoctonia blight control with G 696 4F was not satisfactory.

Previous testing with Prostar formulations gave excellent control of Rhizoctonia blight symptoms and this years test was no exception. Results with Prostar as a 50W or 70DG gave good results even though the product was applied only one time during the field test (Table 1).

Results with Sierra's WP combination of Vorlan + Fungo were generally good for Rhizoctonia blight control on St. Augustinegrass although the higher 2 oz rate was superior to the lower rate. Results with Vorlan Flo and Fungo Flo were also good and ranked among the better treatments (Table 1).

A number of Fermenta/ASC Co. chemicals were tested in the field study. Disease control with Daconil 2787 4F and Daconil/ASC formulations were better than most other products tested (Table 1). *Rhizoctonia* blight control with Daconil 2787 4F, ASC66518b and ASC66518c, and ASC66791 (6 oz) was superior to all other treatments in the study. The poorest results with the ASC chemical treatments were with ASC66608, ASC66900, and ASC66811. Some phytotoxicity was noted in one of the plots treated with ASC66900 (8 oz). Heavy residue was noted on several of the Daconil and Daconil/ASC treated field plots (Table 1).

MON-24000 was evaluated at 14-, 28- and 42-day intervals at rates varying from 0.12 - 1.0 oz. Results with all the tests were generally better than the control. MON-24000 applications at 14-day intervals at rates of 0.12 or 0.25 oz gave excellent control and comparable results at slightly higher rates (0.25 and 0.50 oz) at a 28-day schedule. At the treatment schedule of 42 days, no disease was noted for plots receiving rates of 0.5 and 1.0 oz but disease symptoms were noted for plots receiving the 0.25 oz rate. In this study, the 14-day treatments were applied three times, the 28-day treatment two times and the 42-day treatments only one time.

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PR-4904

Efficacy of Chemical and Biological Treatments for Controlling *Rhizoctonia* Blight on Bentgrass[1]

P.F. Colbaugh and M. C. Engelke

Abstract

'Penncross' creeping Bentgrass (*Agrostis palustris* Huds.) field plots were used to determine efficacy of chemical and biological treatments for controlling *Rhizoctonia* blight. Treatments were initiated on 25 September 1990, and the study continued with varying frequencies of treatment application during a 6-week period on intensively watered and fertilized field plots. *Rhizoctonia* inoculations were made on turfgrass plugs removed from treated field plots 4 and 5 weeks after initiating the study. *Rhizoctonia* foliar blighting on recovered field plugs was less on Daconil 2787® 4F and Daconil/ASC treated field samples than Terraguard® 50W or experimental biological treatments tested. Of experimental biological treatments used in the study,

[1]This publication reports research involving pesticides. It does not imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate state and federal agencies before they can be recommended.

ASC66889-1 and -2, ASC66912-1 and Soil Inoculant I (2.6 kg) gave some disease protection on the 4-week old field plugs. None of the biological treatments gave disease suppression on the 5-week samples. Chemical disease control products generally were superior to biological treatments.

Introduction

Four distinct pathogens are attributed to Rhizoctonia blight diseases of turfgrasses; however, only one *Rhizoctonia* sp. (*R. solani*) is thought to occur on bentgrass (2). Rhizoctonia blight on bentgrass is often referred to as the "brown patch" disease, because of the development of brown circular disease patterns. As the disease progresses, circular brown areas with occasional irregular shaped patches of blighted turf are typical disease symptoms (1). Excessive cultural practices, including heavy fertilization and irrigation are known to increase the incidence and severity of Rhizoctonia blight on bentgrass and other turfgrass species.

Current research is focused on developing practical measures for control of Rhizoctonia blight on turfgrass species. Investigations during 1990 included field experiments with commercial and experimental fungicides for Rhizoctonia disease control. The present study compares the effectiveness of seven fungicides and 18 biological treatments for controlling the disease on 'Penncross' bentgrass.

Methods and Procedures

The Rhizoctonia blight field study was conducted on Penncross Bentgrass field plots located at the Texas A&M Research Center at Dallas, Texas. The experimental block consisted of 144 separate plots evaluating 34 treatments with four replications including untreated plots. Each plot on the bentgrass field nursery consisted of an area equal to 5 x 10 ft. (1.57m x 3.15m). Field plots were arranged in a completely randomized block design for statistical interpretation of the disease data.

Field applications of test fungicides and biological treatments occurred over a 6-week period beginning 25 September and continued through October. Spray applications of chemical treatments were made with a CO_2 pressurized spray rig delivering 30 psi. Chemical treatments were applied in 1,800 ml tap water which was uniformly sprayed on four replicate 50 ft^2 field plots. The rates and frequency of fungicide applications varied by the manufacturer's recommendations as shown in Table 1. Fungicides used in the study were: Daconil 2787® 4F and ASC66518-66900 82FG (chlorothalonil), Fermenta ASC Plant Protection Co., Painesville, Ohio; and Terraguard® (triflumizole), UniRoyal Chemical Co., Raleigh, North Carolina.

Biological treatments used in the study were cultured on sterile grain seed and were administered to the plots at a rate of 1.3 - 5.2 kg/1,000 ft^2 as shown in Table 1. Biological treatments were: Soil Inoculant I (*Gliocladium virens*), Grace-Sierra Chemical Co., Milpitas, California; Biologicals 1-3 (G. virens), Texas Agricultural Experiment Station, TAMU College, Station, Texas; Faerifungin (basidiomycete extract), Vigoro Industries, Winter Haven, Florida; and ASC666889-912 (bacterial antagonists), Fermenta ASC Plant Protection Co., Painesville, Ohio.

Plugs of treated turfgrass were removed from turfgrass plots 4 and 5 weeks after the initiation of chemical and biological treatments on the field plots. The cores were 5.5 cm diameter and were immediately placed in plastic "sundae" cups obtained from the McDonalds Corporation. *Rhizoctonia* spp. inoculation (isolate 31) was performed using agar discs removed from the periphery of an actively growing culture on water agar. Inoculated leaf blades were misted with sterile water using a hand antomizer and caps were placed on the top of the cups to insure high humidity. Fungal outgrowths could be observed 24 hours after inoculation of the foliar canopy of the grasses. The treatment cups were then placed in covered clear plastic dish pans maintained in a walk-in growth chamber held at 27°C. Five days following the inoculation of the bentgrasses severe foliar disease was observed and disease ratings were made using a disease index (0-3max) and percentage area showing disease symptoms (Table 1).

Results and Discussion

Results with Daconil 2787 and all Daconil/ASC experimental fungicides generally were better than other treatments in the study (Table 1). Although the lowest ASC experimental use rate for ASC66811 (0.06 oz ai) gave poorer results than the other ASC series fungicides, all ranked among the best treatments on both sampling dates. In contrast, Terraguard 50W did not suppress the applied inoculum on either of the sampling dates (Table 1).

None of the biologicals used in the test gave very effective results compared to fungicides such as Daconil; however, results during the early sampling (4 weeks) period were encouraging. Results with Soil Inoculant I (*G. virens*) at the 2.6 kg rate demonstrated Rhizoctonia blight suppression on the 4-week but not on the 5-week samples (Table 1). In several cases, higher levels of disease were observed where biologicals were used at the higher rates. This may be due to the added food base associated with applications of the small grain carrier.

Results with the ASC series biologicals on the Bentgrass field plots were generally not as good as with Daconil and Daconil/ASC formulations. Results with the biological ASC66889 were statistically better than the untreated control plots during the 4-week sampling but not the 5-week sampling period (Table 1). Multiple applications of ASC biological treatments generally

Table 1. Rhizoctonia blight ratings on 'Penncross' bentgrass plugs inoculated with *R. solani* and maintained in a controlled environment chamber at 26 °C for 5 days.

Treatment[1]	Freq/Aplic rate[2] per 1,000 FTD[2]		Disease Index[3,4] 4 wk	5 wk	% Disease 5 wk Sample
Not Treated Check	—	—	1.63 bf	2.38 ac	92
Daconil2787 4F	3	4 oz	0 j	0.25 hi	0
ASC66518a 82.5FG	3	4 oz	0 j	0 i	0
ASC66518b 82.5FG	3	4 oz	0.13 ij	0 i	0
ASC66518c 82.5FG	3	4 oz	0.13 ij	0 i	0
ASC66900 82.5FG	3	8 oz	3.50 e	0 i	0
Terraguard 50W	2	8 oz	2.75 a	2.85 ab	98
ASC66791 0.65F	3	4 oz	0 j	0.10 i	10
ASC66791 0.65F	3	6 oz	0 j	0.0 i	0
ASC66608 0.65F	3	5 oz	0.15 ij	1.13 eh	27
ASC66608 0.65F	3	7.5 oz	0.15 ij	0.70 gi	10
ASC66900 0.65F	3	4 oz	0.08 ij	0.63 gi	10
ASC66811 0.65F	3	0.06 oz	0.75 fj	1.88 be	85
Soil Inoculant 1	1	1.3 kg	1.25 cg	3.00 a	100
Soil Inoculant 1	1	2.6 kg	0.88 ej	2.25 ac	95
Soil Inoculant 1	1	3.9 kg	1.63 bf	1.88 be	85
Soil Inoculant 1	1	5.2 kg	2.25 a	1.75 ce	80
Biological #1	1	3 kg	1.25 cg	1.83 be	85
Biological #2	1	3 kg	1.38 bg	1.63 cf	83
Biological #3	1	3 kg	1.88 bd	2.25 ac	95
Faerifungin 99EC	1	4 oz	1.63 bf	1.75 ce	80
Faerifungin 99EC	1	8 oz	1.63 bf	2.25 ac	95
ASC66899-1 SG	1	3 kg	2.13 ac	2.25 ac	95
ASC66899-2 SG	1	3 kg	0.75 fj	2.63 ac	97
ASC66912-1 SG	1	3 kg	0.63 gj	2.63 ac	97
ASC66912-2 SG	1	3 kg	1.00 di	1.93 be	86
ASC66889-1 SG	1	3 kg	0.25 hj	2.13 ad	85
ASC66889-2 SG	1	3 kg	0.65 gj	2.50 ac	97
ASC66899-1 SG	3	3 kg	1.75 be	2.00 be	90
ASC66899-2 SG	3	3 kg	1.25 cg	1.25 dg	60
ASC66912-1 SG	3	3 kg	2.13 ac	2.38 ac	92
ASC66912-2 SG	3	3 kg	1.38 bg	1.75 ce	80
ASC66889-1 SG	3	3 kg	1.13 dh	1.63 cf	83
ASC66889-2 SG	3	3 kg	0.75 fj	2.13 ad	85
ASC66887 SG	3	3 kg	2.25 a	0.75 fi	60

[1]SG = biological products applied on seed grain carrier 3 kg/1,000 ft^2.
[2]Treatment application frequency, 2 = 14 d treatments, 3 = 10 d treatments.
[3]Disease Index = (0 - 3) where 0 = no disease, and 3 = 100% foliar blight. Percent Disease = percentage of area shownig foliar blighting.
[4]Values followed by the same letter are not statistically different by the Duncan's multiple range test P=0.05%.

gave a higher disease rating as noted earlier with the Sierra Soil Inoculant I biological. Results of the second inoculation study were not good for any of the biologicals tested. The presence of cooler weather conditions may have had a significant influence on disease suppression by biologicals.

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PR-4905

Influence of Clippings Recycling on Disease Incidence in Three Turfgrass Species

P. F. Colbaugh, N. E. Cowden, B. W. Hipp, and T. Knowles

Abstract

Mowing practices are being investigated as a means of recycling turfgrass clippings in situ and reducing the burden of clippings disposal in large metropolitan areas. During 1989 and 1990 two types of mowing operations were used on St. Augustinegrass, [*Stenotaphrum secundatum* (Walt) Kuntze], tall fescuegrass (*Festuca arundinacea* Schreb.), and bermudagrass [*Cynodon dactylon* (L.) Pers.] field plots to determine their influence on fungal disease severity from June to

September. Field plots receiving 0, 1.3, 2.7, and 4.0 lbs N/1,000 ft^2 were mowed once weekly using a mulching mower with clippings returned or a standard rotary mower with clippings bagged and removed. Over a 2-year period, damaging fungal diseases were not observed with either of the mower regimens. Direct counts of Helminthosporium leafspot and rust lesions on bermudagrass and tall fescuegrass and gray leafspot lesions on St. Augustinegrass indicated disease severity was more related to seasonal environmental conditions than mowing practices used on field plots. The number of leafspot disease symptoms on plots mowed with the mulching mower was generally less than disease symptoms observed on plots where clippings were bagged and removed.

Introduction

Bagging of turfgrass clippings is an universally accepted practice for the removal of unsightly surface debris during mowing. Clipping removal also has been recommended by University researchers for many years as a sanitary precaution to reduce the development of fungal diseases (5). Decaying turfgrass clippings and dying plant parts are known to be a major contributor to fungal diseases because organic debris serves as a saprophytic food base for growth of pathogenic fungi (1).

Millions of tons of turfgrass clippings are generated in U.S. metropolitan areas each week (2). Because of the cost of clipping collection and disposal in overburdened municipal landfills, future collections of grass clippings and other forms of yard waste appear unlikely. A national effort to ban yard wastes is actively under consideration. Some 15 states have current or pending legislation (targeted for 1993) to severely restrict municipal collections of all types of yard waste debris (4). Turfgrass clippings constitute most of the collection and disposal problem. A typical bermudagrass lawn can generate as much as 300 lbs/1,000 ft^2 (132 kg/93 m^2) during the growing season (2). Mulching lawnmowers can be an alternative turfgrass management tool to recycle turfgrass clippings in situ. The present study is focused on the effects of mulching mower use on the incidence and severity of common fungal diseases on three common turfgrass species grown in the South.

Methods and Materials

Established turfgrass field plots on Austin silty clay soil were used to determine the incidence of common fungal diseases on three turfgrass species. Turfgrasses used in the study were common bermudagrass, 'Raleigh' St. Augustinegrass, and 'Rebel' tall fescuegrass which had been established over a 2-year period. Fertility levels for each turfgrass species varied from 0, 1.3, 2.7, to 4.0 lbs N/1,000 ft^2/yr. Nitrogen application dates were 15 April, 1 June, 15 July, and 1 September for bermudagrass. Application dates for St. Augustinegrass were 1 May, 1 June, and 1 September. Tall fescuegrass was fertilized 1 March, 15 September, and 15 November. Irrigation was supplied three times per week that applied water at a rate equivalent to 0.6 times evaporation from a class A pan.

All turfgrasses were treated with the same care as a regular lawn and received weekly mowing with one of two walk behind power Bolens 4 hp lawnmowers. One of the mowers was a mulching mower (mod. 8643) and the second mower was a standard rotary rear bagging lawnmower (mod. 9062) used to collect grass clippings from the plots. Mowing heights were 1.5 (3.9 cm), 2.0 (5.0 cm), and 2.5 (6.25 cm) inches for bermudagrass, St Augustinegrass and tall fescue, respectively.

Disease observations were used to assess respective turfs and cultural regiments at five intervals from June to September. The incidence and severity of foliar diseases on each replicated plot was determined by placing a 15 cm dia plastic ring on the plots and counting the number of fungal lesions within the given area of the circle (139 cm 2). A hand held 10x magnifying lens was used to assist in the visual definition of lesions where more than one fungal pathogen was active during the observation period.

Results and Discussion

Significant statistical differences in the incidence of leafspot disease symptoms were not observed for levels of fertility or mowing regiments used on field plots of the three turfgrasses during the summer (3). The data reported herein represent mean values for all levels of fertility for each of the mower regimen and date of observation over a 2-year period (Figs. 1-3).

Observations of Helminthosporium leafspot (*Cochliobolus cynodontis*) lesions on common bermudagrass indicated the highest level of disease activity occurred during the transition seasons of spring and fall (Fig. 1). Leafspot lesions on field plots receiving the four fertility levels were highest during the spring and leafspot numbers were lowest during the hot-dry summer period. Comparisons of the mean values for leafspot disease with all levels of fertilizer did not show significant differences (DMRT P=.05%) for plots receiving mulching mower or clipping bagging and removal treatments (Fig. 1). The number of leafspot lesions on the mulching mower treatment plots were consistently lower than lesion counts on plots receiving the bagging and removal mower treatment.

Symptoms of Gray leafspot disease (*Pyricularia grisea*) on St. Augustinegrass were most severe during the late summer when weather conditions were warm and humid (Fig. 2). The lowest incidence of disease lesions on leaf blades was observed during the early spring. Comparisons of the mean values for disease symptoms with all fertility levels and weekly mower treatments,

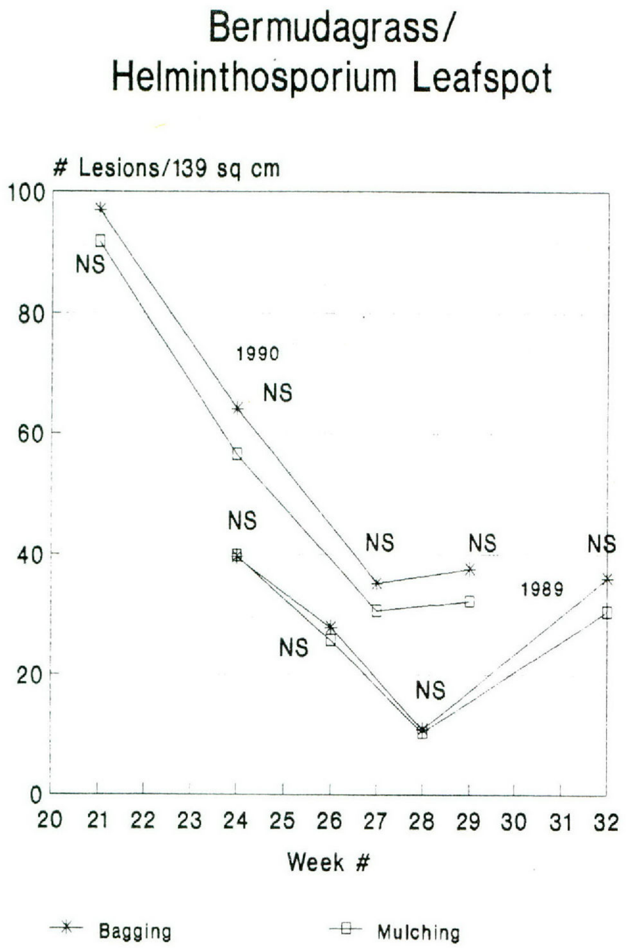

Figure 1. Mean number of Helminthosporium leafspot lesions on common bermudagrass field plots receiving weekly mulching mower and bagging mower operations.

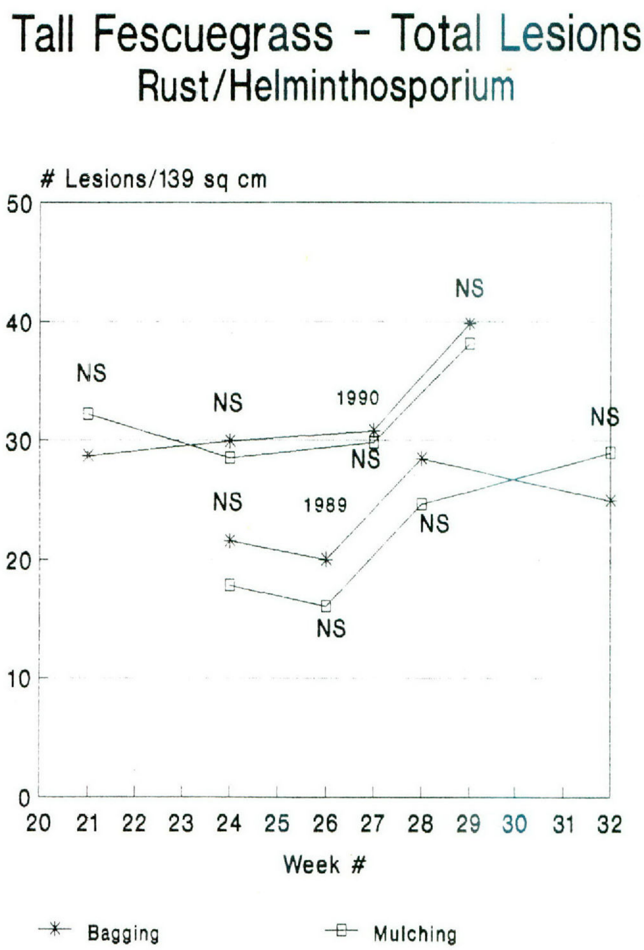

Figure 2. Mean number of Gray leaf spot lesions on Raleigh St. Augustinegrass field plots receiving weekly mulching mower and bagging mower operations.

and with the mulching and clipping, bagging, and removal did not show a statistical difference among treatment means (Fig. 2). Lesion counts were consistently lower on mulching mower treatment plots than counts on plots with the bagging and clipping removal treatment.

