ZOYSIAGRASS PERFORMANCE, WATER USE, AND ROOTING AS AFFECTED BY TRAFFIC AND NITROGEN

UNIVERSITY OF GEORGIA
Griffin, GA

Dr. Robert N. Carrow
Principal Investigator

1992 Research Grant: $20,491
(second year of study)

Zoysiagrass (Zoysia japonica) is a deep rooted, drought resistant species in many areas of the United States, especially the transition zone. Zoysiagrass has been targeted by the USGA as a species that could be developed through breeding/genetics to exhibit better water use efficiency.

Areas requiring special attention for developing a water conserving zoysiagrass are: low ET rates under both non-limited and limited soil moisture; maintenance of a deep, viable root system under the major soil stresses of high soil strength and high acidity; and excellent drought tolerance when tissues are subjected to drying. Objectives of the current study were to evaluate 9 zoysiagrass experimentals from Dr. Milt Engelke's breeding program verses three commercial cultivars for: a) ET, spatial rooting/water extraction patterns, and drought avoidance/ tolerance responses b) basic cultural requirements (fertility, disease, insect, traffic tolerance) and c) data obtained in Georgia can be related to similar data in Texas to determine environmental stability of these grasses to environment, disease, and insect pressures.

Establishment Phase. Grasses were plugged on 12 inch centers on 8-12 July 1991, fertilized to promote establishment, mowed at 1.0 inch, and a preemergence herbicide applied in March 1992. Most rapid coverage was exhibited by 8514, 8512, and El Toro, while slowest were 8701, 8516, Emerald, 8502. DALZ 8701 had some winterkill, the only cultivar with any winter damage, which contributed to slow establishment.

Mature Turf. Cultivars with excellent early spring greenup and degree of color were 8516, 9006, and 8508. Highest visual quality ratings over the study period have been demonstrated by Meyer, 8507, 8512, and 8514; least were 8516 and 8501. In terms of degree of green color, 8502, Meyer, and 8516 have been best, while lowest in ratings were 8501 and 8512. By August 1992, 8516 had a mottled chlorotic sward and scalping problems at the 0.63 inch mowing height used in 1992 appeared on 8501 and 8502. Initial mole cricket insect resistance was determined by Dr. Kris Braman.

Roots were sampled in June and September and are under analysis. Cultivars were not subjected to severe drought stress in 1992 due to establishment. During a moderate stress period in August, cultivar ET rates ranged from 3.2 to 5.0 mm d^{-1}. Traffic and N-Programs will be initiated in 1993.

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Zoysiagrass (*Zoysia japonica*) is a deep rooted, drought resistant species in many areas of the United States, especially the transition zone. Due to considerable genetic diversity among ecotypes, zoysiagrass has been targeted by the USGA as a species that could be developed through breeding/genetics to exhibit low water use, high drought avoidance and high drought tolerance.

Meyer, the most commonly used cultivar, is deep rooted and has very good drought avoidance in many soils. However, in acidic soils (pH < 5.2) and/or soils with high mechanical strength, rooting is markedly restricted. Many humid region soils have surface or subsurface soil horizons within this pH range. Also, Meyer, once exposed to drought, does not have good drought tolerance and tends to demonstrate rapid leaf firing. Most zoysiagrasses, including Meyer, have very high evapotranspiration (ET) rates whenever soil water is not limited. Thus, new zoysiagrasses must demonstrate substantial improvements in these area if they are to be widely used as water conserving grasses. Specifically, water conserving zoysiagrasses must a) have moderate to low ET rates under both non-limited and limited soil moisture, b) develop and maintain a deep, viable root system under the major soil stresses of high soil strength and high acidity, and c) have good to excellent drought tolerance when tissues are subjected to drying.

Objectives of the current study were to evaluate 9 zoysiagrass experimentals from Dr. Milt Engelke's breeding program verses three commercial cultivars for:

a) ET, drought resistance, and spatial rooting/water extraction patterns are being determined under field conditions. These data are essential if the USGA is to substantiate that their turfgrasses are truly superior in these characteristics. Of particular importance, will be to obtain such information under two of the most prominent soil limiting factors warm-season turfgrasses encounter - high soil strength (in our situation, as surface compaction <u>and</u> throughout the profile) and acidic subsoils.

b) basic cultural programs (fertility, disease/insect, traffic tolerance) are being defined. Criteria to determine the "best" cultural programs will not be limited to shoot responses but will entail rooting and ET influences.

c) data obtained in Georgia can be compared to similar data in Texas to determine environmental stability of these grasses with respect to environment, disease, and insect pressures.