Two diseases were present on the tall fescuegrass field plots during the summer so the leafspot data presented (Fig. 3) is combined for both diseases. The disease lesions caused by the rust disease (*Puccinia coronata*) and Helminthosporium leafspot (*Drechslera dictyoides*) were present throughout the growing season and difficult to separate by visual inspection. Lesion activity on tall fescue appeared to be moderately high throughout the growing season (Fig. 3). No statistical differences among combined treatment means across all fertility levels for mower treatment regiments were observed; however, lesions found on mulching mower treatments were generally lower than field plots where clippings were bagged and removed (Fig. 3).

The results of investigations over a 2-year period indicate that weekly use of the Bolens mulching lawnmower was not associated with higher levels of common disease activity on three widely used turfgrass species. Consistently lower levels of leafspot disease activity on mulching mower treatment plots could be related to disease suppression by microorganisms on the mascerated leaf tissue (1). Investigations are in progress to determine the suppressive role of bacte-

St. Augustinegrass
Gray Leaf Spot Lesions

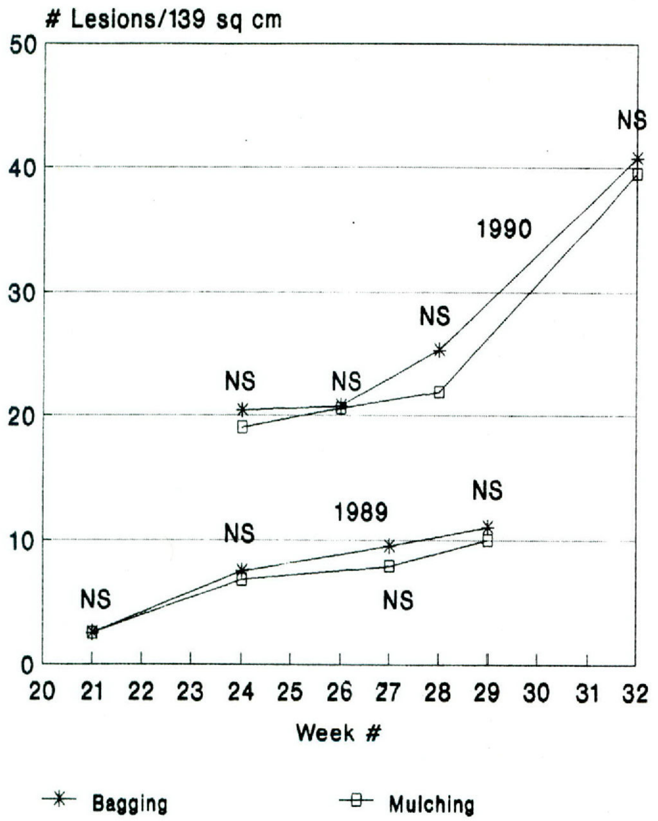

Figure 3. Mean number of rust and Helminthosporium leaf lesions on Rebel Tall Fescue field plots receiving weekly mulching mower and bagging mower operations.

ria on mulching mower generated leaf clippings.

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PR-4906

Factors Affecting Vertical and Horizontal Distribution of White Grubs in Experimental Cages

Robert L. Crocker

Introduction

Caged organism and caged habitat studies are important approaches to many aspects of biological and ecological research. Such studies especially are valuable when dealing with cryptic organisms or when it becomes necessary to limit natural sources of variability. What is essential in such studies is that the cage environment does not affect the physiology or behavior of the test organism in some way that might bias the experiment.

Pest management studies are an important example of where the sensitivity of the experimental system to the impact of cage effects can be crucial. For example, if the microhabitat in a cage stimulates a root-feeding pest to go deep into the soil instead of remaining near the surface as is normal, the herbivore will feed on distal root tips instead of severing roots near their origin on the stem. As a result, the root feeder may cause little damage to the plant. That particular situation apparently was experienced in a recent study at this research center.

The purpose of that study had been to compare the severity of root damage caused to turfgrass by varying numbers of larvae (or white grubs) of *Phyllophaga crinita* Burmeister and *Cyclocephala lurida* Bland. The study was conducted in 25 cm (10-inch) diameter cages of turfgrass grown on raised greenhouse benches. At the end of the test, it was discovered that root damage was much less severe than would have been expected in a lawn. That result was understandable because the insects were concentrated near the bottoms of the cages instead of in the upper few centimeters of soil (as is normal in lawns). Because the grubs themselves appeared to be normal, it was suspected that some cage effect had influenced the results. Probable causes for the abnormal distribution of the insects included (a) atypical thermal conditions in the soil due to solar heating of the walls of the cage, or (b) abnormal distributions of water, oxygen, carbon dioxide, or other gases in the soil due to exposure of the porous bottom of the cages.

Various types of research on white grubs has been conducted under cage conditions, but none are known to have involved validation of the cages themselves. Reinhard (1941, 1942, 1944, 1946) measured the development of several species of *Phyllophaga* in a cellar using tin ointment boxes. Insecticidal efficacy against *P. crinita* has been evaluated using plants caged in pots (Fuchs et al., 1974; Huffman et al., 1976; Huffman and Harding 1980). Potter (1982) measured the impact of *C. lurida*, the southern masked chafer, on Kentucky bluegrass using galvanized steel hoops driven into the sod as cages.

The purpose of the present research was to determine the effect of placement of test cages on an open bench (versus in the soil) on cage temperatures and on the distribution and the impact of *P. crinita* and *C. immaculata* white grubs in the cages.

Materials and Methods

Test cages were 20 cm (8 inch) sections of 15 cm (10 inch) diameter schedule 40 polyvinyl chloride (PVC) pipe. Each cage was filled with sandy loam soil (pH = 8.32) and its upper end was sodded with hybrid bermudagrass (*Cynodon dactylon* L. Pers. X *C. transvaalensis* Davy). The lower end of one group of cages rested on a metal-mesh topped table covered with ground-cover fabric. The fabric permitted excess irrigation water to percolate through the bottom of the cages, but prevented the escape of white grubs. The other group of cages was identical to the first group except that the fabric they were resting on was laid out in a 20-cm deep pit dug in the floor of the greenhouse and the cages subsequently were buried to within 1 cm of their upper rim in the soil. Inter-cage spacing was 10 cm., both on the table and in the floor. The experiment was housed in a glass greenhouse on the campus of the Texas A&M University Research and Extension Center at Dallas, with air temperature regulated at approximately 24-28° C by fans and forced air evaporative cooling pads.

The bench and the floor halves of the experiment included four replications of the following treatments: 15 *P. crinita*, 15 *C. lurida* and uninfested control. The cages were established 30 November 1989. Larvae reared from field-captured adult females were introduced on 1 December 1989. Plots were mowed to uniform height on 4 December 1989 (clippings discarded) and on 25 January 1990 (clippings dried and weighed). On 31 January 1989, the contents of each cage were removed, and the vertical and horizontal position of each grub recorded. The roots were washed on that date and their weight was recorded after they were dried to a constant weight in a warm air drier.

Analysis of variance (ANOVA), multiple analysis of variance (MANOVA), and related procedures were performed using SuperANOVA ver. 1.1 (Abacus Concepts 1989).

Results and Discussion

A MANOVA confirmed that the vertical distribution of larvae in the cages was influenced by the species of the insect ($P = 0.0009$) and the location of the cage (on bench versus buried in soil) ($P \leq 0.0001$). The mean depths of *P. crinita* larvae were 14.2 cm, SE = 0.8 cm, (bench) versus 9.0 cm, SE = 0.8 cm, (buried in soil). The mean depths of *C. lurida* larvae were 11.8 cm, SE = 1.0 cm, (bench) versus 4.6 cm, SE = 0.7 cm, (buried in soil). No significant differences were detected in the vertical distribution according to the lateral part of the cage (N, NE, E, SE, S, SW, W, NW, or Center of cage), and no significant interaction was detected between any two or all three of those factors.

The MANOVA indicated that the mean distance of larvae from the nearest part of the cage wall (radial depth) was significantly affected by the placement of the cage (table versus soil) ($P = 0.0264$) and by the lateral part of the cage ($P = 0.0001$). The only lateral part of the cages that was preferred over the others, was the center. None of the compass directions were preferred over others (Duncan's new multiple range test, $P = 0.05$).

Although large differences were found between the soil temperature in cages based on where the cages were located, temperature was remarkably uniform both laterally and vertically (27.5 ± 0.5°C on bench, 18.0 ± 1°C in soil) within two uninfested cages on the bench and two in the soil that were examined using a thermistor thermometer equipped with a soil probe. The vertical uniformity of temperatures is contrary to what was expected, and may be due to the experiment being conducted in a greenhouse where air temperature (and thus probably soil temperature also) is artificially stabilized. The lateral uniformity of temperatures indicates that cages on the bench were small enough that solar heating of the cage sides was quickly equalized throughout the cage. There was no reason to expect important lateral differences in the temperatures of cages buried in the soil.

An ANOVA indicated that the dry weight of roots was affected by cage location (on bench versus buried in soil) ($P \leq 0.0001$), but not by the species of grub (or no grub) ($P = 0.1309$), and there was no significant interaction between location and type of infestation ($P = 0.2858$). It is probable that higher soil temperatures contributed to the much greater growth of roots in cages held on the bench. Because this experiment was run late in the year when the insects had completed most of their growth, larvae did not feed heavily enough to produce statistically significant differences in the root mass. However, it is possible that the greater amounts of root growth did permit white grubs in cages on the bench to find sufficient concentrations of food at greater depths than did grubs in cages buried in the soil.

It is possible that the vertical distributions of the insects were influenced by differing vertical gradients in soil moisture or gases, but further data would be needed to defend such a hypothesis. What is clear, is that cage conditions generally should be as realistic as possible. This may mean that cages will have to be maintained outdoors. Failure to create highly realistic conditions (or compensate for the lack of them) could produce misleading tests of biological control organisms, chemical insecticides, or ecological interactions. This especially would be the case where inter-species interactions (including herbivory, predation, infection, and competition) are involved, and both species could be affected in different ways by the microhabitat.

Future research should focus on developing test cage conditions that mimic the essential aspects of natural field conditions closely. The realism of behaviors and development of white grubs in such test cages should be validated by comparing test insects to field populations.

Acknowledgment

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Preliminary Studies of White Grub Impact on Turfgrass

Robert L. Crocker

Introduction

White grubs are the larvae of beetles (order Coleoptera) in the family Scarabaeidae. Although certain members of this family are highly beneficial decomposers of manure and other forms of organic matter, the phytophagous scarab species include in their ranks the most damaging soil insects in the American Southwest. The total economic impact (damage plus cost of control) of these phytophagous species on the 3.2 million acres of cultivated turfgrass in Texas is estimated to be $20 million annually. Root feeding by these insects also reduces yield and causes loss of stand in small grains, forage, sugar cane, tree plantations, and commercial ornamentals production. There are no quantitative estimates of the economic impact of white grubs in field crops or ornamental plants.

Two species of white grubs, *Phyllophaga crinita* (Burmeister) (which has no common name) and *Cyclocephala lurida* Bland (southern masked chafer), are key pests of turf in Texas. Potter (1982) found that field cage populations of southern masked chafer white grubs reduced the vigor of Kentucky bluegrass (*Poa pratentis* L.) within 2 weeks, although such effects could be masked by regular irrigation or adequate rainfall. Potter concluded that the accepted economic threshold in Kentucky (six to eight southern masked chafer grubs per 0.1 m^2 of bluegrass turf) probably is too conservative for many situations.

Although the southern masked chafer is one of our two key species of white grub in Texas turf, Kentucky bluegrass and the Kentucky environment are too different from what we have in Texas to permit accurate extrapolation of Potter's data to our state. No measurements are available of how many *P. crinita* larvae are necessary to cause significant turf damage, but it appears on the basis of field observations that comparable sized populations of *P. crinita* may be more damaging than are those of the southern masked chafer. In Texas, a widely accepted criterion has been to treat if more than three or four *P. crinita* larvae were found per square foot; no basis is known for that recommendation.

Almost half of the nation's pesticide usage is by homeowners, public agencies, and urban industries. An estimated 251,000 pounds (active ingredient) of insecticide were applied in the Dallas area alone by homeowners in 1971. Those insecticides were applied chiefly for the control of lawn insects (Rumker et al. 1972). Since these figures were compiled, the size of Texas' urban population has increased considerably. In 1980, 80 percent of the population of Texas lived in towns or cities, compared to 62.7 percent in 1950, 17 percent in 1900, and 3.6 percent in 1850. As of 1982, half of the state's total population had become concentrated in three metropolitan areas (Skrabanek 1985). If it were not necessary to treat one or more times a year for white grub control, most Texas lawns would seldom if ever receive a chemical insecticide treatment. As it is, tens of thousands of residential and commercial lawns in Dallas, Houston, El Paso, and other cities and towns must be treated annually to control these destructive pests.

Sound economics and concern for environmental quality dictate that chemical insecticides be applied only when damaging numbers of pests are present. Unfortunately, no appropriate data exists on how many of these grubs a lawn can tolerate.

The purpose of the research reported here was to develop evidence that would help reduce unnecessary insecticide applications in urban landscapes. My goal was to demonstrate the maximum concentration of white grubs that turfgrass can tolerate without significant injury. Because there are few published techniques for this type of research, many of the devices and procedures used in the research were themselves previously untested.

The research had three complementary parts. Objective I was to test sampling procedures to document the impact of white grub feeding in actual lawns across the state. Objective II was to answer the question of whether mature overwintered grubs feed sufficiently prior to pupation to justify treatment in late spring. Objective III was to determine the relationship of different numbers of artificially infested *P. crinita* and *C. lurida* white grubs to turf injury.

Materials and Methods

Objective I: White grub impact in Texas lawns.

This study was designed to relate the density and species of white grubs present in actual irrigated lawns to the condition of the grass. Extensive preliminary sampling was done in Brownsville, Houston, Dallas, and El Paso to locate irrigated turfgrass sites infested with sufficient numbers of white grubs for damage measurements to be taken.

Turf at 20 locations in and near Brownsville and 25 locations in the Houston area was explored extensively, but no suitable populations of white grubs could be located. Only one golf course between Harlingen and Brownsville had a minor infestation, and the white grub density there (<1 *P. crinita* larva per 0.01m^2) was too low to be useful. This highly unusual lack of useful populations of white grubs near Brownsville and Houston apparently was due to earlier hurricane-induced rains that had drowned many heavy infestations of larvae.

Travel to El Paso disclosed that, in general, lawns there were suffering from severe water restriction. Examination of 34 sites across the city disclosed that most lawns were brown and dormant, such that they could not be evaluated for grub injury. Only one turf (at a golf course) was both green and infested with more than a nominal population of white grubs. That turf, however, had been treated with insecticide so that grub counts were unreliable and could not be included in the study. That site did yield a few white grubs infested with *Bacillus popilliae* (the causal agent of milky spore disease in white grubs) that were taken to the laboratory for further study.

Adequate grub populations were found in Waco and the Dallas area and a total of 245 samples were collected from 52 locations in those cities. In this study, only well-maintained irrigated turfs of hybrid bermudagrass (*Cynodon dactylon* L. Pers. X *transvaalensis* Davy) were sampled (except in Houston and Brownsville, where St. Augustinegrass (*Stenotaphrum secundatum* [Walt.] Kuntze) also was subjected to preliminary sampling).

The sampling program was based on the fact that white grub densities tend to be non-uniform in different parts of a lawn. The objective was to exploit that spatial variability by relating the turf condition at different points in a turf with the numbers of white grubs associated with each point. In general, severely damaged turfs have so little root system remaining that the turf can be lifted easily from the soil. By contrast, the canopy of a healthy turf usually will tear rather than come loose from the ground. At the beginning of the study, root strength was gauged by subjectively grading the resistance of the grass to being pulled from the ground by hand. That procedure was found to be highly dependent on the strength and degree of tiredness of the data gatherer, so a new objective procedure was developed and implemented.

The new procedure needed to be able to directly measure the strength of grass roots in an objective and repeatable manner and to relate that to the number of grubs in the soil. Under the procedure that was devised, a 0.1 m^2 area in a turf was selected and visually graded on a scale of 0-10 (Table 1). Next, a clamping tool (Vice-Grip® 200 mm Locking Sheet Metal Tool 8R) was used to grasp the above-ground portion of the sod. The upper end of the clamping tool was attached by a wire to a spring scale (Homs Model 50 Instrument and Laboratory Scale), which in turn was suspended from the adjustable center column of a photographic tripod. The tripod's center post then was raised progressively higher by a gear-drive mechanism until the grass was ripped free from the soil. During the raising of the tripod's center post, the tension on the scale was noted continuously. The number of kilograms registering on the scale when the grass roots broke was recorded. Then, a golf cup cutter (that took 0.001 m^2 cross section core samples) was used to determine how many white grubs of each species were present in the soil directly below the turf to which the clamp had been attached.

Table. 1. Turf visual grading system.

Grade	Description
10	Full vigor—green, canopy dense, leaves at height of cut
9	Slight reduction in color/vigor
8	Stronger reduction in color/vigor
7	Brown tissue visible but slight; leaves below height of cut
6	86-95% coverage, or canopy density beginning to thin
5	76-85% coverage, or canopy density moderately thinned
4	51-75% coverage, or canopy density severely thinned
3	31-50% coverage
2	11-30% coverage; small islands of green
1	1-10% coverage; scattered green nodes or stolons with leaves
0	Dead

After trying out several variations on the new procedure, it was decided to standardize on clasping the above-ground part of the amount of turf that would fit between the jaws of the tool when they were set at 25 mm separation. The approximately 26 mm wide blades of the clamp were 77 mm long, so that the total sod sample was ca. 1,925 mm^2 (77 mm length x 25 mm blade separation). To grip a sample of turf, the blades of the sheet metal tool were worked down through the 25 mm wide section of sod to soil level; then they were clamped tightly onto the turf. As the tripod's shaft was cranked higher and higher (increasing the tension on the scale and on the sod), readings were taken from the scale until the turf tore loose from the soil. A record was made of the highest reading taken before the major separation of the sod from the soil.

In order to determine the density of white grubs at the precise spot that had been graded, that part of the procedure was upgraded also. Instead, five tightly-clustered (within the graded 0.1 m^2 of sod) independent measurements were taken of the sod strength, and a core sample was taken from directly beneath each subsample to estimate grub density at that location. Thus, each location was visually graded on a subjective quality scale, and then five measurements were taken of plant strength and grub density. Because the measured sods all were hybrid bermudagrass, resistance of the plant to being lifted from the soil was due primarily to the strength of rhizomes and roots that had escaped destruction by the insects.

White grubs were identified (species encountered were *P. crinita* and *C. lurida*, the primary turf damaging white grubs in Texas), and at each site, an effort was made to use 10 sets of five samples each to cover the range of damage conditions within what otherwise should be a homogeneous area of turf. Data were collected in April, September, October, and November and were analyzed to determine the relationship between numbers and species of white grubs recovered and turf damage.

Objective II: Spring turf injury.

The purpose of this test was to determine whether fully-grown white grubs of *P. crinita* or *C. lurida* would cause significant damage to turf in the spring before they transformed into adult beetles. The study was conducted using caged plant material maintained outdoors on the campus of the Texas A&M University Research and Extension Center at Dallas. The cages were made of 20 cm (8-inch) sections of 25 cm (10-inch) diameter schedule 40 PVC pipe. The lower end of each cage was placed on a metal-mesh topped table covered with Typar® landscape fabric (Reeway Corp., Industrial Road, P.O. Box 511, Old Hickory, TN 37138). The fabric permitted excess irrigation water to percolate out of the bottom of the cages, but prevented the escape of white grubs. Each cage was filled with sandy loam soil, which then was irrigated and packed for several days. On 26 April 1989, the upper few centimeters of soil was scraped out of the cages and they were sodded with hybrid bermudagrass.

From 30 March through 1 April 1989, white grubs were collected from turfgrass in the Dallas area. On 26 April these insects were placed in the field cages. The proposal had called for one treatment to be infested with 10 *P. crinita*, a second treatment with *C. lurida*, and a treatment uninfested. That design was expanded to five treatments for each of the grub species, with grub densities of 0, 1, 2, 4, 8, and 16 specimens per 0.015 m^2 (ca. 0.5 ft^2) cage (that is approximately equivalent to 0-32 white grubs per square foot).

On the ninth day after the insects were placed in the cages, grass in all cages was cut to a uniform height (approximately 5 mm) and then allowed to regrow until termination of the experiment. Twenty-three days following infestation, the number of open seed heads on the grass in each cage was counted. On the 37th day following infestation (2 June 1989, shortly before adult beetles were expected to begin to emerge from the cages) clippings were harvested, air dried, and weighed. At that time, all plots were dissected so that grub developmental stage and density, and depth of turf rooting could be recorded. Roots were then washed, dried to constant weight, and then weighed.

Objective III: *Phyllophaga* versus *Cyclocephala* injury.

This field cage study was run to compare the impact of a range of densities of the two dominant turf species of white grubs (*P. crinita* and *C. lurida*) on turfgrass. On 21 September 1989, following summer reproduction of the insects, field cages (0.015 m^2) of hybrid bermudagrass turf (established on 19 September 1989, as in Objective II) were infested with 0, 1, 2, 4, 8, and 16 third instar larvae of *P. crinita* or *C. lurida* (four replications). Plots were irrigated as needed. Each plot was mowed to uniform height (approximately 5 mm) on 28 September, and clippings were discarded. On subsequent dates (20 and 27 November), clippings were kept, weighed, heat-dried to constant weight, and weighed again. On 29 November, the experiment was terminated; data for that date consisted of wet and dry weight of grass roots and the weights of surviving larvae.

Statistical Analyses

Analyses of variance (ANOVA) and related procedures were performed using the general linear modeling program SuperANOVA version 1.1 (Abacus Concepts 1989).

Results and Discussion

Objective I: White grub impact in Texas lawns.

After research on this objective began, it became obvious that better results would be obtained if a new procedure were developed for measuring the impact of white grubs on turfgrass. The original procedure simply proved too subjective and unrepeatable; ratings under that procedure depended too much on the strength and degree of tiredness of the data collector. The new procedure (which will be the only one referred to hereafter) is subjective only to the extent that occasionally some judgment comes into play in interpreting at what point the grass has broken free of its root system and the soil. Although the break usually is relatively quick and clean, at times the connections break gradually or in stages and some interpretation is necessary to decide exactly when the breaking tension should be measured.

The procedure demonstrated that injury caused to turf by field populations of *P. crinita* can ($P = 0.0001$) be quantified by directly measuring the force necessary to rip the turf from the soil. The quantitative effect of *C. lurida* white grubs was weak enough that the regression coefficient was not significantly ($P = 0.0615$) different from zero with the data presently available. These figures were computed by regressing the mean number of kilograms for a group of samples against the total number of grubs of each species recovered from those samples.

The regression formula developed (including the non-significant coefficient for *C. lurida*) was: Mean Kg for Separation = 10.0021 - [4.5499 x (Number of *P. crinita*)] - [2.9925 x (Number of *C. lurida*)] (Table 1). More data probably will permit the generation of a statistically significant estimate of the effect of *C. lurida* white grubs.

The larger slope (Beta) for *P. crinita* tends to confirm our original suspicion that, insect for insect, infestations of *C. lurida* white grubs are not as damaging as are comparable densities of *P. crinita*. This preliminary description of the relationship between root strength and white grub density can be refined as we obtain data representing a broader range of infestation levels.

The measured relationship between sample variance (y) and sample mean (x) for *C. lurida* larvae was: y = -0.0171 + 1.1700x [R^2 = 0.7289] (Table 2). For *P. crinita* larvae, the relationship of sample variance to sample mean was: y = 0.0458 + 0.6525x [R^2 = 0.5143]. This information will be useful in determining numbers of samples needed in future research.

The procedure appears highly satisfactory for further use in this type of research. More field data are needed that represent a wider range of grub intensities. This especially is true of *C. lurida* infestations, for which it appears that much higher population levels will be needed if severe root damage is to be seen. The reason that the coefficient for *C. lurida* is not significant appears to be that comparable numbers of them appear to be much less damaging than are *P. crinita* grubs, and dense populations of that species were not encountered in this research. Natural field conditions, however, always will be highly variable due to the many other factors that can influence root strength. Only through the use of field cages will it be possible to obtain highly precise measurements of root damage by white grubs. Future research should be aimed at obtaining more extensive field data and building a base of field cage data.

Objective II: Spring turf injury.

Physiological stress can cause a plant to alter its amount of seed production. No evidence of that was seen, however, in this research. The number of open seed heads per cage was counted on 19 May 89 to determine whether it might provide a sensitive index of plant stress, but a separate ANOVA for each grub species detected no significant differences in seed head production either in the *P. crinita* cages (P = 0.8308) or in the *C. lurida* cages (P = 0.5767) due to the number of larvae per cage.

Separate ANOVA's showed no significant relationship between the number (0 to 16) of larvae per cage and the dry weight of leaf clippings either on 22 May 1989 (for *C. lurida*, P = 0.8141; for *P. crinita*, P = 0.6166) or on 30 May 1989 (for *C. lurida*, P = 0.7175; for *P. crinita*, P = 0.7350).

Visual grading (0 = no roots, 10 = as good as control cage) of the grass root system in each cage disclosed no detectable reduction of root mass in any cages: all cages received a grade of 10. Under such conditions (no variability in data), no formal statistical analysis was warranted.

All of these data support the conclusion that larvae of *P. crinita* and *C. lurida* do little, if any feeding in the spring. This would indicate that spring treatments to control these species are too late to prevent any damage and should not be recommended. These results should, however, be confirmed in a similar test wherein the cages were buried in the soil; this would confirm that temperature gradients in these cages held on a bench did not mask the results of feeding activities.

Objective III: *Phyllophaga* vs. *Cyclocephala* injury.

Root dry weight. An analysis of covariance (ANCOVA) indicated that the dry weight of roots harvested at the end of the experiment was significantly related both to the number of grubs per cage ($P \leq 0.0001$) and to their species (P = 0.0098), but not the interaction of those factors (P = 0.1268). Separate ANCOVA's for each species of grub then were run.

For *P. crinita* grubs, the relation (P = 0.0015; R^2 = 0.373) between population density and root mass was calculated to be: Grams of Dry Roots per Cage = 9.371 - 0.424 x (Number of Grubs in Cage). For *C. lurida* grubs, the relation (P = 0.0132; R^2 = 0.248) between population density and root mass was calculated to be: Grams of Dry Roots per Cage = 6.521 - 0.206 (Number of Grubs in Cage).

The low R^2 value for both regressions indicates that more work is needed to refine our estimates of the impact of these insects on the root system. Nevertheless, these first-generation results are encouraging. The larvae in this experiment were deeper than was expected when the cages were dissected. This indicates that microclimatic conditions may have been significantly different from field conditions. Specifically, the vertical thermal gradient of these cages (exposed on their sides to the sun) was not natural. Other factors, such as O_2 gradient due to the open bottom of the cages, also will be made more natural in future studies (please see supplemental report). If larvae are at their normal shallow depth, they will cut off a greater percent of the root system when they sever a root, thus, their feeding will be more damaging.

Larval weight. An ANOVA indicated that the weight of larvae was significantly ($P \leq 0.0001$) related to the species (mean for *P. crinita* = 0.802 g, S.E. = 0.009 g; mean for *C. lurida* = 0.687 g, S.E. = 0.010 g) but not to the density (P = 0.3435) of individuals in a cage. This indicates that crowding in the cages was not high enough to cause treatment-related weight reductions in the larvae.

Clipping weights. An ANOVA of dry weight of grass leaf clippings taken on 20 November 1989, from cages of *C. lurida* (24.826 g) was significantly (P = 0.0433) higher than from cages infested with *P. crinita* (20.249 g); the larval population density (0, 1, 2, 4, 8, or 16 grubs per cage) had no significant effect on clippings weight (P = 0.9849). Data at termination of the experiment (27

November 1989) were similar to those of 20 November except that the mean weight of clippings from *P. crinita* infested cages (3.046 g) was significantly (P = 0.0425) higher than from *C. lurida* infested cages (1.883 g); again, grub population density had no significant effect (P = 0.5458).

Dry weight of 20 November 1989 clippings was not affected either by grub species (P = 0.5941) or population density (P = 0.9756). The dry weight of clippings of 27 November 1989 was not related to population density either (P = 0.5635). It was, however, significantly (P = 0.0085) affected by the species of the insect; the mean weight of dry clippings from *P. crinita* (2.240 g) was greater than that of clippings from *C. lurida* (1.315 g).

The impact of white grubs on the production of leaf material in this experiment may have been affected by the location of this experiment on a bench versus in the soil. For that reason, it would be desirable to confirm the results of this study using cages buried in the soil (please see supplemental report).

Acknowledgment

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PR-4908

Test of NTN-33893 for Control of Southern Chinch Bug in St. Augustinegrass (1990)

Robert L. Crocker

Introduction

New chemical pesticides and formulations must be tested for efficacy against many insects in order to determine their potential range of usefulness. The southern chinch bug, *Blissus insularis* Barber (Hemiptera: Lygaeidae), is a key pest in St. Augustinegrass (*Stenotaphrum secundatum* [Walt.] Kuntze) lawns and for that reason, it frequently is the object of pesticide efficacy tests. The purpose of the present field cage research was to test the utility of three rates each of NTN-33893-240F and NTN-33893-0.5G in comparison to diazinon 5G which is widely used for the control of the southern chinch bug in St. Augustinegrass.

Materials and Methods

The test was performed at the Texas A&M University Research and Extension Center at Dallas. The experiment involved six replications of eight treatments (three rates each of NTN-33893-240F and of NTN-33893-0.5G, one treatment with diazinon 5G, and an untreated check) in a randomized complete block design. The test was a modification of the method of Crocker and Simpson (1981), a procedure that eliminates insect distributional variation and among-plot insect migration encountered in open field-plot tests. The modified procedure maintains a natural turf environment where insects can behave normally and where factors such as thatch can affect pesticide availability (Niemczyk et al. 1977; Sears and Chapman 1979).

Southern chinch bugs for the test were collected 13 September 1990, using a D-Vac™ model 24 vacuum insect net (D-Vac Co., Riverside, CA) from severely damaged lawns of St. Augustinegrass turf in Pasadena, Harris County, Texas. The insects were transported the same day to TAES-Dallas and released immediately into a holding cage with some St. Augustinegrass. The next day, the chinch bugs were divided into groups of 50 unsexed adults. These adult bugs were randomly assigned, one group per plot, to 186 cm^2 field plots. All 50 plots were delimited by the walls of an open-ended PVC cylinder 15 cm diameter by ca. 16 cm high. The bottom end of each cylinder was embedded approximately 5 cm into the soil.

The test plots were in established irrigated minimally thatched St. Augustinegrass turf on the TAMU-Dallas campus. Preliminary sampling indicated that there were few or no chinch bugs in the plot area prior to the test. Soil in the plots was Austin - Houston type, alkaline montmorillonite clay typical of the Texas Blackland Prairies.

The experiment was designed to test the efficacy of treatments on insects in the plots at time of treatment. All cages were infested 14 September 1990. Insects were allowed 1 day to distribute themselves naturally in the turf before treatments were applied on 15 September 1990. Liquid treatments were applied with a hand-held sprayer in 50 ml (the equivalent of 2.5 liters/m^2) of final spray mix. To prevent cross-contamination by overspray, plots adjacent to the one being sprayed were covered during treatment application. Dry treatments were irrigated with 50 ml water immediately posttreatment. At all times, except when treatment was being applied and when samples were being taken, each field cage was covered by a nylon mesh. This barrier permitted air exchange and passage of light, but prevented insect escape (Crocker and Simpson 1981). Control treatment plots were not treated. Data were collected 17-18 September 1990 (Table 1).

Plots were sampled repeatedly until no further bugs could be recovered from the grass with a Craftsman Electric Blower Model No. 257.798850 equipped with vacuum attachment (Sears, Roebuck and Co., Chicago, IL). The insects were trapped in the wand of the vacuum attachment's intake hose by a layer of fabric mesh that was stretched across the connection between two sections of the wand.

Statistical analyses of treatment effects were performed on data transformed according to $X_t = (n + 0.5)^{0.5}$ x arcsine{[(f + 0.375) / (n + 0.75)]$^{0.5}$} where X_t is the transformed value, f = observed frequency, and n = sample size. That transformation produces a distribution of constant variance over the entire range of proportions (i.e., 0/n through n/n) (Anscombe 1948; Zar 1974). The data were analyzed on an Apple Macintosh II® using the general linear model program SuperANOVA, with treatment separations determined by Duncan's new multiple range test (Gagnon et al. 1989). Reported means were calculated from untransformed data.

Results and Discussion

All treatments produced significant (P = 0.05) southern chinch bug mortality compared to the untreated plots, but only diazinon applied at the label rate produced a practical level of control (Table 1). In general, NTN-33893-240F treatments were more effective than comparable NTN-33893-0.5G treatments, but neither group of treatments caused greater than ca. 53 percent mortality compared to the untreated plots. No significant (P = 0.05) differences in insect mortality due to rate of chemical application were detected for either of the experimental insecticides. No phytotoxicity was detected in any test plots. The results of this test indicate NTN-33893-5G is superior to NTN-33893-240F for control southern chinch bug, but that the tested doses are too low for practical levels of control.

Table 1. Mean numbers of southern chinch bugs per plot following treatment with various insecticides; initial population = 50 adult chinch bugs/caged field plot; six replications; Dallas, Texas; September 1990.

Material applied	Kg AI Per Ha[1]	Mean number of Chinch Bugs (±SD) per Plot
Diazinon 5G	7.32	0.8 ± 0.8 a
NTN-33893-240F	0.42	19.5 ± 2.4 b
NTN-33893-240F	0.28	20.0 ± 7.3 b
NTN-33893-240F	0.56	24.2 ± 7.5 bc
NTN-33893-5G	0.28	25.8 ± 9.5 bc
NTN-33893-5G	0.56	28.8 ± 8.2 c
NTN-33893-5G	0.42	29.3 ± 6.3 c
Untreated Control	0.00	41.7 ± 3.6 d

[1] 1kg ai/ha = 0.890 lbs ai/A. Means (computed from untransformed data) followed by the same letter are not significantly different at P=0.05, according to Duncan's multiple range test of arcsine transformed data (Analysis of Variance: *df* = 7,34; F = 23.2461, *P* < 0.0001 [SuperANOVA, Gagnon et al. 1989]). NTN-33893-240F and NTN-33893-0.5G are experimental products of the Mobay Corporation.

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PR-4909

Chemical Control of Southern Chinch Bug in St. Augustinegrass: 1990 Test

Robert L. Crocker

Introduction

The southern chinch bug, *Blissus insularis* Barber (Hemiptera: Lygaeidae) infests St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze] turf throughout the southern United States. At times, environmental conditions or attacks by natural enemies of the pest can cause the rapid collapse of large populations. It often is necessary, however, to use chemical insecticides to prevent the complete destruction of lawns. The purpose of this research was to test the efficacy of several insecticides for the control of the southern chinch bug in St. Augustinegrass.

Materials and Methods

The experimental procedure involved six replications of selected treatments including an untreated check in a randomized complete block design. The research was performed at the Texas A&M University Research and Extension Center at Dallas. Insects were extracted from the test plots by air suction rather than by repeated flooding of the test cages; except for that, the methods were in accordance with Crocker and Simpson (1981). This test procedure eliminates variation in insect distributional and among-plot migration of insects that frequently cause problems in open field-plot tests. The procedure also maintains a natural turf environment where insects can behave normally and where factors such as thatch can affect pesticide availability (Niemczyk et al., 1977; Sears and Chapman, 1979).

On 31 August 1990, southern chinch bugs were collected using a D-Vac[1] model 24 vacuum insect net (D-Vac Co., Riverside, CA) from severely damaged lawns of St. Augustinegrass turf in Pasadena, Harris County, Texas. The insects were transported the same day to TAES-Dallas and released immediately into a greenhouse holding plot of St. Augustinegrass. When it was time to begin the experiment, they were vacuumed from the greenhouse holding plot and divided into groups of 50 unsexed adults. These adult chinch bugs were randomly assigned, one group per plot, to 186 cm^2 field plots. All 50 plots were delimited by the walls of an open-ended PVC cylinder 15 cm diameter by ca. 16 cm high. The bottom end of each cylinder was embedded approximately 5 cm into the soil.

The test plots were in established irrigated minimally thatched 'Raleigh' St. Augustinegrass turf on the TAMU-Dallas campus. Preliminary sampling indicated that there were few or no chinch bugs in the plot area prior to the test. Soil in the plots was Austin - Houston type, alkaline montmorillonite clay typical of the Texas Blackland Prairies.

The experiment was designed to test the effect of treatments on insects in the plots at time of treatment. Insects were introduced into the plots on 1 September 1990 and allowed 1 day to distribute themselves naturally in the turf. Eleven chemical treatments were applied 2 September; control treatment plots were not treated. Data were collected 4-6 September 1990 (Table 1).

Treatments were applied with a hand-held sprayer in 50 ml (the equivalent of 2.5 liters/m^2) of final spray mix. Dry treatments were irrigated with 50 ml water immediately posttreatment. Before and immediately after treatment, each field cage was covered by a nylon mesh. This barrier permitted air exchange and passage of light, but prevented insect escape (Crocker and Simpson 1981). Plots were sampled repeatedly until no further chinch bugs could be recovered. The insects were sucked from the grass using a Craftsman Electric Blower Model No. 257.798850 equipped with vacuum attachment (Sears, Roebuck and Co., Chicago, IL). The insects were recovered from a layer of fabric mesh stretched across the connection between two sections of the intake tube of the vacuum attachment.

Table 1. Test 1: Mean numbers of southern chinch bugs per plot following treatment with various insecticides; initial population = 50 adult chinch bugs/caged plot; six replications; Dallas, Texas; September 1989.

Material applied	kg ai per ha[1]	Mean number of Chinch Bugs (±SD) per Plot
Diazinon 5G	8.55	0.0 ± 0.0 a
Bifenthrin 80F	0.11	0.0 ± 0.0 a
Ethoprop 5G	5.61	0.2 ± 0.4 a
Bifenthrin 80F	0.056	0.2 ± 0.4 a
Bifenthrin 10WP	0.056	0.3 ± 0.5 a
Isazophos 4E	2.29	0.3 ± 0.5 a
Bifenthrin 10WP	0.11	0.8 ± 1.0 a
Chlorpyrifos DF	1.12	1.5 ± 2.0 a
Chlorpyrifos 20ME	0.56	13.8 ± 5.1 b
Tempo 2	0.15	19.8 ± 3.5 c
Untreated Control	0.00	25.5 ± 10.1 d

[1] 1 kg ai/ha = 0.890 lbs ai/A. Untransformed means followed by the same letter are not significantly different at P=0.05, according to Duncan's multiple range test of transformed data (Analysis of Variance: $df = 11,55$; $F = 61.7$, $P \leq 0.0001$ [Gagnon et al. 1989]). Tempo 2 is a Mobay Corp. brand name for (cyano(4-flouro-3-phenoxyphenyl)methyl 3-(2,2dichloroethenyl)-2,2-dimethyl-cyclopropanecarboxylate).

The procedure of Crocker and Simpson (1981) includes the repeated flooding of test cages to extract insects that had not been killed by the insecticides. That approach was an adaptation of Kerr's (1966) technique for estimating the density of natural populations of southern chinch bugs. Kerr's procedure involved removing both ends from a metal can, and then pushing one end of the cylinder a few centimeters into the soil. Several such containers (at various locations in an infested turf) were flooded for several minutes using a water hose, and all insects that floated to the surface were counted. We have found that vacuum extraction of surviving insects is quicker and less messy than water extraction. Vacuum extraction also allows the tedious process of sorting samples (to recover insects from loose plant and soil debris) to be performed indoors or in the shade instead of under the full force of the summer sun.

Even small test cages of St. Augustinegrass can offer an almost limitless number of hiding places from which chinch bugs can resist efforts to extract them. We have found with vacuum and with water extraction, that more insects can be recovered from plots that have ceased to yield more survivors if the plots are left alone for an hour or so. The plots then are resampled after the insects presumably moved to more vulnerable positions. Sometimes, it has proven worthwhile to repeat a "sample, wait, and resample" cycle several times. To avoid biasing the results, each plot in a replication always must be sampled the same number of times. Sampling of a replication is terminated when the untreated control plot (always the longest to be productive) yields no further specimens.

Comparison of the mean numbers of insects recovered from control groups by the two techniques indicates that vacuum extraction is at least as effective as is water extraction. Control group counts in 1980, 1985, 1986, 1987, and 1988 (using the flooding technique) averaged 33.7 (range: 29.5-37.0) of the 50 insects caged per plot. Three tests in 1989 using the vacuum technique averaged recovery of 35.7 (range: 33.3-37.5) insects in the control group. Because vacuum extraction also is more convenient than is water extraction, we used vacuum extraction in the present research, and anticipate using it exclusively in future experiments.