The twelve zoysiagrasses are listed in Table 1. Establishment was on 8-12 July 1991 by plugging at 12 inch centers with 1.8 x 1.8 x 2.5 inch plugs supplied by Dr. Milt Engelke. After plugging, the initial ground cover was 15%. Once full turf cover is attained for all cultivars, the following treatments are to be initiated:

a) N-Programs. Annual N levels of 1.25, 2.50, and 3.75 lb N/1000 ft^2 split into three equal applications at mid-April, mid-June, and mid-August.

b) Traffic.
   * Alone, except mowing.
   * Wear + compaction, using a differential slip traffic device. This unit was designed based on the differential slip concept (P. M. Canaway, 1982. Simulation of fine turf wear using the DS wear machine and quantification of wear treatments in terms of energy expenditure. J. Sports Turf Res. Inst. 58:9-15); however, our unit is a riding unit that applies 30 to 38 psi per stud versus 21.8 psi for the Canaway device for more compaction force.
   * Wear only, using a riding differential slip device with golf car tires designed by us that applies < 4 psi pressure (i.e., minimal soil compaction) but has a wear action on the turf.

Plots were treated with Ronstar 2G at 1.75 lbs ai/acre for preemergence annual grass control immediately after plugging and in March 1992. Fertilization was with 10-10-10 applied on 12 July, 14 August, and 4 September 1991 and at 1.0 lb N/1000 ft^2 per treatment. In 1991 mowing was at 1.0 inch but was decreased to 0.63 inch in 1992 with clippings returned.

In 1992 all grasses received 1.0 lb N/1000 ft^2 on 14 April (10-10-10) and 18 May (33-0-0), as well as 0.75 lb N on 29 June (33-0-0). By late-July all plots had 100% turf coverage; thereby, fertilizer treatments were initiated on 12 August with 0.42, 0.83, and 1.25 lb N/1000 ft^2 to the low, medium, and high N plots, respectively, using 33-0-0. Due to the wait until late July for full coverage before N-Programs could be started, Traffic treatments will be delayed until February/March 1993. This will allow N-Programs to be in effect prior to Traffic treatments.

The soil is Cecil sandy loam of 67.4% sand, 18.1% silt, and 14.5% clay. Soil pH is 4.50 (0 to 4 in), 5.04 (4 to 8 in), 5.65 (8 to 12 in), and 5.75 (12 to 16 in).

The experimental design without the N-Program or Traffic treatments is a Completely Randomized Block with 3 replications in 3 x 22 m plots. The LSD procedure was used for treatment mean separation. If the treatment F-test is not significant, then the LSD are unprotected.

Results to date are discussed below with the caution that, except for establishment data, the results are tentative and may change over time:

<u>Establishment Phase</u>. Plugging was on 10 July 1991 and by late October 1991, three grasses exhibited > 90% cover; namely 8514, El Toro, and 8512 (Table 1). Least coverage was apparent for 8516 and 8502 by this date. By late June 1992, all grasses except 8701 (85%), 8516 (86%), Emerald (90%), and 8502 (92%) has > 95% cover. Over the winter period from 24 October 1991 until 15 May

1992, only one cultivar lost cover (8701). This cultivar will bear close observation in future winter periods

Early spring greenup on 9 April 1992, as expressed as percent of the plot with green turf, was best for 8516, 9006, 8502, 8508, and Meyer with all demonstrating > 85% green cover (Table 2). Least green cover was observed on 8514, El Toro, 8701, and 8501; all with less than 40% green. Early spring greenup, however, is a factor that can change rapidly. For example, by 14 April (5 days later), after an unusually warm, rainy weekend, all cultivars had > 78% greenup.

The degree of green color each cultivar had is shown by the turf color ratings in April (Table 2). DALZ 8516, 9006, and 8508 were darkest green on 9 April, while 8514, 8501, 8502, and 8701 were least (i.e., < 3.5). Again, the 5 day warm, moist weather enhanced the degree of green color to > 5.5 for all cultivars on 14 April.

Mature Turf. Cultivars with visual quality ratings within the highest group throughout all rating dates were Meyer, 8507, 8512, and 8514 (Table 3). DALZ 8516 and 8501 scored within the lowest rating group on the most dates. Reasons for differences in visual quality are discussed in the data that follows.

All zoysiagrasses had very good shoot density by August 1992 (Table 4). Highest shoot density ratings occurred for 8502, 8507, 8508, and 9006.

In 1991 turf color ratings tended to be higher than in 1992 due to the high N used for initial establishment (Table 5, 6). Under the high N of 1991, 8516,8508, and 9006 were darkest green, while 8501 was least.