Statistical analyses of treatment effects were performed on data transformed according to $X_t = (n + 0.5)^{0.5} \times \arcsin\{[(f + 0.375) \times (n + 0.75)]^{0.5}\}$ where X_t is the transformed value, f = observed frequency, and n = sample size. That transformation produces a distribution of constant variance over the entire range of proportions (i.e., 0/n through n/n) (Anscombe 1948; Zar 1974). The data were analyzed using the general linear model program SuperANOVA, with treatment separations determined by Duncan's multiple range test (Gagnon et al. 1989). Reported means were calculated from untransformed data.

Results and Discussion

All tested materials caused significant (P = 0.05) insect mortality compared to the untreated control (Table 1). Moreover, all treatments except the Empire ME formulation of chlorpyrifos and Tempo 2 (cyano(4-flouro-3-phenoxyphenyl)methyl3-(2,2dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate) produced levels of control that would be highly acceptable for practical control. The low efficacy of the Empire 20ME may have been because it was applied at 0.5 lbs ai/A; other formulations of chlorpyrifos (Pageant DF and Dursban 4E) were applied at 1.0 lbs ai/A.

Although bifenthrin (Talstar®) was present in two formulations (80F and 10WP) at two rates each (0.05 and 0.10 lbs ai/A), the bifenthrin treatments were so effective in all cases that they could not be separated statistically.

It should be noted that a large proportion of the live insects recovered from the Tempo 2 plots 48-72 hours posttreatment exhibited diminished activity and poor coordination. Some appeared near death. These surviving insects were kept in one cage and all other surviving insects in another cage in the laboratory (with fresh sprigs of grass for food) for 48 hours longer. Most of the Tempo 2 insects still were alive at the end of the observation period.

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PR-4910

Evaluation of Neem Extract for Control of Southern Chinch Bug in St. Augustinegrass

Robert L. Crocker

Introduction

Botanical insecticides derived from the neem plant have been found to affect certain insects. Just as is the case with purely synthetic insecticides, testing is necessary to determine whether a particular insect in a particular habitat can be controlled with a botanically derived insecticide. The purpose of the present field cage research was to test the efficacy of azadirachtin 720-F, an experimental neem-derived product, in comparison with diazinon 5G for the control of the southern chinch bug *Blissus insularis* Barber (Hemiptera:Lygaeidae) in St. Augustinegrass (*Stenotaphrum secundatum* [Walt] Kuntze).

Materials and Methods

Research was performed at the Texas A&M University Research and Extension Center at Dallas. The experimental procedure involved six replications of eight treatments in a randomized complete block design.

Southern chinch bugs for the research were collected 26 October 1990, from severely damaged lawns of St. Augustinegrass turf in Pasadena (a suburb of Houston), Harris County, Texas, using a D-Vac™ model 24 vacuum insect net (D-Vac Co., Riverside, CA). The insects were transported the same day to TAES-Dallas. The next day, they were divided into groups of 50 unsexed adults, 25 large (3-5th instar) nymphs, and approximately 25 small (1-2nd instar) nymphs. Small nymphs were obtained by determining density of such insects in several 5 ml samples of fine debris sand and dust, and then measuring the appropriate amount of debris into each container. The chinch bugs were randomly assigned, one group of each size category per plot, to each of 60 field plots.

Plots were 730 cm^2 (= 113 in^2) each and were delimited by the walls of an open-ended PVC cylinder 15 cm (= 12 in) diameter by ca. 20 cm (= 8 in) high. The bottom end of each cylinder was sodded with Texas common St. Augustinegrass and was embedded approximately 5 cm into the underlying soil. Plots were irrigated on all nontreatment days. Except for the brief time when treatments were being administered, cages were covered continuously with a synthetic fabric mesh which freely permitted passage of light and air but which prevented escape of the insects. Plots were covered with plastic film during rainfall in order to prevent excessive irrigation.

Six of the eight treatments consisted of two rates (15 or 30 ppm spray applied at rates equal to 300 gal/acre) of NPI-720-F (an experimental formulation of neem extract containing 3 percent active ingredient (ai) by weight of azadirachtin, manufactured by Native Plants International, 417 Wakara Way, Salt Lake City, UT 84108) applied either (1) only on week one, (2) only on weeks one and two, or (3) on weeks one, two, and three. No irrigation was applied to the NPI-720-F plots on treatment days. The other two treatments were a standard, diazinon 5G (applied at 7.26 lbs ai/acre only on week one, and irrigated immediately after application with the equivalent of 2.5 liters/m^2), and an untreated control.

Six replications of the high treatment rate of NPI-720-F and of the untreated control were duplicated in additional plots identical to those in the main test, but which were outside of the formal experimental design. Every 7 days starting with the second treatment date and continuing through final data collection, these two treatments were sampled just prior to spray application in order to obtain a rough measurement of the progress of the experiment without disturbing any of the actual data plots.

Final data were vacuum extracted from the plots 1 week following final treatment application. Plots were sampled repeatedly until no further bugs could be recovered. The insects were sucked from the grass using a Craftsman Electric Blower Model No. 257.798850 equipped with vacuum attachment (Sears, Roebuck and Co., Chicago, IL). The insects were recovered from a layer of fabric mesh stretched across the connection between two sections of the intake tube of the vacuum attachment. Nymphs were classified as large (4th -5th instar), medium (2nd - 3rd instar) and small (1st instar). Classification of 3rd and 4th instar nymphs probably erred by ±1 instar in some cases. With the exception of some details discussed to this point, the protocol was that of Crocker and Simpson (1981). That procedure eliminates insect distributional variation and among-plot insect migration encountered in open field-plot tests. The procedure also maintains a natural turf environment where insects can behave normally and where factors such as thatch can affect pesticide availability (Niemczyk et al., 1977; Sears and Chapman, 1979).

Statistical analyses of treatment effects were performed on data transformed according to $X_t = (n + 0.5)^{0.5} \times \text{arcsine}\{[(f + 0.375) / (n + 0.75)]^{0.5}\}$ where X_t is the transformed value, f = observed frequency, and n = sample size. That transformation produces a distribution of constant variance over the entire range of proportions (i.e., 0/n through n/n) (Anscombe 1948; Zar 1974). Because this experiment lasted long enough for reproduction and growth to cause differences in the numbers of insects, the 'n' used in these transformations is only an estimate. Examination or residuals, however, showed that the transformation was adequate because no correlation was found between variance and mean of transformed data. The data were analyzed using the general linear model program SuperANOVA, with treatment separations determined by Duncan's multiple range test (Gagnon et al., 1989). Reported means were calculated separately from untransformed data.

Results and Discussion

Diazinon 5G, adopted as a standard in this test because of its wide usage, was highly effective against adults and all sizes of nymphs. No survivors of this treatment were recovered, and it was statistically (P = 0.05) superior to all other treatments (Table 1). None of the azadirachtin 720-F treatments were significantly different from the untreated control. Survival in control plots was much lower than we are accustomed to having in short-term tests (>30 insects/ cage), but it was very uniform across replications, and thus, was suitable for analysis. It is reasonable to expect that future experiments using this new technique will have higher mean rates of survival in control plots.

It appears that most of the mortality in all treatments occurred prior to the first preview sampling date at the end of the first week (Table 2). It should be noted that preview sampling was not as intensive as was final sampling. That was to minimize injury to the insects and the grass. Because the purpose of the preview data was to obtain insight rather than to test an hypothesis, no formal analysis was performed on it although it was replicated 6 times. The preview data (Table 2) are presented for informal comparison along with data from the formal test. Although none of the experimental treatments produced statistically significant (P = 0.05) levels of control among either nymphs or adults, the trends of the data indicate that a weak response may have been produced. This argues that higher doses may be desirable. Higher levels of active ingredient could be achieved either by applying the total dosage at one time or by increasing the dose for each date.

Table 1. Mean number of living southern chinch bugs per cage 1 week following the application of the last of several insecticidal treatments to caged St. Augustinegrass. Dallas, Texas; October 1990.

Chemical	Weeks Applied	Kg ai Per Hectare	Mean Number of Chinch Bugs Per Plot				
			Adults	Lg. nymphs	Med. Nymphs	Sm. Nymphs	Tot. Nymphs
Diazinon 5G	1	8.5	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Azadirachtin 720-F	1,2,3	0.042	7.7 b	2.5 ab	1.8 a	0.7 ab	5.0 b
Azadirachtin 720-F	1	0.084	10.5 bc	2.5 ab	1.7 a	1.0 ab	5.2 b
Azadirachtin 720-F	1,2,3	0.084	11.3 bc	1.7 ab	1.3 a	1.3 ab	4.3 b
Untreated Control	—	0.000	12.8 bc	2.7 ab	1.5 a	1.8 b	6.0 b
Azadirachtin 720-F	1,2	0.042	13.3 bc	1.5 ab	2.3 a	1.0 ab	4.8 b
Azadirachtin 720-F	1,2	0.084	14.2 bc	4.3 b	2.7 a	1.0 ab	8.0 b
Azadirachtin 720-F	1	0.042	15.8 c	3.2 ab	1.7 a	0.5 ab	5.3 b

1 kg ai/ha = 0.890 lbs ai/A. Six replications; untransformed means followed by the same letter are not significantly different at P=0.05, according to Duncan's multiple range test (DMRT) of arcsine transformed data. The analysis of variance (ANOVA) for treatment effect on adults was significant ($P \leq 0.0001$), indicating strong concurrence with DMRT. Respective ANOVA's for large, medium, small, and total nymphs were P = 0.3690, = 0.5569, = 0.3580 and 0.1327, none of which is close to the accepted standard of P = 0.05. Statisticians differ on acceptability of multiple range tests accompanying insignificant ANOVA's, and the researcher urges that readers be cautious in interpreting DMRT separations of nymph data.

Table 2. Mean number of living southern chinch bugs per cage. Data marked 'Preview' were taken on the second, third, and fourth (final) week of the experiment. Data marked 'Formal' were collected on the fourth week of the experiment (1 week following the application of the last of several insecticidal treatments to caged St. Augustinegrass). Dallas, Texas; October 1990.

Treatment	Weeks Applied	Kg ai Per Hectare	Mean Number of Chinch Bugs Per Plot				
			Adults	Lg. nymphs	Med. Nymphs	Sm. Nymphs	Tot. Nymphs
Untreated Control (Wk2 Preview)	—	0.000	13.0	3.0	0.3	0.2	3.5
Untreated Control (Wk3 Preview)	—	0.000	14.4	1.2	0.3	1.5	3.0
Untreated Control (Final Preview)	—	0.000	12.5	1.5	0.3	0.7	2.5
Untreated Control (Formal)	—	0.000	12.8	2.7	1.5	1.8	6.0
Azadirachtin 720-F (Wk2 Preview)	1,2,3	0.084	12.8	2.3	0.8	0.3	3.5
Azadirachtin 720-F (Formal)	1	0.084	10.5	2.5	1.7	1.0	5.2
Azadirachtin 720-F (Wk3 Preview)	1,2,3	0.084	18.0	1.7	0.8	3.0	5.5
Azadirachtin 720-F (Formal)	1,2	0.084	14.2	4.3	2.7	1.0	8.0
Azadirachtin 720-F (Final Preview)	1,2,3	0.084	10.8	1.0	0.8	1.0	2.8
Azadirachtin 720-F (Formal)	1,2,3	0.084	11.3	1.7	1.3	1.3	4.3

1 kg ai/ha = 0.890 lbs ai/A. Six replications; these means computed for informal interpretation rather than formal analysis.

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Chemical Control of Southern Chinch Bug in St. Augustinegrass: 1988 Test

Robert L. Crocker

Introduction

Hot summer weather dramatically increases reproduction and speeds up development of the southern chinch bug, *Blissus insularis* Barber (Hemiptera: Lygaeidae). Under favorable summer conditions, severely damaging populations can develop very quickly. Densely infested areas in St. Augustinegrass (*Stenotaphrum secundatum* [Walt.] Kuntze) lawns frequently contain several hundred of the small pests per square foot. Feeding damage due to these dense populations is seen in the form of expanding patches of dead and dying grass.

Only a few cultivars of St. Augustinegrass are resistant to chinch bugs; thus, chemical insecticides are in many cases the only practical means of control. The purpose of this paper is to report the results of a 1988 test of the efficacy of certain insecticides for control of southern chinch bug in St. Augustinegrass turf.

Materials and Methods

An experiment with six replications of six treatments plus an untreated check (Table 1) was performed at the Texas A&M University Research and Extension Center at Dallas according to the methods of Crocker and Simpson (1981). Use of this procedure eliminates insect distributional variation and among-plot insect migration that is encountered in open field-plot tests. It also maintains a natural turf environment where the insects can behave normally and where factors such as thatch can affect pesticide availability (Niemczyk et al., 1977; Sears and Chapman, 1979).

On 26-27 September 1988, southern chinch bugs were collected using a D-Vac™ model 24 vacuum insect net (D-Vac Co., Riverside, CA) from damaged lawns of St. Augustinegrass turf around Brownsville, Cameron County, Texas. The insects were transported 27 September to TAES-Dallas on St. Augustinegrass stolons. On 28 September, unsexed adults were divided into groups of 50. These insects were placed randomly, one group per plot, in 186 cm^2 field plots delimited by the walls of an open-ended metal cylinder (15 cm diameter by ca. 16 cm high) and allowed 24 hours pretreatment to distribute themselves naturally in the turf. Cylinders were embedded ca. 6 cm in established irrigated 'Raleigh' St. Augustinegrass turf with minimal thatch on TAES-Dallas turf plots. Preliminary sampling had indicated that there were few or no chinch bugs in the plot area prior to the test. Soil in the plots was Austin-Houston type alkaline montmorillonite clay typical of the Texas Blackland Prairies.

Treatments (Table 1) were applied in the equivalent of 2.5 liters/m^2 final product, by the method of Reinert (1972, 1974) on 29 September 1988. Before and immediately after treatment, each field cage was covered by a nylon mesh which permitted air exchange and passage of light, but which prevented insect escape (Crocker and Simpson 1981). Data on insect mortality were collected 2 days later.

Statistical analyses of treatment effects were performed using data transformed according to X_t=arcsine (S/100) where X_t is the transformed value and X is the total number of adult chinch bugs recovered from a plot (Steel and Torrie 1960). The data were computer-analyzed using SAS Proc ANOVA with treatment separations determined by the Waller-Duncan-K-ratio t-test (SAS Institute 1988). Reported means were calculated using untransformed data.

Table 1. Mean numbers of southern chinch bugs per plot 2 days following treatment with various insecticides; initial population=50 adult chinch bugs/caged plot; six replications; Dallas, TX; September 1988.

Material applied	kg [ai] per ha	Mean number of Chinch Bugs/Plot	Percent Efficacy
Untreated Control	0.00	35.2 a	0.0
Chlorpyrifos 1.1G	1.23	23.3 b	33.6
Ethoprop 5G	2.80	12.2 c	65.4
Isazofos 4E	0.56	8.5 cd	75.8
Ethoprop 5G	5.60	6.0 de	82.9
Isazofos 4E	ʹ.12	3.8 e	89.1
Ethoprop 10G	5.60	3.5 e	90.0

1 kg [ai]/ha=0.890 lb [ai]/Acre. Means followed by the same letter are not significantly different at P=0.05, according to Waller-Duncan k-ratio t-test (SAS Institute 1988). Two-way analysis of variance of arcsine transformed date ($F=30.02$; $df = 6.30$; $p<0.0001$). Reported means calculated from untransformed data. Percent efficacy = (1 - [Mean number of insects recovered from treatment plots/ Mean number of insects recovered from control plots]) x 100.

Results and Discussion

Highest levels of control were produced by ethoprop 10G and 5G at 5.60 [ai] per ha, and by isazofos 4E at 1.12 [ai] per ha. Lower rates of ethoprop 5G and isazofos 4E produced moderate levels of control.

Chlorpyrifos 1.1G yielded poor control in this experiment. This agrees with moderate control in 1985 (Crocker, 1987) of southern chinch bugs from College Station, Brazos Co., Texas, but contrasts with good control in 1986 (Crocker, 1989) and 1987 (unpublished) of southern chinch bugs from South Houston, Harris County, Texas. The inconsistent efficacy of granular chlorpyrifos does not indicate broad resistance to organophosphate insecticides such as has been found in parts of Florida (Reinert and Portier, 1983) because other organophosphate treatments in this test produced superior results.

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PR-4912

Laboratory Testing of Milky Spore Disease, *Bacillus popilliae*, for Control of *Phyllophaga crinita* White Grubs

Robert L. Crocker

Introduction

At present, our ability to control white grubs in turfgrass is dependent on a small number of chemical insecticides. Any of those pesticides could quickly be eliminated by regulatory restrictions, marketing decisions, or loss of efficacy. Breaking that vulnerability will require development of a broader array of management techniques. Among the most promising alternatives is that of microbial control: harnessing natural microorganisms as pest management tools. Several factors are auspicious to the use of microorganisms for control of white grubs in turf. Physical stability of the habitat is a major consideration. In contrast to annual field crops, perennial turfgrasses typically persist with little root zone disturbance for decades. Because white grubs live in the soil rather than in the plant canopy, microorganisms are not readily removed from the target zone by water, plant growth, or maintenance practices.

Environmental stability of the turf habitat also augments the prognosis for a microbial control approach. Soil (especially in an irrigated turf habitat) is a much more stable and sheltered environment for entomopathogens than is a plant's canopy. Soil can shield an entomopathogen from deactivation by ultraviolet light and buffer it from extremes in moisture and temperature. The dispersal stage of some entomopathogens, such as *Bacillus popilliae* Dutky, can remain viable in the soil for years. Finally and perhaps most important is the question of safety. Children, adults, and family pets come into heavy physical contact with turfgrass in the course of recreation and other activities. Also, much turf management is performed by homeowners or other personnel with little or no training in pesticide safety. Most broad-spectrum chemical insecticides are toxic to man and other vertebrates. In contrast, entomopathogens are highly target specific, and typically are quite safe to nontarget organisms.

White grubs are known to be vulnerable to many types of entomopathogens. At times, Texas white grubs are infected with any of several naturally occurring pathogens including an entomopoxvirus, a nematode (*Steinernema* sp.), various bacteria (*Bacillus thuringiensis* Berliner, *B. popilliae*, *B. cereus* Frankland, *Pseudomonas aeruginosa* [Schroeter]), yeast, and a spore forming protozoan (*Pseudomonocystis* sp.) (Crocker et al., 1982). *B. popilliae* infects white grubs in many parts of the world (Fleming, 1968; Gupta and Avasthy, 1960; Lim et al., 1981; Illingworth, 1921). The 'milky spore disease' that results from such infections causes the haemolymph (insect blood) of the host to become filled with spores of the infectious organism. The name of the disease arises from the fact that the high concentration of bacterial spores causes the normally clear haemolymph to look like diluted milk. Infected larvae eventually die. Crocker and Grismer (1982) produced milky spore disease in *Phyllophaga crinita* Burmeister larvae by injecting them with spores of *B. popilliae*. The purpose of the present research was to evaluate the potential of various isolates of *B. popilliae* for controlling *P. crinita* white grubs in turf.

Materials and Method

Bacteria in Soil. The experiment was in a randomized complete block design with three replications, four treatments, and 12 insects per treatment group. The experiment was run in a controlled environment chamber on the campus of the Texas A&M University Research and Extension Center at Dallas. Experimental conditions were 30 + 1°C with continuous illumination from fluorescent lamps. Insects were individually housed in 50 mm diameter X 9 mm deep biologically tested polystyrene petri dishes, each of which contained ca. 20 g of damp sandy loam soil and sprouting seeds of bermudagrass (20 g seed/kg soil). To minimize moisture loss from the soil, each treatment group of 12 petri dishes was enclosed in a plastic food bag along with a moist paper towel. A few drops of water and extra grass seeds were added to the soil as needed. Insects used in the research were field-collected 3rd instar *P. crinita* larvae from Dallas, Dallas County, Texas. All larvae were vigorous and free of obvious defects at the start of the experiment.