Cultivars that were within the highest color rating group most consistently in 1992 were 8502, Meyer, and 8516 (Table 6). DALZ 8501 and 8512 exhibited the lightest green color. Turf color on 29 October reflect late fall color retention over a period of 40 to 50°F night-time temperatures but without any frost. Under these conditions, color retention was best for 8516 and 8514, but least for 8501.

By August 1992, certain cultivars started to exhibit features that caused a loss of visual quality (Table 7). Chlorosis, a yellowing of the turf in an irregular pattern similar to Fe chlorosis symptoms, appeared in early August, especially on 8516, 9006, Emerald, and 8514. The actual cause of the chlorosis was not discernable.

Mottling, due to a color decline in irregular patches, was noted in early September. The term mottling, rather than chlorosis, was used since some color loss was due to scalping damage and not just a loss of color in existing leaf tissues. Mottling was greatest on 8516, Emerald, and 9006. However, careful observation revealed different reasons for mottling, such as a) rust on Meyer, b) failure of the mower to cleanly cut the leaf tissues (i.e., mower required backlapping) on 8507, 8501, 8508, and 9002, c) scalp on 8502, and d) unknown cause on 8516. By early October, further evidence of mower scalp, due to either a puffy nature of the sward or possible thatch, was especially apparent on 8501 and 8502 (Table 7). Minor scalp damage occurred on 9006, 8508, and 8701. We did not increase the mowing height from 0.63 inch over the season to compensate for any stem elongation and loss of lower stem leaves as is common on bermudagrasses.

Some individuals prefer a fine textured grass - i.e., a grass with narrow leaf blades. All of the zoysiagrasses in this study have relatively narrow (i.e., < 3.4 mm or 0.14 inch) (Table 8) leaves in a mowed, full cover sward. Thus, leaf texture was considered a very minor component of overall quality of these grasses. Those with narrowest leaves during the establishment period when leaves are wider, due to a more open sward, were 8502, 8508, and 9006. Under a full cover situation, leaf texture decreased for all cultivars with the finest leaf blades evident for 8502, 8507, 8501, 9002, 8508, and Emerald. El Toro, 8512 and 8514 had the widest blades.

Cultivars with abundant rhizomes should have an advantage for recovery from shoot damage and reestablishment of a sod field after sod cutting. At 12 months after establishment, 15.8-fold (volume basis) and 24.7-fold (weight basis) differences in rhizome development were apparent (Table 8). Best rhizome producers were 8502 and 8701, while poorest was Meyer. Even the lowest DALZ cultivar for rhizomes (8514) exhibited 4.0-fold (vol.) and 2.8-fold greater rhizomes than Meyer.

After full establishment, boxes for soil moisture measurement probes were inserted in the ground and probes installed. A short dry period in late August allowed some moisture data to be obtained. Over the 6 day period, least deep soil water extraction (20 to 60 cm soil depth) was apparent for 8701 and 8508 (Table 9). However, since the late August rooting data (nor the late June data) are available at this time, rooting-to-water extraction comparisons cannot be made. It should be noted that all plots were maintained under good soil moisture conditions until August in order to favor full establishment. Thus, the periodic subsoil moisture stress that may influence deep rooting was not present for 1992.

Evapotranspiration (ET) during moist soil conditions is provided by the 0 to 4 day ET data (Table 9). El Toro and 9006 had the highest ET for 0-4 days, while 8701 and 8502 were least. Overall ET for the 6 day period ranged from 3.2 to 5.0 mm d^{-1} (0.88 to 1.37 inches wk^{-1}) under this period of little actual soil moisture stress. Beard [J. B. Beard, 1985. An assessment of water use by turfgrasses. <u>In</u> V. A. Gibeault and S. T. Cockerham (ed.). Turf. Water Conservation. Univ. of Cal. Pub 21405, Oakland, CA] reported a range of 4.8 to 7.6 mm d^{-1} for semi-arid and arid regions. Carrow (1991) reported summer time average of 3.54 mm d^{-1} for Meyer Zoysiagrass under moderate soil moisture stress [R. N. Carrow 1991. Turfgrass water use, drought resistance, and rooting patterns in the Southeast. ERC01-91 of Envir. Res. Center, Georgia Inst. of Tech., Atlanta and UGA, Athens, GA]. Carrow (1991) noted that ET rates of turfgrasses in humid climates are 33 to 63% lower than for the same cultivar in arid or semi-arid situations due to higher humidity, greater cloud cover and reduced wind speed.