Three treatments consisted of *B. popilliae* spores presented at $2(10)^9$ spores/kg of moist soil, as recommended by Dutky (1942). This concentration is considered a standard rate for evaluating the pathogen on experimental host species of scarabs. The fourth treatment was an untreated control. The spores were washed in 2 ml of deionized water from haemolymph slides of *Holotrichia oblita* Fald., *Rhizotrogus majalis* (Razoumowsky) (European chafer), and *P. crinita*. The concentration of spores in the wash water was measured at 200-1,000x using a Levy Double Neubauer counting chamber and a Wild M20 phase contrast compound microscope. Spore concentrations of each isolate were estimated on the basis of spore counts in 40 randomly selected grid areas. The concentrations of spores in the wash water were $4.5(10)^9$/ml (CL95 percent = ± $4.0(10)^8$ (*H. oblita*), $6.1(10)^7$ ml (CL95 percent = ± $6.3(10)^6$ (*R. majalis*) and $2.1(10)^9$/ml (CL95 percent = ± $2.7(10)^8$ (*P. crinita*). A volume of the wash sufficient to yield 2 $(10)^9$ spores/g of moist soil was added to the media by mixing it with the soil in serial dilutions.

The experiment began 19 October 1988, and terminated 12 December 1988. Larvae were examined two to three times a week for signs of infection. At termination, haemolymph from each larva was examined at 1,000x under phase contrast for the presence of bacterial spores or rods; insects that were alive on the termination date were sacrificed so that their haemolymph could be examined.

Bacteria on Carrots. Except as noted, procedures were similar to those in the preceding section. Instead of mixing the bacterial spores into the soil, they were placed on the surface of a approximately 7 mm thick slice of raw carrot that was placed in the dish as food for the insect. No grass seed were added. Only one strain of bacteria was used, that recovered from *P. crinita* larvae collected in El Paso, Texas.

The treatment variable was the number of spores placed on the slice of carrot. Dosages were 0, $2(10)^3$, $2(100)^4$, $2(10)^5$, and $2(10)^6$ spores. Spores were applied to the upper surface of each carrot using a 100 µl capacity gas-tight syringe; the surface of the carrot was allowed to air dry before the carrot was placed in the petri dish. Each dish was inspected three to five times per week, at which times the fraction of the carrot that had been eaten was estimated. Fresh untreated carrots were added when the treated carrot had been eaten. The experiment began 6 November 1988, and terminated 11 January 1989. Haemolymph of each insect was examined for *B. popilliae* spores or rods; insects that were alive on the termination date were sacrificed so that their haemolymph could be examined.

Results and Discussion

Bacteria in Soil. One grub exposed to *B. popilliae* spores from the Japanese beetle, *Popillia japonica* Newman became infected; no other insects in the experiment displayed symptoms, and none had spores in their haemolymph. Failure to produce infection was not due to the grubs being in a non-feeding state, because grass seedlings in the soil were fed on heavily.

Bacteria on Carrots. This experiment involved only spores recovered from naturally infected grubs (from El Paso, Texas) of *P. crinita*. A mean of 8.0 of the 10 insects in each treatment group consumed all of the spore-treated carrot. In one treatment group, six of the 10 ate no carrot; except for that, no more than one to two of the insects failed to feed. As a result, there is no doubt that most of the grubs ingested the spores into the gut where infection should take place.

Even under these conditions, the mean infection rates for 0, $2(10)^3$, $2(10)^4$, $2(10)^5$, and $2(10)^6$ spores per grub were 0, 10, 17, and 37 percent, respectively. The high rate is equal to the total number of spores in one gram of soil under standard USDA Japanese beetle test conditions. These results suggest two conclusions: (1) that even though the larvae in the first experiment fed, they did not ingest many spores, and (2) that the pathogen exhibited a relatively low level of infectivity.

From these two tests, it appears that none of the tested strains of *B. popilliae* is sufficiently effective against *P. crinita* white grubs for them to be considered a practical source of control. Numerous other isolates of the pathogen are known from various parts of the world, and some of them or some yet unknown strain may be more aggressive against this host. If such a strain can be found, it should prove to be highly useful as a long-term suppressant of white grub populations in Texas.

Acknowledgment

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PR-4913

Feeding Preference Among Bentgrass Turf Varieties by Adult *Phyllophaga congrua* (Coleoptera: Scarabaeidae)

Robert L. Crocker and M. C. Engelke

Abstract

Nocturnal observations on the feeding activities of *Phyllophaga congrua* (LeConte) adults disclosed preference among cultivars of creeping bentgrass, *Agrostis palustris* Huds. (Poaceae). A mean of 3.6x the number of beetles fed per plot on 'Emerald' compared to 'Penneagle' in replicated field plots in a 2- year study in Dallas, Dallas County, Texas. Intermediate numbers of beetles fed on 'Cobra,' 'Prominent,' 'Syn2-Penncross,' 'Penncross,' 'Seaside,' and 'Pennlinks.' Repeated observations on experimental clones of bentgrass in unreplicated field plots indicated a wide range of preferability. We are unaware of any previous records of adult *Phyllophaga* species feeding preferences among species or varieties of turfgrass.

Introduction

Phyllophaga spp. and other phytophagous scarab beetles are key pests of cultivated members of the grass family (Poaceae) throughout the world. Although some pest species such as the Japanese beetle, *Popillia japonica* Newman, can be reduced by *Bacillus popilliae* Dutky, which causes a 'milky disease' in larvae, most pest management is through the application of broad spectrum chemical insecticides.

Host plant resistance has been pursued as a means of controlling some white grub species. Such investigations have not been considered highly promising, however, because white grubs tend to be highly polyphagous on grasses. *Phyllophaga crinita* Burmeister, for example, is a key pest in the American Southwest on diverse grass family (Poaceae) species that include bermudagrass (Chloridae tribe, *Cynodon dactylon* [L.] Persoon), buffalograss (Chloridae tribe, *Buchloë dactyloides* [Nutt.] Engelm.), St. Augustinegrass (Paniceae tribe, *Stenotaphrum secundatum* [Walt.] Kuntze), tall fescue (Festuceae tribe, *Festuca arundinaceae* Schreb.) (Crocker unpublished data), corn (Tripsaceae tribe, *Zea mays* L.) (Reinhard 1940, Rodíguez-del-Bosque 1980), wheat (Tribe Hordeae, *Triticum aestivum* L.), sorghum (Andropogoneae tribe, *Sorghum vulgare* Pers.) (Teetes 1973), and sugar cane (Andropogoneae tribe, *Saccharum officinarum* L.) (Fuchs et al. 1974). *P. crinita* also damages plants outside of the grass family (reviewed in Rodguez-del-Bosque 1988). H. Tashiro (New York State Agricultural Experiment Station, Geneva; personal communication, 1988) in about 1980, found no resistance to grubs of the European chafer, *Rhizotrogus (Amphimallon) majalis* (Razoumowsky) or Japanese beetle, *Popillia japonica* Newman, among cool season grasses in the northeastern United States.

The objective of this study was to test for nonpreference by adults of *P. congrua* (LeConte) for certain cultivars and experimental lines of creeping bentgrass, *Agrostis palustris* Huds. (Poaceae).

Materials and Methods

Research on the nocturnal activities on bentgrass of a natural population of *P. congrua* adults was performed at the Texas A&M University Research and Extension Center at Dallas in April and May of 1986 and 1987. The study area encompasses two sets of plots separated by approximately 80 m of tall fescue turf. One set of plots (15 cm dia. on 1 m centers) contained unreplicated plantings of 'Penncross' and 81 numbered accessions of bentgrass separated from one another by tall fescue turf. The other set of plots involved three replications of eight cultivars of bentgrass planted November 1985 in a randomized block design in plots (1.2 x 1.8 m, separated by 0.2 m of bare ground). The plots were 6 months old at the initiation of this study.

Data were collected by direct observation of the insects between approximately 1,900 and 2,330 hours, CST. In the course of other observations (not reported here), it was noted on several occasions that numerous *P. congrua* adults were feeding on certain research plots of bentgrass but not on others. On May 3, 1986, the total number of adult *P. congrua* feeding on each plot was counted. Insect visibility was increased by use of a battery powered incandescent head lamp. The insects' behavior was not visibly affected by the illumination. Although fewer beetles were present on the plots the next spring, they were counted on May 15, 1987.

Statistical analyses of the data were performed using data transformed according to $X_t = (X + 0.5)^{1/2}$, where X_t is the transformed value and X is the total number of adult beetles recovered from a plot. For the unreplicated plots, repeated measures (1986 versus 1987) provided the error mean square. The transformed data were analyzed using SAS Proc GLM, with treatment separations determined by the Waller-Duncan k-ratio t-test (SAS Institute, 1987). Reported means were calculated using untransformed data.

Results and Discussion

The results (Table 1) from replicated field plots indicate that *P. congrua* adults exhibit strong feeding preferences among different cultivars of bentgrass turf. Compared over 2 years with 'Emerald', fewer than 50 percent as many adult beetles fed on Penncross and 'Seaside', 33.8 percent as many injured 'Pennlinks', and only 27.7 percent as many attacked 'Penneagle' when compared to 'Emerald'.

Table 1. Mean numbers of adult *Phyllophaga congrua* per plot on various cultivars of creeping bentgrass. Three replications.

Cultivar	1986	1987	Overall
Emerald	10.7 a	2.3 a	6.5 a
Cobra	9.7 ab	1.3 a	5.5 ab
Prominent	8.3 ab	1.7 a	5.0 abc
Syn2-Penncross	8.7 ab	0.7 a	4.7 abc
Penncross	5.3 bc	1.0 a	3.2 bcd
Seaside	5.0 bc	1.0 a	3.0 bcd
Pennlinks	4.3 bc	0.0 a	2.2 cd
Penneagle	3.0 c	0.7 a	1.8 d

Means within columns followed by the same letter are not significantly different ($P = 0.05$; Waller-Duncan K-ratio T test [GLM, SAS Institute, Inc. 1985]).

Repeated (1986, 1987) samples from unreplicated plots suggest a wide range of attractiveness to *P. congrua* adults among the experimental clones of bentgrass under development in Texas. The observations are not completely independent, because the measurements were replicated only in time. There was, however, no obvious basis (other than the grass) for preference, and the beetles were from two completely different generations that selected their feeding sites independently. Clones (all of which bear the prefix "TAES") with an average of "0" beetles on the two sampling dates were 150, 287, 290, 1253, 1254, 1259, 1248, 1257, 1258, 1261, 1418, 1486, 1755, 1906, 2558, 2559, 2560, 2734, 2735, 2736, 2738, 2741, 2745, 2753, 2754, 2758, 2764, 2767, 2771, 2773, 2778, and 2869. An average of 0.5 beetles were on the clones 137, 141, 1235, 1249, 1251, 1252, 1414, 1416, 1487, 2380, 2557, 2739, 2740, 2750, 2761, 2763, 2766, 2768, 2769, 2779, and the variety Penncross; an average of 1.0 beetles were on the clones 139, 153, 288, 1199, 1255, 2742, 2744, 2765, 2775, and 2777. An average of 1.5 beetles were recovered from 145, 1198, 1410, 1886, 2562, 2737, 2743, 2752, 2755, 2762, and 2774. An average of 2.0 beetles were taken from clones 1256, 2561, 2563, and 2751. An average of 2.5, 3.0, and 3.5 beetles were found on 1250, 289, and 1197, respectively (Fig. 1).

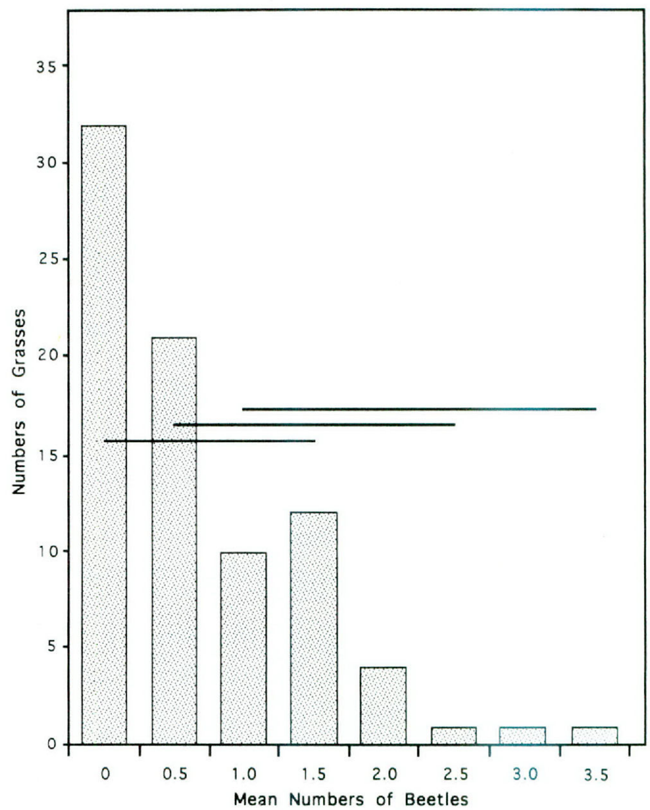

Figure 1. Numbers of experimental clones and varieties of bentgrass with stated numbers of *P. congrua* adults feeding on their foliage in repeated (1986, 1987) measures of unreplicated field plots. Columns crossed by the same horizontal bar are not significantly different ($P = 0.05$; Waller-Duncan K-ratio T test [GLM, SAS Institute, Inc., 1985]).

Differences similar to those found here in feeding preferences of adult *P. congrua* may also occur in other bentgrass varieties and among species of turfgrass. Further research is needed to determine whether these differences in adult preference are reflected in differential oviposition rates and commensurate differences in damage by white grubs. These findings also indicate that screening within other turf species for nonpreference by damaging *Phyllophaga* species would be worthwhile.

Acknowledgment

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PR-4914

Host Plant Resistance to Apple Grain Aphid, *Rhopalosiphum insertum* (Homoptera: Aphididae), in Texas Bluegrass, Canada Bluegrass, and Their Hybrids

Robert L. Crocker, James C. Read, and E. Zuzanna Moore

Introduction

Texas bluegrass, *Poa arachnifera* Torr. (Poaceae), and interspecific hybrids with Canada bluegrass, *P. compressa* L., are being investigated for use as turfgrass and forage in Texas (Walker et al., 1991). Canada bluegrass grows well in open ground, woods, meadows, and waste places from Newfoundland to Alaska, south to Georgia, Tennessee, Alabama, Oklahoma, New Mexico, and California. It was introduced from Europe, and is cultivated for pastures in poor soil. Texas bluegrass is native to the American prairies and plains, southern Kansas to Texas and Arkansas. Texas bluegrass sometimes is cultivated for winter pasture, and has been introduced in Idaho and eastward to North Carolina and Florida (Hitchcock 1950).

A key part of the evaluation of new forage and turf cultivars is the detection and measurement of potential pest problems. In the present case, we have noted the apple grain aphid, *Rhopalosiphum insertum* Walker (Homoptera: Aphididae) causing severe damage to some cultivars and accessions of bluegrass (*P. arachnifera*, *P. compressa*, and their interspecific hybrids) in the greenhouse. This points to a serious potential for field problems with the insect. Another aphid, the greenbug (*Schizaphis graminum* Rondani), is known to be an important pest of Kentucky bluegrass, *P. pratensis* L (Bowen, 1983; Garman, 1926). The insect problems of Texas bluegrass have received little attention to date, and are not well known. The purpose of our research was to bioassay a cross-section of the experimental accessions and hybrids along with selected commercial cultivars of bluegrass for resistance to that aphid.

Materials and Methods

The experiment involved eight replications of each of four experimental accessions, two interspecific hybrids, and four cultivars of bluegrass. The plants were held indoors on a bench under continuous fluorescent light at 25°C in separate 10 x 10 cm pots. The experimental unit was a single potted plant. On October 17, 1990, five mature-size aphids, *R. insertum*, were put on four of each type of plant. The other four plants of each type were kept on a separate bench about 2 meters away; the second group of plants were not infested, but there was no barrier to prevent movement among plants. Under these conditions, plants in both blocks soon were heavily infested. The aphids on each plant were counted on 29-October-1990, 4-November-1990, 11-November-1990 and 18-November-1990. Data were submitted to analysis of variance (Gagnon et al., 1989).

Results and Discussion

The results of the test (Table 1) indicate the presence of significant levels of resistance to apple grain aphid in various cultivars and accessions of bluegrass. The average aphid population on the least attractive host ('Georgetown') was less than half that on the most attractive host (Texas x Canadian B). This research involving a small sample of the available bluegrass germplasm clearly suggests that damage due to apple grain aphid may be avoided or reduced through the use of resistant cultivars. The presence of intermediate population levels on some hosts may be due to the resistance being controlled by multiple genes or alleles. The practical importance of this resistance will depend on the pressure exerted by the apple grain aphid under various field conditions.

Table 1. Overall mean populations for four sampling dates (29 October through 18 November 1990) of apple grain aphid on selected cultivars and accessions of bluegrass in a growth room, 8 replications.

Grass	Bluegrass Species	Mean Number of Aphids
Georgetown	Kentucky	16.4 a
#20-88	Texas	16.5 a
Huntsville	Kentucky	18.5 a
Baron	Kentucky	22.6 ab
#38-88	Texas	38.3 bcd
#39-88	Texas	41.8 bcd
Rubens	Canadian	43.4 cd
Texas x Canadian A	hybrid	43.4 cd
#2-88	Texas	49.3 cd
Texas x Canadian B	hybrid	62.0 d

Untransformed means followed by the same letter are not significantly different at P=0.05, according to Games-Howell test of square-root transformed data (Repeated Measures Analysis of Variance: F = 6.8975, df = 9,68; $P \leq 0.0001$ [Gagnon et al. 1989]).

Further research is needed to determine whether antibiosis or nonpreference is the type of resistance that has been encountered here, to confirm the present findings, to extend them to other germplasm, and to determine the potential importance of the apple grain aphid under field conditions. In this test, statistical analysis indicated that the two hybrids of Texas and Canadian performed similarly to (although numerically worse than) their parent stock (Rubens was the male and #38-88 was the female parent). It would be instructive to test whether hybrids of plants in the best category would perform as well as or better than their progenitors. Also, it may prove useful to test for cross-resistance to other species of aphids that attack these plants. Because the greenbug (a key pest of wheat in Texas) is known to be a problem in another species of bluegrass, the potential for that aphid attacking Texas bluegrass certainly should be tested.

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PR-4915

The Effects of Spray Volume and a Nitrogen-Iron Adjuvant on the Control of Weedy Grasses Using MSMA

W. G. Menn, J. B. Beard, and M. H. Hall

Introduction

The organic arsenical herbicides have been used for weed control in turfgrass management for over 40 years. During this period, MSMA (monosodium methanearsonate) has been the leading postemergent herbicide for use in selectively controlling weedy grasses (i.e., crabgrass, barnyardgrass, goosegrass, dallisgrass, etc.) from bermudagrass, Kentucky bluegrass, and zoysiagrass turfs. Even though MSMA might cause temporary leaf burning or discoloration on some of these species, they will survive and are quite tolerant of this herbicide. Product labels caution against the use of MSMA on St. Augustinegrass, carpetgrass and centipedegrass as these species might be seriously damaged by this material.

At last count, there were more than a dozen products which contained MSMA as an active ingredient. For the most part, product labels are very similar in recommended rates, spray volumes, etc. Among the high concentrate formulations (i.e., 6.0+ pounds active ingredient per gallon), the recommended rate is typically 1 to 2 fluid ounces per 1,000 square feet. This rate is equivalent to 2 to 4 pounds of active ingredient per acre (2.24 to 4.48 kg ai ha^{-1}). The typical recommended spray volume found on most labels is 2.5 to 5.0 gallons per 1,000 square feet (8.8 L are^{-1}). This volume is roughly equivalent to 100-200 gallons per acre (935-1870 L ha^{-1}).

Among the many turf managers who use MSMA in their weed control program, it would be safe to say that the majority do not apply this herbicide in the recommended spray volume. The primary reason for this failure to comply with label recommendations is that most turf sprayers have tank capacities of between 50 and 150 gallons (189 and 568 liters). Those responsible for spraying large turf areas (i.e., golf course fairways, parks, athletic complexes, etc.) do not want to spend the majority of their time mixing and filling the sprayer tank. Consequently, the applicator reduces the recommended spray volume and thereby drastically decreases mixing time. With the increased concern and necessity for following label recommendations, this study was conducted to determine the need, if any, for the high spray volume when treating grassy weeds in a Common bermudagrass turf.

Another reason for conducting this study was to prove or disprove a common complaint from applicators concerning a failure of MSMA to control certain grassy weeds. Here again, the question was, does spray volume affect efficacy of MSMA for the control of certain grassy weeds?

Materials and Methods

The study was conducted on a 12-year old stand of Common bermudagrass (*Cynodon dactylon* L. Pers.) on the campus of Texas A&M University in College Station, Texas. The area was heavily contaminated with smooth crabgrass [*Digitaria ischaemum* (Schreb.)] and dallisgrass (*Paspalum dilatatum* Poir.). Soil in the test area was a Lufkin fine sandy loam surface with a rather shallow, dense, clay pan subsoil. The test site was mowed at 1.25 inches (31.3 mm) on a twice per week schedule using a reel-type mower. Irrigation was accomplished by an automatic system programmed to operate so as to prevent signs of visual wilt.