<u>Insects</u>. In Appendix A (following Table 9) is a report of progress to date of an evaluation of mole cricket resistance within the 12 cultivars. Dr. Kris Braman conducted this research. It was not in the project but was funded from R. N. Carrow's project funds as a separate item.

Table 1. Rate of establishment (1991-1992)

Cultivar	1991 8 August	1991 29 August	1991 24 October	1992 15 May	1992 24 June
	% Turf Cover				
DALZ 8701	22cb[z]	32ef	78c	69e	85e
DALZ 8502	19cb	27f	58e	80d	92bc
El Toro	43a	74a	94a	100a	100a
Meyer	24b	41d	82c	92bc	95abc
DALZ 8507	23b	39de	78c	94ab	99a
DALZ 8512	44a	55c	93ab	98ab	99a
DALZ 8516	17c	28f	54e	79d	86de
DALZ 8501	22cb	34def	76cd	86cd	96ab
Emerald	22cb	34def	69d	85cd	90cd
DALZ 8508	22cb	35def	85bc	92bc	98a
DALZ 9006	21cb	33def	83c	93ab	99a
DALZ 8514	47a	65b	97a	96ab	100a
LSD (0.5) =	5.5	8.0	9.1	7.2	5.2
SIGN. F-test =	**	**	**	**	**
CV (%)	12	11	7	5	3

[z]Initial percent turf coverage at establishment by plugging on 10 July, 1991 was 15%.

Table 2. Early spring greenup and turf color in 1992.

Cultivar	Spring Greenup		Greenup Turf Color	
	9 April	14 April	9 April	14 April
	---------------- % ----------------		9 = dark green, 1 = no green	
DALZ 8701	32d	78e	3.3f	5.8d
DALZ 8502	88a	86cde	6.2d	6.1d
El Toro	32d	79e	3.2f	5.5d
Meyer	85ab	94abc	6.8bcd	7.2c
DALZ 8507	75b	92abc	6.3d	7.4bc
DALZ 8512	52c	87abc	4.3e	6.0d
DALZ 8516	93a	100a	7.7a	8.4a
DALZ 8501	35d	80de	3.2f	5.7d
Emerald	73b	93abc	6.5cd	7.1c
DALZ 8508	85ab	96ab	7.2abc	7.7abc
DALZ 9006	88a	96ab	7.4ab	8.0ab
DALZ 8514	30d	82de	2.7f	5.9d
LSD (0.5) =	12.8	8.9	.76	.68
SIGN. F-test =	**	**	**	**
CV (%)	12	6	8	6

Table 3. Turf quality in 1992.

	Turf Quality^{z}				
Cultivars	24 June	3 August	26 August	3 September	6 October
DALZ 8701	5.6e	7.6abcd	7.6ab	7.6ab	7.3ab
DALZ 8502	6.6bcd	8.1a	7.6ab	7.4ab	7.0bc
El Toro	7.6a	7.3cde	7.8a	7.6ab	7.4ab
Meyer	7.0abc	7.9ab	7.6ab	7.7a	7.5ab
DALZ 8507	7.4ab	7.7abc	7.5ab	7.5ab	7.6ab
DALZ 8512	7.4ab	7.6abcd	7.5ab	7.5ab	7.4ab
DALZ 8516	5.8de	6.8e	6.6e	6.7c	6.6c
DALZ 8501	7.0abc	7.4cd	6.8de	6.7c	5.9d
Emerald	6.4cde	7.4cd	7.4ab	7.3abc	7.7a
DALZ 8508	7.3ab	7.5bcd	7.3bc	7.1bc	7.5ab
DALZ 9006	7.6a	7.2de	7.0cd	7.1bc	7.4ab
DALZ 8514	7.5a	7.6abcd	7.7ab	7.5ab	7.4ab
LSD (0.5) =	.86	.51	.38	.53	.54
Sign F-test =	**	**	**	**	**
CV (%)	7	4	3	4	4

^{z}Turf Quality: 9 = ideal shoot density, color, uniformity; 1 = no live turf.

Table 4. Turfgrass shoot density in 1992.

	Turf Density[z]	
Cultivar	3 August	26 August
DALZ 8701	7.9ef	8.4b
DALZ 8502	8.8a	8.8a
El Toro	7.8f	8.5ab
Meyer	8.0def	8.4b
DALZ 8507	8.4b	8.6ab
DALZ 8512	7.9ef	8.4b
DALZ 8516	7.8f	8.0c
DALZ 8501	8.3bc	8.4b
Emerald	8.1cdef	8.5ab
DALZ 8508	8.2bcd	8.5ab
DALZ 9006	8.1bcde	8.6ab
DALZ 8514	7.9ef	8.5ab
LSD (0.5) =	.28	.29
Sign F-test =	**	**
CV (%)	2	2

[z]Turf Density: 9 = ideal; 1 = no live turf.

Table 5. Zoysiagrass color in 1991.

Cultivar	Turf Color		
	8 August	29 August	24 October
	------------------------------ 9 = dark green; 1 = no live turf ------------------------------		
DALZ 8701	7.8cd	8.0bc	7.7d
DALZ 8502	8.0ab	8.0bc	7.9d
El Toro	7.8cd	8.1abc	7.8d
Meyer	7.9bc	8.2abc	8.0cd
DALZ 8507	7.8cd	8.1abc	7.9d
DALZ 8512	7.8cd	7.9c	7.6de
DALZ 8516	8.2a	8.4a	8.8a
DALZ 8501	7.8cd	7.9c	7.3e
Emerald	7.9bc	8.3ab	7.9d
DALZ 8508	8.0ab	8.2abc	8.2bc
DALZ 9006	8.0ab	8.1abc	8.4b
DALZ 8514	7.7d	8.1abc	7.7d
LSD (0.5) =	.21	.34	.34
Sign F-test =	**	.25	**
CV (%)	2	3	3

Table 6. Turf color rating in 1992.

Cultivar	Turf Color						
	14 April	24 June	3 August	26 August	3 September	6 October	29 October
	---------------------------------- 9 = dark green; 1 = no live turf------------------------------------						
DALZ 8701	5.8d	7.4cd	7.7bcd	7.5a	7.4ab	7.2c	6.3bc
DALZ 8502	6.1d	7.9a	8.1a	7.6a	7.5a	7.5ab	6.2bc
El Toro	5.5d	7.8ab	7.4de	7.6a	7.5a	7.2c	6.4b
Meyer	7.2c	7.7ab	7.8abc	7.6a	7.6a	7.6a	6.2bc
DALZ 8507	7.4bc	7.5bc	7.6cde	7.5a	7.6a	7.5ab	6.2bc
DALZ 8512	6.0d	7.5bc	7.6cde	7.1bc	7.5a	7.2bc	6.4b
DALZ 8516	8.4a	7.9a	7.9ab	7.0bc	7.1c	7.4abc	6.9a
DALZ 8501	5.7d	7.2d	7.3e	6.6d	6.9c	6.8d	4.0e
Emerald	7.1c	7.7abc	7.6bcd	7.5a	7.4ab	7.6a	6.5ab
DALZ 8508	7.7abc	7.6abc	7.5de	7.2b	7.2b	7.4abc	5.7d
DALZ 9006	8.0ab	7.8ab	7.4de	6.9c	7.2b	7.4abc	5.9cd
DALZ 8514	5.9d	7.6bc	7.5de	7.6a	7.4ab	7.4abc	6.6ab
LSD (0.5) =	.68	.31	.30	.23	.30	.32	.48
Sign F-test =	**	**	**	**	**	**	**
CV (%)	6	2	2	2	2	3	5

Table 7. Chlorosis, mottling and scalping in 1992.

	Chlorosis	Mottling[z]	Scalp[y]	
Cultivar	3 August	3 September	3 September	6 October
	--- % Plot ---	--- % Plot ---	9 = none; 1 = all turf scalpers	
DALZ 8701	0b	0c	8.7ab	8.7ab
DALZ 8502	0b	5.0bc	7.4c	7.2c
El Toro	1.7b	0c	9.0a	9.0a
Meyer	0.7b	1.3bc	9.0a	9.0a
DALZ 8507	1.7b	4.3bc	9.0a	9.0a
DALZ 8512	5.0b	0.7bc	9.0a	9.0a
DALZ 8516	48.3a	49.3a	9.0a	9.0a
DALZ 8501	0b	0c	5.5d	5.2d
Emerald	10.7b	11.7b	8.3b	9.0a
DALZ 8508	0.7b	3.3bc	7.1c	8.7ab
DALZ 9006	11.7b	6.7bc	7.4c	8.2b
DALZ 8514	7.3b	0c	9.0a	9.0a
LSD (0.5) =	18.5	11.2	.25	.31
Sign F-test =	**	**	**	**
CV (%) =	150	96	10	5

[z]Mottling. Due to rust (Meyer) tendency to not cut clean (8507, 8501, 8508, 9002), unknown (8516), or tendency to scalp from puffy nature (8502).

[y]Scalp: Due to either puffy nature of sward or leaves not cutting cleanly on 3 September. On 6 October all scalping due to puffy nature of turf.

Table 8. Leaf texture (1991, 1992) and rhizome development (1992).