Initial treatments were applied on 7/11/90 using a small, hand-held CO_2 pressurized plot sprayer. Treatments are listed in Table 1. Spray pressure was set at 25 psi. Individual plot size was 6 x 12 feet (1.8 x 3.6 meters)

Table 1. Effects of spray volume and an iron/nitrogen adjuvant on phytotoxicity of MSMA to Common bermudagrass, College Station, Texas.

Treatment	Formulation	Application rate in lbs ai/A (kg ha^{-1} or L ha^{-1})	Spray volume in gal/acre (L ha^{-1})	Shoot phytotoxicity ratings[1] 7/19/90 (Initial)	8/2/90 (Sequential)
Untreated Check	—			1.0 b[3]	1.0 c
MSMA[2]	6E	3.0(3.36)	100 (935)	2.3 a	2.3 b
MSMA	6E	3.0(3.36)	80 (748)	2.3 a	2.3 b
MSMA	6E	3.0(3.36)	40 (374)	3.0 a	2.0 b
MSMA	6E	3.0(3.36)	20 (187)	2.7 a	3.3 a
MSMA+Fe+N	6E	2.0(2.24) +			
adjuvant	AC	3.4gal(12.8)	40 (374)	1.0 b	1.0 c
MSMA+Fe+N	6E	3.0(3.36) +			
adjuvant	AC	3.4gal(12.8)	40 (374)	1.0 b	1.0 c

[1] Ratings based on 1 = no phytotoxicity and 9 = severe phytotoxicity.
[2] MSMA source was Daconate® 6E.
[3] Values followed by the same letter are not significantly different at the 5 percent level of Duncan's Multiple Range Test.

with 3 replications for each treatment. Plots were arranged according to a randomized block design.

Sequential treatments were applied to one half of each of the original plots on 7/25/90 (14-day interval) using the same techniques and materials as were used in the initial application. Air temperatures at the time of application for both the initial and sequential treatments were 88°F and 85°F (31°C and 29°C), respectively. Soil moisture content during both applications was good and both the weeds and the bermudagrass were actively growing. Both applications were made 3 days following mowing and the area was not mowed for 5 days following each treatment.

An iron + nitrogen adjuvant (Ferromec AC®), was mixed and applied with 2 rates of MSMA to determine if the nitrogen and/or iron contained therein would decrease the phytotoxicity caused by MSMA on the Common bermudagrass.

Ratings of phytotoxicity were made at approximately one week following each application to assess the extent or lack of damage to the Common bermudagrass caused by each treatment. Efficacy of the six treatments in controlling weedy grasses was determined through visual ratings taken on 8/14/90.

Results

Ratings of phytotoxicity were taken 8 days after the initial treatment. At this time, MSMA applied alone did cause a slight discoloration of the Common bermudagrass leaves regardless of spray volume. There was a tendency for a very slight increase in phytotoxicity on turfs receiving the lower spray volumes; however, this increase was not statistically significant (Table 1). MSMA treatments containing the iron + nitrogen adjuvant (Ferromec AC®) showed no signs of burn or discoloration on the Common bermudagrass.

Ratings of the sequential treatments made 8 days after treatment (DAT) produced results very similar to those observed after the initial treatment. The 20 gallon per acre (GPA) (187 L ha^{-1}) spray volume treatment produced the greater phytotoxicity to the Common bermudagrass in this part of the study. Again, the iron + nitrogen adjuvant (Ferromec AC®) safened those respective treatments so as to eliminate any phytotoxicity to the Common bermudagrass.

Under the conditions of this study, spray volume had a minimal to no effect on the phytotoxicity of MSMA applied to Common bermudagrass. The repeat application, 20-gallon per acre (187 L ha^{-1}) spray volume, could contribute to a slight increase in discoloration, but not enough to cause concern. The addition of an iron + nitrogen adjuvant (Ferromec AC®) to the spray mixture definitely decreased the phytotoxic effects of MSMA on Common bermudagrass.

The effects of 4 spray volumes on efficacy of MSMA in controlling the grassy weeds, smooth crabgrass and dallisgrass, was determined by visual ratings taken 2 weeks after the second sequential treatment. The results of this study showed that the spray volumes applied in this test had no significant effect on weed control (Table 2). These data suggest a slight tendency for the lower spray volumes to be more effective in controlling the two grassy weeds, which would parallel results reported with other postemergent herbicides (i.e., glyphosate).

The decrease in phytotoxicity caused by the addition of iron + nitrogen adjuvant (Ferromec AC®) to the spray mixture as discussed earlier, carried over in terms of affecting efficacy of smooth crabgrass and dallisgrass weed control. Whatever caused the Fe + N adjuvant to protect the Common bermudagrass from discoloration by MSMA also protected the two grassy weeds against control by this compound (Table 2).

This study confirmed the recommendation that two applications of MSMA are required to achieve complete control of grassy weeds, especially the dallisgrass. As shown in Table 2, a single treatment of MSMA at the 3.0 lb ai A (3.36 kg ai ha^{-1}) rate produced between 65 and 75 percent control of the grassy weeds regardless of spray volume.

Table 2. Effects of spray volume and an iron/nitrogen adjuvant on control of grassy weeds by MSMA, College Station, Texas.

Treatment	Formulation	Application rate in lbs ai/ac (kg ha^{-1} or L ha^{-1})	Spray volume in gal/acre (L ha^{-1})	Weed control ratings[1] 8/14/90 Treated Once	Treated Twice
Untreated Check	—			1.0b[3]	1.0 c
MSMA[2]	6E	3.0(3.36)	100 (935)	6.2 a	8.8 a
MSMA	6E	3.0(3.36)	80 (748)	6.7 a	9.0 a
MSMA	6E	3.0(3.36)	40 (374)	7.0 a	9.0 a
MSMA	6E	3.0(3.36)	20 (187)	7.0 a	9.0 a
MSMA+Fe+N	6E	2.0(2.24) +			
adjuvant	AC	3.4gal(12.8)	40 (374)	2.8 b	5.0 b
MSMA+Fe+N	6E	3.0(3.36) +			
adjuvant	AC	3.4gal(12.8)	40 (374)	2.5 b	5.0 b

[1] Ratings based on 1 = no phytotoxicity and 9 = severe phytotoxicity.
[2] MSMA source was Daconate® 6E.
[3] Values followed by the same letter are not significantly different at the 5 percent level of Duncan's Multiple Range Test.

Summary

1. When applying MSMA at the recommended rate, spray volume had only a slight effect on the phytotoxicity of the chemical to Common bermudagrass.
2. Under the conditions of this study, spray volume differences of 20 to 100 gallons per acre (187 to 935 L ha^{-1}) did not significantly affect control of two grassy weeds, smooth crabgrass and dallisgrass.
3. Two applications of MSMA spaced 2 weeks apart were necessary to achieve complete control of the two grassy weeds under the conditions of this study.
4. The iron + nitrogen adjuvant, Ferromec AC®, did decrease phytotoxic effects on Common bermudagrass. However, its addition also substantially negated the control of two grassy weeds.
5. Consideration should be given to revising MSMA product labels to allow the applicator the option of using a spray volume of from 20 to 100 gallons per acre (187 to 935 L ha^{-1}).

Acknowledgment

Appreciation is extended to the Grounds Maintenance Department of Texas A&M University for providing a location and general lawn maintenance for this study.

PR-4916

Pre- and Postemergent Control of Mexican Sprangletop [*Leptochloa uninvervia* (Presl) Hitchc.] in Emerald Zoysiagrass - 1990

W. G. Menn, R. L. Duble, and J. B. Beard

Introduction

Mexican sprangletop is more of a problem in sod production fields than in established turf areas. It is adapted to the Southern and Southwestern United States and quite prevalent along streams, in ditches and swales, and in any bare area that stays wet for prolonged periods (i.e., a harvested sod field). Mexican sprangletop is an annual and a very prolific seed producer that flowers from March to December under favorable conditions. Heretofore, commonly used pre- and postemergent applied herbicides have not been very effective in controlling this grassy weed. This study was conducted to evaluate four newer materials for their effectiveness in controlling Mexican sprangletop.

Materials and Methods

This study was conducted at Warren's Turf Nursery near Cameron, TX on a 5-year old Emerald zoysiagrass (*Zoysia japonica* x *Z. tenuifolia*) sod field. Soil at the site was a clay loam and rather poorly drained which had previously yielded heavy populations of Mexican sprangletop. The test area was fertilized in April with 21-0-0 (ammonium sulfate) at a rate of 0.75 lbs of actual N per 1,000 ft^2 (0.84 kg of N/ha). Soil phosphorus and potassium levels were in the high range. The site was irrigated on an "as-needed" schedule so as to prevent visual signs of wilt. Soil pH in this area measured 7.8.

Initial treatments as shown in Table 1 were applied preemergently on 3/21/90 using a small, hand-held, CO_2 pressurized plot sprayer. Spray pressure was set at 30 psi and spray volume was equivalent to 40 gallons per acre (170 L/ha). Individual plot size was 72 square feet (6.8 m^2) or 6 x 8 ft (1.8 x 2.4 m), with three replications of each treatment arranged in a randomized block design. Air temperature at the time of the initial treatment was 65°F (18°C). The preemergence herbicide metolchlor (Pennant®) was applied alone and in combination with simazine. Sequential and postemergent treatments were applied on 5/7/90 and 5/21/90 as described (Table 1). Postemergent applications of primisulfuron (Rifle®) were made to sprangletop when in the 2 to 3 tiller stage and prior to flower emergence.

Ratings for control of Mexican sprangletop were made on 5/7, 5/21, 6/11, and 6/27/90 and reflect a visual estimation based on a scale of 1 to 9 with 1 being equal to no control and 9 equal to complete control.

Results

The metolachlor and combinations of simazine with metolachlor applied preemergent all produced excellent control of Mexican sprangletop for at least 14 weeks after treatment (WAT). Even though it was not statistically significant, the sequential application of metolachlor 7.8 E at 47 days after treatment (DAT) tended to yield a more uniform and complete control of the sprangletop. It might be noted that by 8 WAT, considerable emergence of barnyardgrass [*Echinochloa crusgalli* (L.) Beauv.] and spotted spurge (*Euphorbia maculata* L.) occurred in most of the plots treated with metolachlor. Based on this study neither metolachlor nor simazine were very effective in preemergent control of these two weed species.

Table 1. Effects of seven herbicide treatments on pre- and postemergent control of Mexican Sprangletop.

Treatment	Formulation[3]	Application rate lbs ai/A (kg/ha-1)	Weed control ratings[4] by date			
			5/7/90	5/21/90	6/11/90	6/27/90
Untreated Check			1.0 b[5]	1.0 c	1.0 c	1.0 d
Metolachlor	7.8 E	4.0(4.8)	8.7 a	8.3 a	8.7 a	8.7 a
Metolachlor	7.8 E	4.0 + 4.0[1](4.48+4.48[1])	9.0 a	9.0 a	9.0 a	9.0 a
Metolachlor + Simazine	8.0 E 4.0 AS	4.0(4.48) + 2.0(2.24)	9.0 a	8.7 a	9.0 a	8.3 a
Metolachlor + Simazine	7.8 E 4.0 AS	4.0(4.48) + 1.0(1.12)	9.0 a	9.0 a	8.7 a	8.3 a
Primisulfuron	75 WG	0.12(0.13)	1.0 b	1.3 bc	1.0 c	2.0 cd
Primisulfuron	75 WG	0.25(0.28)	1.0 b	2.0 b	1.3 c	2.3 c
Primisulfuron	75 WG	0.12 + 0.12[2](0.13+0.13[2])	1.0 b	1.7 bc	2.3 b	3.7 b

[1] Sequentially applied 47 days after initial treatment.
[2] Sequentially applied 17 days after initial treatment.
[3] E = emulsifiable concentrate; AS = aqueous solution; WG - water dispersible granule.
[4] Weed control ratings based on: 1 = no control and 9 = complete control.
[5] Values followed by the same letter are not significantly different at the 5 percent level of Duncan's Multiple Range Test.

As a postemergent applied compound, primisulfuron (Rifle®), was not effective in controlling existing Mexican sprangletop. It should be noted that these plots were not mowed after treatment application. Observations of the sprangletop plants several weeks after application of primisulfuron revealed stunted shoot growth and a very abbreviated root system. It might be speculated that under regular mowing, the Mexican sprangletop might have been more adversely effected. It was also observed that primisulfuron was excellent in controlling the spotted spurge which was prevalent throughout the test area, but had no effect on the barnyardgrass.

None of the treatments applied in this study showed any visible phytotoxic effects on the Emerald zoysiagrass. The primisulfuron (Rifle®) treatments did cause a noticeable dwarfing of some Common bermudagrass that had encroached into several of the plots.

Conclusions

1. Both formulations of metolachlor (7.8 E and 8.0 E) when applied at a rate of 4 lbs ai/A (4.48 kg ha-1) produced excellent control of Mexican sprangletop.
2. In an unmowed situation, the rates of primisulfuron 75 WG applied in this study did not control Mexican sprangletop.
3. In this study, metolachlor was not effective in controlling barnyardgrass or spotted spurge when applied preemergently.
4. At the rates applied, primisulfuron was very effective in controlling spotted spurge, but not barnyardgrass.

Acknowledgment

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PR-4917

'Prairie' Buffalograss Response to Selected Pre- and Postemergence Herbicides

M. C. Engelke, R. H. White, S. J. Morton, and K.B. Marcum

Introduction

Buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.) is becoming more important for use in the low maintenance and ecologically sensitive landscapes. Regardless of its ultimate use, effective establishment of buffalograss is influenced by existing vegetation, and weed seeds in the soil. To facilitate full establishment in a reasonable period of time, effective weed control measures may be required. Since few chemicals are presently labeled for use on buffalograss, a study was defined to determine the phytotoxicity of selected pre- and postemergence herbicides on buffalograss.

Materials and Methods

Preemergence Herbicides

Field studies were conducted on mature Prairie Buffalograss turf in 1990 and 1991. The first study was conducted in 1990 on a field site where sod had recently been harvested and only 4 inch wide turf strips remained. Eleven herbicides were applied to this site on

July 27, 1990 (Table 1). The second study was initiated in 1991, with 13 herbicides (Table 1) applied to a different and fully turfed area. Granular formulation herbicides were applied May 7, and all other applications on May 8. Two treatments, Balan at 6 lbs active ingredient ai/acre, and Surflan at 3 lbs ai/acre, were applied as split applications, the second application was applied 8 weeks later. Performance was measured by visual evaluation on level of turf injury, percent coverage, and number of stolons developed.

Postemergence Herbicides

Nine postemergence herbicides were tested on established Prairie Buffalograss turf in 1990 (Table 2). Applications were made on August 9. Visual evaluation of tissue discoloration was made, and/or general turf injury was noted.

The field design for all studies was a randomized complete block, with four replications. Individual treatment areas measure 6 x 10 ft. Data were tested by analysis of variance, and for those ANOVA's with $p<0.05$, Waller-Duncan mean separation was performed.

All pre- and postemergence herbicides were applied at the full manufacturer's recommended rates unless otherwise indicated. Spray volume was 24 GPA. Statistical analysis of the data was as for preemergence herbicide data.

Table 1. Preemergent herbicide list for Prairie Buffalograss phytoxicity studies 1990 and 1991.

Chemical Name	Trade Name	Timing	Formulation	ai	Rate ai per acre
Atrazine	Atrazine	Pre,Post	L	4.0 #/gal	2.0 #
Benefin	Balan	Pre	EC	1.5 #/gal	1.5 #
Benefin (split application, 3#+3#)	Balan	Pre,Post	EC	1.5#/gal	6.0 #
Benefin + Oryzalin	Elanco XL	Pre	G	2 %	3.0 #
Benefin + Trifluralin	Team	Pre	G	2 %	3.0 #
Bensulide	Betasan	Pre	G	3.6 %	10.0 #
Ethofumesate	Prograss[1]	Pre,Post	EC	1.5 #/gal	2.0 #
Oryzalin	Surflan	Pre	AS	4.0 #/gal	2.0 #
Oryzalin (spit) application, 1.5#+1.5#)	Surflan	Pre, Post	AS	4.0#/gal	3.0 #
Oxidiazon	Ronstar	Pre	WP	50 %	3.0 #
Siduron	Tupersan	Pre	WP	50 %	10.0 #
Simazine	Princep	Pre,Post	WP	90 %	2.0 #
Isoxaben	Gallery	Pre	DF	75 %	0.7 #
Metolachlor	Pennant[2]	Pre	L	85 %	4.0 #
Metsul. methyl	Ally[2]	Pre	DF	60 %	0.1 oz

[1]Included in 1990 study only.
[2]Included in 1991 study only.

Results and Discussion

Preemergence Herbicides

Prograss was the most phytotoxic of all preemergence chemicals tested in this study. Within 12 days of applications, significant discoloration of turf occurred and persisted, with a corresponding reduction in rate of plant growth (percent coverage), and in stolon production throughout the remainder of the study (Table 3). Ronstar caused considerable initial discoloration at 12 days postapplication, however, within 24 days the level

Table 2. Postemergent herbicide list for Prairie Buffalograss phytoxicity study.

Chemical Name	Trade Name	Timing	Formulation	ai	Rate ai per acre
Fenoxaprop	Acclaim	Post	EC	1.0 #/gal	0.35 #
Asulam	Asulox	Post	EC	3.3 #/gal	2.0 #
Atrazine	Atrazine	Pre,Post	L	4.0 #/gal	2.0 #
Bentazon	Basagran	Post	EC	4.0 #/gal	2.0 #
Chlorimuron	Classic	Post	DF	25 %	1.0 oz
Imazaquin	Image	Post	EC	1.5 #/gal	0.5 #
MSMA	MSMA	Post	EC	6.6 #/gal	2.0 #
Simazine	Princep	Pre,Post	DF	90 %	2.0 #
Metribuzin	Sencor	Post	WP	75 %	0.3 #/gal

Table 3. Turf injury (%), plot coverage, (%) and stolon counts (#) of Prairie Buffalograss treated with preemergence herbicides on July 27, 1990, at TAES-Dallas.

Herbicide	Date: Aug 8	Date: Aug 20	Mean	Date: Aug 28	Date: Sep 14	Mean	Date: Aug 28	Date: Sep 14	Mean
	% Turf Injury			% Coverage			# Stolons		
Atrazine	40.0	7.7	23.8	36.2	82.5	59.0	60.2	90.5	75.0
Balan	11.2	3.0	7.1	45.0	84.0	64.0	69.5	100.0	84.0
Betasan	7.5	1.0	4.2	35.7	64.4	50.0	77.4	83.0	80.0
Elanco XL	6.2	2.0	4.1	69.4	95.5	82.0	90.2	100.0	95.0
Gallery	7.5	4.2	5.8	26.2	56.6	45.0	63.2	75.2	69.0
Princep	18.7	4.0	11.3	50.6	77.5	64.0	63.4	100.0	81.0
Prograss	95.0	95.0	95.0	1.4	8.0	4.0	39.4	22.9	31.0
Ronstar	90.0	22.5	56.2	31.5	73.5	52.0	73.0	95.1	84.0
Surflan	15.0	3.0	9.0	29.4	54.4	41.0	67.5	82.0	74.0
Team	7.5	1.0	4.2	49.4	79.8	64.0	81.8	100.0	91.0
Tupersan	20.0	6.5	13.2	31.2	59.4	45.0	66.7	82.5	74.0
Control	5.0	0.0	2.5	50.2	95.4	72.0	79.5	100.0	89.0
MSD[1]	6.8	6.6		24.6	21.7		53.2	21.7	

[1]MSD = Minimum Significant Difference for comparison of means within columns based on Waller-Duncan k-ratio t test (k-ratio = 100).

of injury had been significantly reduced. The subsequent rate of coverage, measured 32 days and 45 days posttreatment was not significantly reduced from nontreated areas. Rate of fill in of sod-stripped plots was measured by two variables, percent plot cover and stolon count. On August 28, 32 days after application, plot cover was decreased by Atrazine, Betasan, Ronstar, Tupersan, Surflan, and Gallery (Table 3). By September 14, plot cover had improved for all treatments, but was still severely inhibited from Prograss.

Some other chemicals appeared to have only moderate and temporary tissue discoloration, with very little long term influence on turfgrass coverage or stolon development (Table 3).