	Leaf Texture		Rhizomes (17 July 1992)	
Cultivar	August 1991	August 1992	Volume[z]	Weight
	-------------------- mm -----------------		--- cm^3---	---mg $100cm^{-3}$--
DALZ 8701	3.0e	2.1b	5.3b	105ab
DALZ 8502	2.5f	1.0c	9.5a	173a
El Toro	5.0a	3.4a	2.3bc	32bc
Meyer	4.4b	3.1a	0.6c	7c
DALZ 8507	2.9ef	1.2c	2.3bc	38bc
DALZ 8512	5.0a	3.4a	3.7bc	62bc
DALZ 8516	3.6c	2.6b	2.2bc	33bc
DALZ 8501	3.5cd	1.1c	2.8bc	61bc
Emerald	3.1de	1.4c	4.3bc	86b
DALZ 8508	2.9e	1.3c	2.7bc	44bc
DALZ 9006	2.8ef	1.2c	3.0bc	58bc
DALZ 8514	5.0a	3.3a	1.7bc	29bc
LSD (0.5) =	0.4	0.4	4.0	76
Sign F-test =	**	**	*	*
CV (%)	13	10	70	74

[z]Volume per 1646 cm^3 of soil (2 cores per plot of 5.08 cm radius, 10.2 cm depth).

Table 9. Water extraction and evapotranspiration date (1992).

Cultivar	Water Extraction 28 August to 3 September			Evapotranspiration 28 August to 3 September		
	0 to 10cm	10 to 20cm	20 to 60 cm	0 to 4[†]	4 to 6d	0 to 6d
	----------mm----------			---------- mm d^{-1} ----------		
DALZ 8701	6.2b	5.4ab	7.7b	3.6c	2.5	3.2b
DALZ 8502	7.3ab	4.6b	11.1ab	4.0bc	3.5	3.8ab
El Toro	7.2ab	5.2ab	17.5a	6.3a	2.3	5.0a
Meyer	8.7ab	5.8ab	11.3ab	5.0abc	2.8	4.3ab
DALZ 8507	8.2ab	4.9ab	15.2ab	5.6ab	2.9	4.7a
DALZ 8512	9.8a	5.0ab	11.1ab	4.9abc	3.3	4.3ab
DALZ 8516	7.9ab	5.8ab	11.2ab	5.0abc	2.4	4.2ab
DALZ 8501	8.7ab	5.9a	11.9ab	5.3abc	2.7	4.4ab
Emerald	7.0b	5.9a	11.1ab	4.7abc	2.7	4.0ab
DALZ 8508	6.9b	5.5ab	10.4b	4.6abc	2.3	3.8ab
DALZ 9006	7.9ab	5.8ab	15.1ab	5.8a	2.8	4.8a
DALZ 8514	7.0b	5.7ab	12.4ab	5.0abc	2.6	4.2ab
LSD (0.5) =	2.9	1.2	6.7	1.8	1.4	1.2
Sign F-test =	.70	.66	.55	.44	.91	.59
CV (%)	26	16	39	25	36	21

[†]Moisture soil conditions.