Prograss was determined to have considerable phytotoxicity to Prairie buffalograss and therefore was not included in the 1991 study. Two additional chemicals were added to the study, as were split applications for selected chemicals (Table 1.) As with the 1990 study, Ronstar appeared to show the greatest phytotoxicity within a week of application, however within 35 days all evidence of turf injury had disappeared (Table 4). In contrast to the previous study, Atrazine appeared to cause significant but temporary injury as did Elanco XL at the 3-lb rate. None of the other preemergence herbicides caused significant injury to the turf.

Postemergence Herbicides

Acclaim was the most detrimental to Prairie buffalograss when applied on active growing turf. It persisted longer than other chemicals and significantly reduced the stand of grass (Table 5). The turf recovered by the following spring and provided acceptable quality turf however. Atrazine likewise caused considerable and lasting damage to Prairie, but not as severe as Acclaim. A significant reduction in coverage was noted but was not long lasting. Image caused some damage but was not persistent. Asulox and Classic also caused injury, which was significant at the second and third observation dates, respectively (August 20 and 31).

Turf quality was measured on May 20 of the following year. At that time quality was not reduced by any herbicide, indicating that total recovery had occurred (Table 5). Only Classic appeared to have a residual affect on turf quality, although it did not appear to cause major damage during the previous year.

Table 5. Percent turf injury, percent plot coverage (measured August 28, 1990), and turf quality (measured May 20, 1991) of Prairie Buffalograss treated with postemergence herbicides on August 9, 1990.

	% Injury-date			%	Quality
Herbicide	Aug 17	Aug 20	Aug 31	Coverage	1-9,9=Best
Acclaim	86.7	93.3	88.3	43.3	7.0
Asulox	13.3	20.0	5.0	75.0	7.0
Atrazine	56.7	68.3	60.0	60.0	7.0
Basagran	11.7	10.0	5.3	78.3	6.7
Classic	18.3	11.7	15.0	80.0	5.0
Image	28.3	16.7	8.3	83.3	7.0
MSMA	8.3	13.7	8.7	80.0	6.7
Princep	8.3	8.7	3.7	90.0	6.7
Sencor	11.7	11.7	3.7	91.7	7.3
Control	5.0	3.7	5.3	88.3	7.0
MSD[1]	14.4	10.8	7.1	20.3	2.2

[1] MSD = Minimum Significant Difference for comparison of means within columns based on Waller-Duncan k-ratio t test k-ratio = 100).

Table 4. Percent turf injury of Prairie Buffalograss treated with preemergence herbicides on May 8-9, 1991, at TAES-Dallas.

	Rate	Date							
Herbicide	lb/A	5/9	5/10	5/13	5/15	5/24	6/11	6/24	Mean
Control	0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.8
Elanco XL	2	1.0	1.0	1.0	1.0	1.0	0.0	0.3	0.8
Elanco XL	3	1.0	1.0	1.0	24.0	22.3	0.0	1.7	7.3
Team	2	1.0	1.0	1.0	1.0	1.0	0.0	0.3	0.8
Team	3	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.7
Balan	3	1.0	1.0	1.0	1.0	1.0	0.0	1.7	1.0
Balan	3x2	1.0	1.0	1.0	1.0	1.0	0.0	0.0	6.0
Gallery	1	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.7
Gallery	2	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.7
Surflan	2	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.7
Surflan	1.5	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.7
Surflan	1.5x2	1.0	1.0	1.0	1.0	1.0	0.0	0.3	1.0
Princep	2	1.3	1.3	1.0	1.0	1.0	0.0	2.0	1.1
Ronstar	3	1.7	5.0	86.7	90.0	90.0	9.7	0.0	40.4
Atrazine	2	1.0	1.0	53.3	47.0	55.3	1.0	0.7	22.8
Betasan	10	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.7
Tupersan	10	1.7	1.7	2.0	1.0	1.0	0.0	0.0	1.0
Pennant	4	1.0	4.0a	5.3	7.3	1.0	0.0	0.3	2.7
Ally	.1 oz	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.7
MSD[1]		N.S.	2.4	4.4	20.4	2.9	1.8	N.S.	7.9

[1]MSD = Minimum Significant Difference for comparison of means within columns based on Waller-Duncan k-ratio t test (k-ratio = 100).

PR-4918

Nitrogen Fertilization and Mowing Height Effects on Zoysiagrass Performance

M. C. Engelke, R. H. White, S. J. Morton, and K. B. Marcum

Introduction

Zoysiagrass, *Zoysia* spp. L., 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. Zoysiagrass is considered one of the most promising turfgrass species for the future. Its inherent characters of being highly competitive under low maintenance, and having comparatively low water and nutritional requirements, makes this species a strong target for use in an environmentally conscience urban industry. Consequently, new cultivars have been introduced, and developmental research promises additional cultivars in the near future. As with other species, a properly defined cultural program is required to optimize the value of the species for turf. In essence, a zoysiagrass management program must be defined to ultimately displace the higher maintenance "bermudagrass mentality" with a more conservative, environmentally sensitive "zoysiagrass mentality". Acceptance and utilization of new cultivars of zoysia depends on development of appropriate and efficient management strategies. The purpose of this work is to 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.

Materials and Methods

Turf Establishment

During the winter of 1987-88, plant material was increased vegetatively 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 rooted plugs planted on 0.3 m centers. The field plot design was a randomized complete block, consisting of three replications of 10 entries. Plot size is 5.79 m by 4.27 m. Cultivars in this trial include: 'Meyer', 'Emerald', 'El Toro', 'Belair', 'Cashmere', and one proprietary line designated TAES3372. Experimental varieties developed at Texas A&M Research and Extension Center-Dallas include: DALZ8501, DALZ8502, DALZ8508, and DALZ8516. These same cultivars and varieties are also in regional field trials throughout the Southern United States.

Management Studies

The management treatment plots for this study were overlaid on each of the established turf plots described in the previous statement. Management treatments consisting of mowing heights and nitrogen fertility levels were initiated in July 1990. Mowing treatments included heights of 0.63 (5/8 inch) and 2.54 cm (1 inch). Nitrogen treatments consisted of 0.12, 0.37, and 0.75 Kg N are^{-1} applied April, May, July, and September for total yearly amounts of 0.5, 1.5, and 3 Kg N are^{-1} (1, 3 and 6 lb N 1,000 ft^2), respectively. Mowing and nitrogen treatments were applied in a strip plot design. Data collected on the effects of management treatments included winter green color retention and turf quality. Statistical analysis was by standard ANOVA procedures, with comparison between means through Waller-Duncan k-ratio t test (k-ratio = 100).

Results and Discussion

Green Color Retention

All entries maintained green leaves under their canopies over the winter. On December 18, 1990, green cover was the greatest (>65 percent green canopy cover) for DALZ8502, El Toro, and TAES3372 and was least for Meyer, Belair, and Cashmere (<25 percent green canopy cover, Table 1). On this date, plots mowed at 0.63 cm (5/8 inch) had on average 54 percent green canopy cover, which was significantly higher ($P=0.05$) than the 45 percent observed of plots at 2.54 cm (1 inch) mow heights. By December 18, DALZ8501 had 50 percent green cover at 3 kg N per year, but retained 64 percent green cover when fertilized with 1.5 kg (3 lb) N per year. Cashmere lost green less rapidly when supplied 0.5 kg (1 lb) N per year than when supplied higher rates of nitrogen. Nitrogen fertilizer did not affect the rate of green canopy loss for other entries.

Turf Quality

By mid-winter (January 24, 1991), the turf generally had entered winter dormancy and all varieties exhibited relatively poor turf color. Emerald and DALZ8508 retained the best color and appearance. Fertility levels and mowing treatments did not contribute to variability in winter performance, however, mowing at 0.63 cm resulted in a higher percentage of green canopy cover. By April 25, 1991, turf quality differences among the entries increased. Half of the entries, including Meyer and DALZ8508 had acceptable turf qualities. Poor qualities were observed for DALZ8502 and TAES3372. Poor establishment was the main contributing factor to the poor rating of DALZ8502. Differences among the management treatments were not evident.

Future Work

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

Table 1. Fall/Winter color retention (1990), expressed as percent green ground cover of zoysiagrasses planted 21 June 1988 at TAES-Dallas as influenced by nitrogen rates and mowing heights.

Mow Height Treatment	Entry	Nov. 21 (1 lb N)	Dec. 18 (1 lb N)	Nov. 21 (3 lb N)	Dec. 18 (3 lb N)	Nov. 21 (6 lb N)	Dec. 18 (6 lb N)	PS[3]	Total PS[4]
		% Green Cover							
5/8" Reel mow	Belair	76.7a	16.7	76.7a	16.7	80.0a	11.7	3	
	El Toro	82.5a	68.3a	85.0a	75.0a	85.0a	75.0a	6	
	Emerald	77.5a	45.0	77.5a	46.7	85.0a	56.7	3	
	Meyer	70.0a	16.7	70.0a	18.3	70.0	13.3	2	
	DALZ8501	86.7a	76.7	86.7a	75.0a	91.7a	63.3a	5	
	DALZ8502	78.3a	80.0a	83.3a	87.5a	86.7a	78.3a	6	
	DALZ8508	75.0a	60.0	81.7a	68.3	90.0a	65.0a	4	
	DALZ8516	83.3a	78.3a	86.7a	73.3a	91.7a	68.3a	6	
	TAES3372	83.3a	73.3a	65.0a	71.7a	83.3a	73.3a	6	
	Cashmere	80.0a	33.3	80.0a	23.3	88.3a	21.7	3	
	MSD entry[1]	n.s.	15.5	n.s.	16.9	14.1	19.0		
Mean mow		79.3	54.8	79.1	54.4	85.2	52.7		
1" Rotary	Belair	78.3a	12.3	76.7a	16.7	76.7a	13.3	3	
	El Toro	80.0a	61.7a	80.0a	65.0a	80.0a	66.7a	6	
	Emerald	77.5a	45.0	82.5a	40.0	80.0a	46.7	3	
	Meyer	65.0	14.0	66.7a	12.3	63.3	10.7	1	
	DALZ8501	85.0a	56.7a	90.0a	63.3a	90.0a	45.0	5	
	DALZ8502	80.0a	65.0a	80.0a	67.5a	81.7a	66.7a	6	
	DALZ8508	61.7	46.7	70.0a	51.7	60.0	51.7	1	
	DALZ8516	75.0a	66.7a	83.3a	66.7a	86.7a	61.7a	6	
	TAES3372	80.0a	58.3a	71.7a	70.0a	81.7a	68.3a	6	
	Cashmere	80.0a	30.0	71.7a	25.0	83.3a	25.0	3	
	MSD entry[1]	15.5	15.4	n.s.	17.8	18.1	23.1		
Mean mow		76.0	45.6	77.0	47.1	78.2	45.6		
1" Reel	Belair	66.7a	20.0	71.7	11.3	73.3	16.7	1	7
	El Toro	75.0a	63.3a	82.5a	60.0a	80.0a	70.0a	6	18
	Emerald	75.0a	41.7a	85.0a	43.3	85.0a	38.3	4	10
	Meyer	65.0a	13.0	76.7	16.7	70.0	13.3	1	4
	DALZ8501	85.0a	45.0a	90.0a	55.0a	91.7a	45.0	5	15
	DALZ8502	85.0a	56.7a	88.3a	50.0a	81.7a	67.5a	6	18
	DALZ8508	68.3a	53.3a	76.7	55.0a	76.7	63.3a	4	9
	DALZ8516	85.0a	61.7a	90.0a	58.3a	90.0a	55.0a	6	18
	TAES3372	80.0a	66.7a	75.0	63.3a	83.3a	70.0a	5	17
	Cashmere	83.3a	36.7a	86.7a	21.7	93.3a	16.7	4	10
	MSD entry[1]	n.s.	29.2	8.8	19.8	15.0	22.5		
Mean mow		77.0	45.8	82.1	43.2	82.5	44.8		
MSD mow[2]		n.s.	5.8	n.s.	5.2	4.0	6.4		

[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 mowing treatments means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).
[3] PS = Phenotypic Stability, the number of times an entry was in the highest rating group.
[4] Total PS = accumulative PS for this data set.

Table 2. Turf quality of zoysiagrasses planted 21 June 1988, at TAES-Dallas. Effects of nitrogen enrichment and mowing height.

Mow Treatment	Entry	Jan. 24	Apr. 25	June 20	Jan. 24	Apr. 25	June 20	Jan. 24	Apr. 25	June 20	PS[3]	Total PS[4]
		1# N			3# N			6# N				
		Turf quality										
5/8" Reel	Belair	2.3a	4.7a	6.0a	2.7a	5.0a	6.7a	3.0a	5.0a	7.3	8	
	El Toro	2.7a	4.7a	6.3a	2.7a	4.7	6.7a	3.0a	6.0a	7.7	7	
	Emerald	3.3a	5.7a	6.7a	3.3a	5.0a	7.0a	3.3a	5.3a	6.7	8	
	Meyer	3.3a	5.0a	6.3a	3.0a	6.7a	7.0a	3.3a	6.3a	7.3	8	
	DALZ8501	2.0	3.0	4.7	2.3a	3.7	5.3a	2.3a	3.7	6.0	3	
	DALZ8502	1.7	2.7	2.3	1.0	4.0	3.7a	1.7a	3.0	3.0	2	
	DALZ8508	3.0a	5.3a	6.0a	3.3a	5.7a	6.7a	3.7a	6.3a	6.7	8	
	DALZ8516	2.3a	3.7	5.5	2.3a	3.7	5.3a	3.0a	4.0	6.7	4	
	TAES3372	1.7	2.3	3.7	1.0	2.3	4.3a	2.7a	3.7	5.0	2	
	Cashmere	2.3a	3.7	6.0a	3.0a	4.7	6.0a	3.0a	5.3a	6.7	6	
	MSD entry[1]	0.9	1.9	2.0	1.7	1.8	n.s.	n.s.	1.8	2.1		
Mean mow		2.5	4.1	5.3	2.5	4.5	5.9	2.9	4.9	6.3		
1"Rotary	Belair	2.3a	4.7a	6.0a	2.3	5.0	7.3a	3.0a	5.3a	7.3	6	
	El Toro	2.7a	5.0a	6.0a	2.7	4.7	7.3a	3.0a	6.0a	7.7	6	
	Emerald	3.3a	5.3a	6.7a	3.7a	5.3a	7.3a	3.3a	5.3a	7.0	8	
	Meyer	3.0a	5.3a	7.0a	3.0a	6.7a	8.0a	3.3a	6.0a	8.0	8	
	DALZ8501	2.0	2.7	4.0	2.0	3.3	4.7	2.0	3.3	5.3	—	
	DALZ8502	1.7	2.7	3.3	0.7	3.0	3.7	1.0	2.0	3.3	—	
	DALZ8508	3.0a	5.3a	5.3	3.7a	5.7a	6.0	3.7a	6.3a	6.7	6	
	DALZ8516	2.0	3.3	4.3	2.0	3.7	5.0	3.0a	4.7	6.0	1	
	TAES3372	1.7	2.3	3.7	1.0	3.0	3.0	2.3	3.7	5.7	—	
	Cashmere	2.3a	4.0	4.7	2.7	4.7	6.7a	3.7a	5.7	7.3	3	
	MSD entry[1]	1.2	0.8	1.4	0.8	1.6	1.4	1.2	1.5	2.2	—	
Mean mow		2.4	4.1	5.1	2.4	4.5	5.9	2.8	4.8	6.4		
1"Reel	Belair	2.7a	4.7a	6.0a	2.0	5.0a	6.3a	2.7a	5.0a	7.0a	8	22
	El Toro	2.7a	5.0a	5.7a	2.7	5.0a	7.0a	3.0a	6.0a	7.7a	8	21
	Emerald	3.0a	5.7a	6.3a	3.3a	5.3a	7.3a	3.3a	6.0a	6.3a	9	25
	Meyer	3.0a	5.3a	6.3a	3.0a	6.7a	7.3a	3.0a	6.3a	7.7a	9	25
	DALZ8501	2.0a	2.7	4.7a	1.7	3.3	4.7	2.0a	3.7	7.0a	4	7
	DALZ8502	1.3a	2.7	3.0	0.3	2.7	3.7	1.3a	2.7	3.7	2	2
	DALZ8508	3.0a	5.3a	5.3a	3.7a	5.7a	6.3a	3.0a	6.0a	6.7a	9	18
	DALZ8516	1.7a	3.7	4.3a	2.0	4.3	4.7	2.7a	4.7a	5.7a	5	9
	TAES3372	1.3a	3.0	4.7a	1.7	2.7	3.0	2.0a	4.0	5.3	3	8
	Cashmere	2.0a	4.0a	4.7a	2.3	5.0a	5.7a	3.3a	5.7a	6.7a	8	14
	MSD entry[1]	n.s.	1.7	2.2	0.9	1.7	1.8	n.s.	2.0	2.2		
Mean mow			2.3	4.2	5.1	2.3	4.6	5.6	2.6	5.0	6.4	
MSD mow[2]		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.		

[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 mowing treatments means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).
[3] PS = Phenotypic Stability, the number of times an entry was in the highest rating group.
[4] Total PS = accumulative PS for this data set.

Table 3. Turf quality of zoysiagrasses planted 21 June 1988, at TAES-Dallas during winter 1990 - spring 1991.

Entry	Turf Quality 1990						Turf Quality 1991			PS²
	May 17	June 27	July 10	Aug. 8	Sept. 12	Oct. 17	Jan. 24	Apr. 25	June 20	
	Quality 1 to 9, where 9=best									
Belair	4.3a	4.7a	4.3	5.7a	6.0a	5.3	2.6	4.9	6.7a	5
El Toro	5.0a	4.7a	5.7a	6.7a	6.0a	5.7	2.8	5.2	6.9a	6
Emerald	5.3a	5.0a	5.3a	7.3a	7.0a	6.3a	0.3	5.4	6.8a	7
Meyer	5.0a	5.3a	6.0a	7.0a	6.3a	6.7a	3.1a	6.0a	7.2a	9
DALZ8501	2.7	2.7	3.0	4.0	4.0	3.7	2.0	3.3	5.1	—
DALZ8502	1.7	1.3	2.0	3.3	3.0	2.3	1.2	2.8	3.3	—
DALZ8508	5.3a	4.7a	5.3a	6.0a	6.0a	6.0a	3.3a	5.7a	6.2	8
DALZ8516	2.7	3.0	2.7	3.3	3.7	3.3	2.3	4.0	5.3	—
TAES3372	1.7	2.0	2.0	4.0	3.7	3.0	1.7	3.0	4.3	—
Cashmere	3.7	3.7	3.7	4.3	5.0	4.3	2.7	4.7	6.0	—
MSD¹	1.0	1.1	1.2	1.4	1.6	0.9	0.3	0.4	0.5	

¹ MSD = Minimum Significant Difference for comparison of entry means within columns based on the Waller-Duncan k-ratio t test (k-ratio = 100).
² PS = Phenotypic Stability, the number of times an entry was in the highest rating group.

PR-4919

A Comparison of Two Formulations of Dithiopyr (Dimension®) at Multiple Rates with Two Other Preemergent Herbicides in Terms of Root Effects on Two Hybrid Bermudagrasses

W. G. Menn, J. B. Beard, and M. H. Hall

Introduction

In recent years, more concern has been shown toward the effects of preemergent herbicides on turfgrass root systems. Previously, if the shoot portion of the grass plant was unaffected by herbicide applications, it was assumed that the material was not harming the plant. Recent studies have shown that some preemergent herbicides do cause a reduction in turfgrass root systems without causing any visible damage to the shoot portion of the plant. This reduction in root system does; however, render the grass plant more susceptible to damage during periods of stress (i.e., drought, high temperature, insects, diseases, etc.).

This study was conducted to compare the effects on rooting of dithiopyr (Dimension®), bensulide, and a 5.25 percent bensulide + 0.131 percent oxadiazon combination, both of which have previously shown little or no effect on turfgrass root systems.

Materials and Methods

The study was conducted on a green located at the TAM Turfgrass Field Research and Teaching Laboratory on the campus of Texas A&M University in College Station, Texas. The green was constructed according to USGA specifications in 1978. The surface consisted of one half Tifgreen bermudagrass and the other half Tifdwarf bermudagrass (both *Cynodon dactylon* x *C. transvaalensis* hybrids). The growing medium was composed of 90 percent sand and 10 percent organic matter and measured 12 inches (30 cm) in depth. The root zone was laid on top of a drainage system constructed of a 4-inch (10 cm) layer of 3/8-inch (9.4 mm) pea gravel and 4-inch (10 cm) perforated, flexible, plastic pipe drain system with an outlet into a nearby pond.