APPENDIX A

Title: Potential Resistance in Zoysiagrasses to Tawny Mole Crickets

Authors: Kris Braman and Andrew Pendley

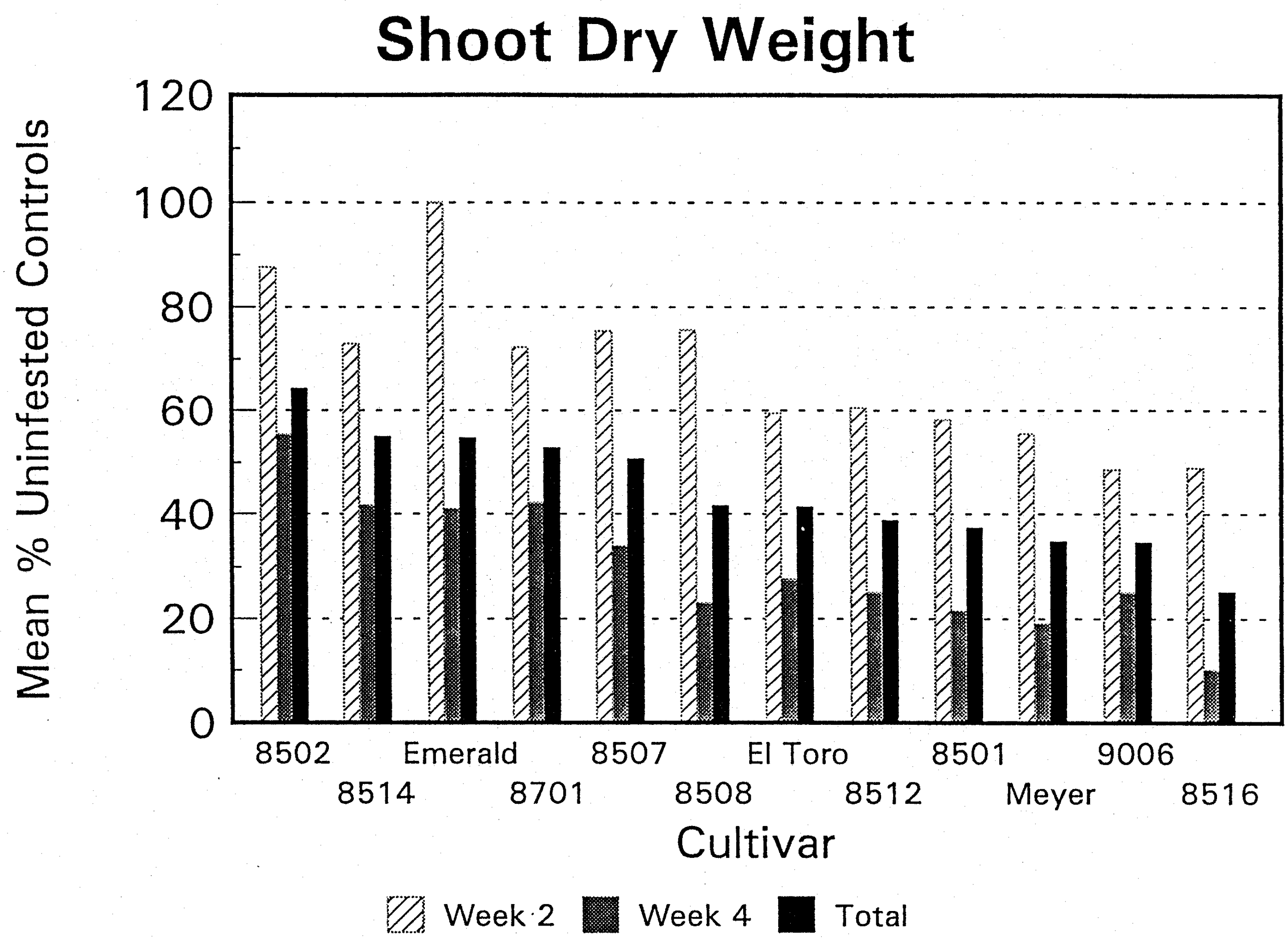
Objective: To evaluate nine zoysiagrass (*Zoysia japonica*) experimentals from Dr. Milt Engelke's breeding program and three commercial cultivars for susceptibility to damage by the tawny mole cricket. Suitability of these grasses as hosts for adult survival and oviposition were also examined.

Justification: Host plant resistance is a viable pest management option for integrated management of pests of importance in turf, including mole crickets. Comparatively little information is available to date concerning the potential resistance or tolerance of turfgrasses to subterranean pests. Incorporation of pest resistance in the plant breeding process will be increasingly important as chemical management options become more limited.