The entire green was mowed daily at a cutting height of 3/16 inch (4.7 mm) throughout the study, with clippings removed. The fertilization program for this green consisted of monthly applications of a 30-5-7 slow release type material at a rate of 3.3 lbs of product per 1,000 sq ft (1.4 kg are^{-1}). Irrigation of the green turf was scheduled so as to prevent visual signs of wilt. The green was treated with isofenphos (Oftanol®) and ethoprop (Mocap®) for white grubworms during the study period. Both treatments were applied at the label recommended rates.

Identical treatments were applied on both bermudagrass hybrids on 26 June 1990. Liquid materials, MON15104 (dithiopyr) and bensulide, were applied using a hand-held, CO_2 pressurized plot sprayer (treatments are shown in Table 1). Materials were sprayed in a volume of water equivalent to one gallon per 1,000 square feet (4 L are^{-1}). Granular treatments, MON15152 (dithiopyr) and a 5.25 percent bensulide and 1.31 percent oxadiazon combination, were weighed for each plot, the amount per plot divided in half and the materials applied as evenly as possible by hand in each of two directions. All treatments were then drenched in with 0.25 inch (6.25 mm) of irrigation water. Individual plot size was 3 x 6 feet (0.9 x 1.8 m), with each treatment being replicated four times and arranged in a randomized block design.

On 1 August 1990, or 6 weeks after treatment, two turf plugs were collected from each replication of each treatment. The turf plug size measured 2 inches (50 mm) in diameter by 6 inches (150 mm) in depth. The sand was washed away from the root system, the roots clipped directly beneath the crown and the sample bagged and subsequently dried for 72 hours in a forced draft oven at 150°F (65°C). After drying, the samples were weighed to the nearest milligram and the weight recorded.

Results

There were no visible signs of shoot phytotoxicity to either of the bermudagrass hybrids from any of the seven treatments applied in this study.

Results from the seven treatments on Tifgreen bermudagrass rooting will be discussed first. As can be seen in Table 1, there were no statistical differences in rooting from any of the treatments. Based on the results of this study, it would suggest that the roots of established Tifgreen bermudagrass would tolerate normal rates of dithiopyr under the maintenance conditions previously described. It also indicates that established roots of Tifgreen bermudagrass tolerate the recommended rates of bensulide and the bensulide/oxadiazon combination included in this study.

The root system of Tifdwarf bermudagrass did not respond negatively to the seven herbicide treatments (Table 2). With the exception of the lower rate of MON15152, all treatments caused a significant increase in the root mass of Tifdwarf bermudagrass in this study. Without a second year's repeat of this study, it would be premature to suggest that dithiopyr consistently promotes an increase in root mass of Tifdwarf bermudagrass. Certainly, established Tifdwarf, like Tifgreen, will tolerate normal rates of dithiopyr, bensulide, and the bensulide/oxadiazon combination under the maintenance regime followed in this study.

Summary

Under the conditions of this study, both Tifgreen and Tifdwarf bermudagrass hybrids tolerated normal levels of dithiopyr with little or no damage to the root systems of either grass, as did bensulide and a 5.25 percent bensulide + 1.31 percent oxadiazon combination.

Acknowledgment

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Table 1. Effects of Dithiopyr, Bensulide, and a Bensulide-Oxadiazon Combination on the root system of Tifgreen bermudagrass maintained under green conditions, College Station, Texas.

Treatment	Formulation[1]	Application rate lbs ai/A (kg ai ha^{-1})	Root mass dry weight (milligrams)
Untreated Check	—	—	162.5 a[3]
MON15152	0.25 G	0.25(0.28)	168.8 a
MON15152	0.25 G	0.50(0.56)	165.0 a
MON15104	1 EC	0.38(0.43)	167.5 a
MON15104	1 EC	0.50(0.56)	187.5 a
MON15104	1 EC	0.75(0.84)	146.3 a
Bensulide	1 EC	10.0(11.2)	167.5 a
5.25% bensulide and 1.31% oxadiazon[2]	6.56 G	7.50(8.4)	147.5 a

[1] G= granular; EC = emulsifiable concentrate.
[2] Scotts Goosegrass/Crabgrass Control®.
[3] Values followed by the same letter are not significantly different at the 5 percent level of Duncan's Multiple Range Test.

Table 2. Effects of Dithiopyr, Bensulide, and a Bensulide-Oxadiazon Combination on the root system of Tifdwarf bermudagrass maintained under green conditions, College Station, Texas.

Treatment	Formulation[1]	Application rate lbs ai/A (kg ai ha^{-1})	Root mass Root mass dry weight (milligrams)
Untreated Check	—	—	105.0 b[3]
MON15152	0.25 G	0.25(0.28)	101.3 b
MON15152	0.25 G	0.50(0.56)	146.3 a
MON15104	1 EC	0.38(0.43)	151.3 a
MON15104	1 EC	0.50(0.56)	137.5 a
MON15104	1 EC	0.75(0.84)	170.0 a
Bensulide	1 EC	10.0(11.2)	145.0 a
5.25% bensulide and 1.31% oxadiazon[2]	6.56 G	7.50(8.4)	143.8 a

[1] G= granular; EC = emulsifiable concentrate.
[2] Scotts Goosegrass/Crabgrass Control®.
[3] Values followed by the same letter are not significantly different at the 5 percent level of Duncan's Multiple Range Test.

PR-4920

An Evaluation of CGA163935 and Glyphosate for Use as Chemical Edgers of a Tifway Bermudagrass Turf Perimeter

W. G. Menn and J. B. Beard

Introduction

In addition to a plant growth regulator (PGR) that will inhibit or reduce vertical shoot growth, there is a definite need for a material that will also reduce or inhibit lateral stem growth. Mechanical edging of stoloniferous turfs along curbs, driveways, sidewalks, around cemetery headstones, and at the perimeter of bunkers on golf courses is a never-ending job that is very expensive from a labor and a materials standpoint. Any material which might significantly reduce the frequency of mechanical edging would be welcomed by the turf manager. This study was conducted to assess the benefits of the plant growth regulator CGA163935 at three rates and two band widths, plus glyphosate, for inhibiting lateral stem growth on Tifway bermudagrass.

Materials and Methods

This study was conducted on a 16-year old stand of Tifway bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) located at the TAM Turfgrass Research and Teaching Field Laboratory on the campus of Texas A&M University in College Station, TX. To create a distinct boundary and a mechanically edged effect, strips of sod were removed from the test site which left a bare soil surface bordered on either side by Tifway bermudagrass. These mechanically formed edges were divided into plots measuring 8 feet (2.4 m) in length and subsequently treated with three rates of CGA163935. All treatments were applied on 8/7/90 using a single nozzle, hand-held, CO_2 pressurized plot sprayer. Spray pressure was set at 25 psi and treatments applied in a volume of water equivalent to 1 gallon per 1,000 square feet (4 L are^{-1}). All three rates of CGA163935 were applied in bands 8 and 16 inches (20 and 40 cm) wide. Glyphosate (Roundup®), a commonly used chemical edging compound, was applied in an 8-inch (20-cm) band, only. Application rates are shown in Table 1.

The test area was being mowed at a 1-inch (2.5-cm) cutting height throughout the study using triplex reel-type riding mower. The site received monthly applications of 21-0-0 (ammonium sulfate) fertilizer at a rate of 1.0 lb of actual N per 1,000 ft^2 (1.12 kg N/ha) and was irrigated as needed to prevent visual wilt.

There were 4 replications of each treatment and the replicates were arranged according to a completely randomized design. Two types of measurements were made on 17 September 1990 or 6 weeks after treatment (WAT). First, the total number of measurable stolons from each treatment replicate were recorded. Second, the 3 longest stolons in each 8-foot long treatment replicate were measured to the nearest centimeter and recorded.

Results and Discussion

Lateral stem regrowth in terms of total number of emerging stolons from a mechanically edged border was significantly reduced by all but one treatment, the CGA163935 at a 0.72 lb/ac (0.8 kg ai/ha) rate in a 16-inch (40-cm) band. In general, the number of stolons was reduced by approximately 50 percent in the treated versus untreated plots. Width of the treated band of 8 versus 16 inches (20 vs. 40 cm) did not affect the number of stolons recorded as regrowth.

Measuring the length of the 3 longest stolons emerging from the mechanically edged border indicated another effect of treatments on regrowth suppression. Statistically, there was no significant effect from all but two to the treatments applied, specifically CGA163935 at a 1.44 lb ai/ac (1.61 kg ai ha^{-1}) rate in a 16-inch (40-cm) band and glyphosate at a 2.0 lbs ai/ac (2.24 kg ai ha^{-1}) rate in an 8-inch (20-cm) band (Table 1). The results do suggest a trend toward more stem length suppression from the wider 16-inch (40-cm) band. This might indicate that some, or perhaps all, of the regrowth is originating beyond and extending across the treated band.

Treatments of CGA163935 did affect turf color along the border, while glyphosate caused a distinct and rather objectionable yellowing for several weeks.

Summary

1. A substantial reduction in total number of stolons produced from a mechanically edged border was realized from treatments of CGA163935 and glyphosate.
2. Stolon regrowth appeared to be affected by band width more than material rate when comparing the CGA163935 treatments.
3. Further studies of stolon regrowth origin are necessary to determine the band width mechanistic effect.

Acknowledgment

This research was partially supported by a grant from Ciba-Geigy Corp., Agricultural Division.

Table 1. Effects of CGA163935 and Glyphosate on lateral stem regrowth from a mechanically edged border of Tifway bermudagrass, College Station, Texas.

Treatment	Application Rate lbs ai/A (kg ai ha^{-1})	Band width in inches (cm)	Average number of stolons per 8 ft long plot	Average length of 3 longest stolons (cm)
Untreated Check	—	—	28.8 a[1]	11.6 a
CGA163935	0.72(0.80)	8(20)	12.0 b	9.0 ab
CGA163935	1.10(1.23)	8(20)	15.0 b	9.8 ab
CGA163935	1.44(1.61)	8(20)	13.5 b	9.0 ab
CGA163935	0.72(0.80)	16(40)	20.5 ab	8.3 ab
CGA163935	1.10(1.23)	16(40)	11.8 b	8.4 ab
CGA163935	1.44(1.61)	16(40)	12.0 b	5.8 b
Glyphosate	2.0(2.24)	8(20)	12.0 b	5.7 b

[1] Values followed by the same letter are not significantly different at the 5 percent level of Duncan's Multiple Range Test.

Cutting Height and Nitrogen Fertility Requirements of Adalayd Seashore Paspalum (*Paspalum vaginatum*) - 1988-1989

J. B. Beard, S. I. Sifers, and M. H. Hall

Introduction

This is the fourth progress report of this investigation concerning cutting height and nitrogen fertility requirements of *Paspalum vaginatum* Sv. Agrostology references cite the common names of "sand knotgrass" and "seashore paspalum", with the latter now more commonly accepted. The cultivar utilized in this study is Adalayd (Excaliber®), which is the main turf-type seashore paspalum now commercially available in the United States. It shows good promise for closely mowed turf uses, especially on problem saline soils.

Materials and Methods

The experimental area at the Texas A&M Turfgrass Field Research and Teaching Laboratory on the campus of Texas A&M University in College Station was vegetatively planted in late April 1984. The stolons were provided by Coastal Turf, Inc., Bay City, Texas. The soil was a modified sandy clay root zone. Prior to planting, the soil was rotary tilled and fumigated with methyl bromide. The plot size was 6 x 5 ft (1.8 x 1.5 m) with three replications of each treatment arranged in a randomized block design.

Mowing was accomplished twice weekly, with the clippings removed. The four cutting height treatments were 0.5, 1.0, 1.5, and 2.0 inches (13, 25, 38, and 50 mm, respectively). The soil pH was maintained between 7.0 and 7.8 based on an annual soil test. Nitrogen was applied monthly from April through September, with treatments of 0.25, 0.5, 1.0, and 1.5 lbs N/1,000 sq ft (0.13, 0.25, 0.5, and 0.75 kg 100 m^{-2}, respectively) per growing month (Figure 1). Other nutrients such as P and K were applied as needed, based on an annual soil test. Irrigation was applied as needed to prevent visual wilt. Herbicides, fungicides, and insecticides were to be applied as needed to prevent a severe loss of turf density; however, none were required as no disease or insect damage was noted. Also, no vertical cutting or turf cultivation was practiced.

For 1988 and 1989, visual turfgrass quality was assessed biweekly by two scientists. The visual turfgrass quality rating was based on a 9 to 1 scale in which 9 = best and 1 = poorest, with 5.0 = minimum acceptable turfgrass quality for lawn use, and 6.0 or above, the minimum for sports fields and golf fairways. Quality estimates were based on a composite of two primary components: (a) uniformity of appearance and (b) shoot density. Fall low temperature color retention was visually assessed in November. Spring greenup rate was visually assessed in February, March, and April 1989.

Few weeds appeared in the turf under any of the treatments during the first 3 years. Then a marked increase in weed invasion, mostly broadleafs, occurred in spring 1989.

Results

Two visual turfgrass quality ratings were made in late 1985 (2). However, these were not conclusive, as the observers reported that quality differences were very difficult to distinguish. This was possibly due to the young age of the turf and the newly imposed mowing and nutritional treatments. During 1986, the same observers reported no difficulty in making significant differential assessments of turfgrass quality.

The visual turfgrass quality ratings of Adalayd seashore paspalum, as affected by height of cut and nitrogen fertility level, are presented in Table 1 for 1988 and 1989. The lower cutting heights resulted in higher turfgrass quality, as did the higher levels of nitrogen. In 1988 and 1989, only the 0.5-inch (13-mm) cutting height treatment produced acceptable turfgrass quality for lawn use. Cutting height had more influence on turfgrass quality than the nitrogen fertility level.

The influences of cutting height and nitrogen fertility level on fall low temperature color retention are shown in Table 2. As with the turfgrass quality ratings, the lower cut turfs exhibited better fall low temperature color retention. The cutting height influence on fall low temperature color retention appeared to dominate over nitrogen fertilization. Seashore paspalum exhibited better late fall color retention than the bermudagrasses and the zoysiagrasses.

Spring greenup ratings for 1989 responded to the cutting height treatments similar to the other turf parameters assessed (Table 3). Also, spring greenup rate was enhanced at the higher nitrogen levels, but the effect was not as great as that of cutting height.

Summary

These data are similar to those of 1986 and 1987 and strongly suggest that cutting height, and not nitrogen fertility level, is the controlling factor in maintaining a quality Adalayd seashore paspalum turf. A height of cut of 0.5 inch (13 mm) was best for turfgrass quality, and fall low temperature color retention.

Table 1. The influence of four heights of cut and four nitrogen fertility levels on visual turfgrass quality ratings of Adalayd seashore paspalum during 1988 and 1989, College Station, Texas.

Height of cut in inches (mm)	Seasonal turfgrass quality[1]		Nitrogen fertility level in lb/1,000 sq ft pgm (kg are^{-1} pgm)	Seasonal turfgrass quality[1]	
	1988	1989		1988	1989
0.5(13)	5.8[2]a	6.5 a	1.5(0.75)	4.5 a	5.2 a
1.0(25)	4.5 b	4.8 b	1.0(0.5)	4.2 a	4.8 b
1.5(38)	3.7 c	4.4 c	0.5(0.25)	4.4 a	4.6 bc
2.0(50)	3.2 d	3.4 d	0.25(0.13)	4.2 a	4.5 c

[1]Visual estimates of turfgrass quality based on a 9 to 1 scale: 9 = best and 1 = poorest; with 5.0 = to the minimum acceptable turfgrass quality for lawns and 6.0 or above the minimum for sports fields and golf course fairways.
[2]Means followed by the same letter within the same column are not significantly different. LSD, T Test, alpha = 0.05.

Table 2. The influence of four heights of cut and four nitrogen fertility levels on the fall low temperature color retention of Adalayd seashore paspalum during 1988 and 1989, College Station, Texas.

Height of cut in inches (mm)	Fall color retention[1]		Nitrogen fertility level in lb/1,000 sq ft pgm (kg are^{-1} pgm)	Fall low temperature color retention[1]	
	1988	1989		1988	1989
0.5(13)	4.5 a	5.2 a	1.5(0.75)	2.8 a	3.3 a
1.0(25)	2.2 b	3.6 b	1.0(0.5)	2.6 a	3.1 a
1.5(38)	1.9 b	2.7 b	0.5(0.25)	2.2 a	2.8 a
2.0(50)	1.4 c	0.5 c	0.25(0.13)	2.3 a	2.9 a

[1] Visual estimates of green cover based on 9 to 1 scale: 9 = best and 1 = poorest.
[2] Means followed by the same letter within the same column are not significantly different, LSD T Test, alpha = 0.05.

Table 3. The influence of four heights of cut and four nitrogen fertility levels on the visual rating of spring greenup rate of Adalayd seashore paspalum during 1989, College Station, Texas.

Height of cut in inches (mm)	Spring greenup[1] 1989	Nitrogen fertility level in lb/1,000 sq ft pgm (kg are^{-1} pgm)	Spring greenup 1989
0.5(13)	6.5 a	1.5(0.75)	4.5 a
1.0(25)	3.3 b	1.0(0.5)	4.0 ab
1.5(38)	3.0 c	0.5(0.25)	3.7 b
2.0(50)	2.6 d	0.25(0.13)	3.3 b

[1]Visual estimates of turfgrass spring greenup rate based on a 9 to 1 scale: 9 = total green and 1 = no green.
[2]Means followed by the same letter in same column are not significantly different, LSD T Test, alpha = 0.05.

Table 4. The influence of four heights of cut and four nitrogen fertility levels on shoot density of Adalayd seashore paspalum during 1988, College Station, Texas.

Height of cut (inches)	Shoot density (per sq cm) 1988	Nitrogen fertility level (lb/1,000 sq ft pgm)	Shoot density (per sq cm) 1988
0.5	101 a[1]	1.5	71 a
1.0	62 b	1.0	62 a
1.5	54 b	0.5	66 a
2.0	43 c	0.25	61 a

[1]Means followed by the same letter within the same column are not significantly different. LSD, T Test, alpha = 0.05.

Table 5. The influence of four heights of cut and four nitrogen fertility levels on visual ratings of weed invasion of Adalayd seashore paspalum during 1989, College Station, Texas.

Height of cut (inches) 1989	Visual rating[1] weed (lb/1,000 sq ft pgm)	Nitrogen fertility invasion level 1989	Visual rating[1] weed invasion
0.5	1.8 a	1.5	4.9 a
1.0	3.3 b	1.0	4.5 a
1.5	4.9 c	0.5	4.2 a
2.0	6.8 c	0.25	3.4 a

[1]Visual estimate of weed invasion based on a 9 to 1 scale: 9 = total weeds, 1 = no weeds.
[2]Means followed by the same letter within the same column are not significantly different. LSD, T Test, alpha = 0.05.

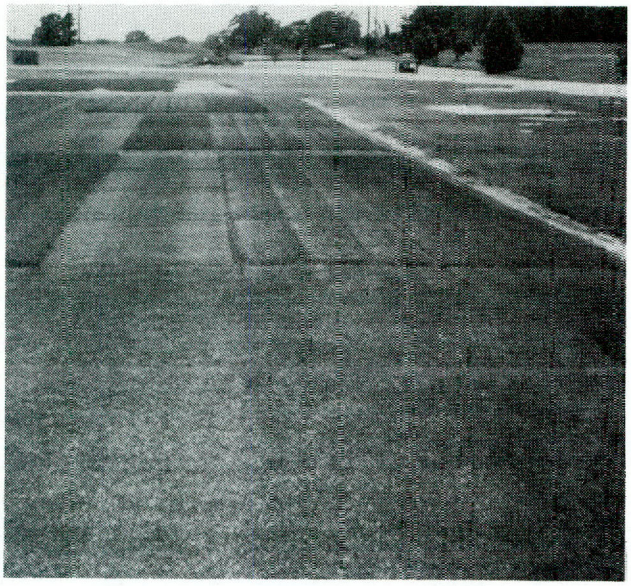

Figure 1. Adalayd seashore paspalum experimental assessment study area at Texas A&M Turfgrass Field Research and Teaching Laboratory, College Station, Texas.

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Metric Equivalents

Metric units	English equivalents
1.0 hectare (ha)	2.47 acres (A)
1.0 are or ar (a) (100 m^2)	1076 square feet (ft^2)
1.0 kilogram (kg)	2.20 pounds (lb)
1.0 meter (m)	39.4 inches (in)
2.54 centimeters (cm)	1.0 inch (in)
28.3 grams (g)	1.0 ounce (oz)
454 grams (g)	1.0 pound (lb)
1.0 liter (l)	1.06 quarts (qt)
3.78 liters (l)	1.0 gallon (gal)
48.9 kg/ha	1.0 lb/1000 square feet (ft^2)

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