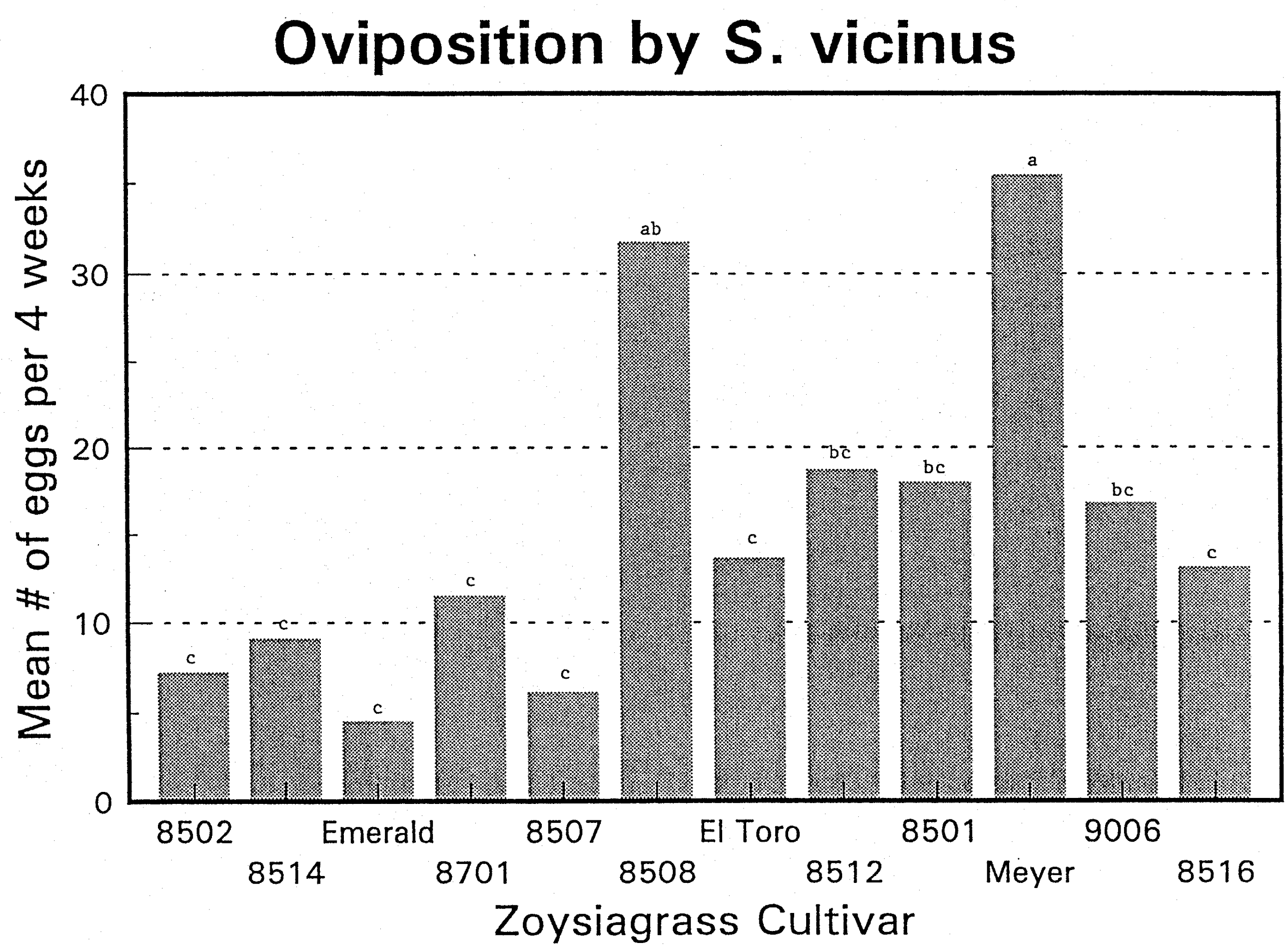
Methods: Zoysiagrasses developed by Milt Engelke in the Texas A&M breeding program were evaluated in microplots in the greenhouse for potential resistance to pests predominant in the southeastern region. Plugs 1.8 X 1.8 X 2.5 inches of twelve cultivars of zoysiagrass were potted in turface and increased in the greenhouse for six months. Six inch diameter plugs were then transplanted in 15 inch tall PVC pipe tubes containing sand and equipped with drip irrigation. A randomized complete block design of the twelve varieties replicated seven times was infested one month later with two female and one male tawny mole crickets. Seven replicates were also left uninfested within the design for comparison with infested grasses. Top growth clipping dry weights were taken at two and four weeks post infestation. Number of green shoots per 18 cm^2 at the termination of the trial was determined. Roots were washed, dried, and weighed. Adult survival was recorded. Sand was sifted and number of eggs per tube determined. Top growth, root weight, adult survival, and oviposition for uninfested controls versus infested microplots were compared for the twelve varieties. Mean separation by LSD was accomplished for each comparison of interest following a significant analysis of variance.

Results: Shoot growth expressed as a clipping dry weight percentage of infested vs. uninfested controls of each cultivar after two weeks of exposure to 3 adult crickets per 0.19 ft^2 (0.02m^2) ranged from 49% for DALZ 8516 to 100% for 'Emerald' . Differences were not statistically significant perhaps because plot to plot variability was extremely high. Above ground growth during the second two week evaluation period was significantly ($P<0.05$) influenced by cultivar and ranged from 10% for DALZ 8516 to 55.4% of the corresponding uninfested control for DALZ 8502. Total reduction in growth for the entire trial period was most severe for DALZ 8516 and least for DALZ 8502 . Root mass as a percentage of uninfested controls did not vary with cultivar ($P>0.05$).

When shoot density was an indicator of relative mole cricket damage, DALZ 8516 was again most severely affected with a 91% reduction in number of green shoots. DALZ 8701, however experienced only a 19% reduction in density. Commercial varieties Emerald, EL Toro, and Meyer experienced low, moderate, and severe damage, respectively. Cricket survival was not affected by turfgrass cultivar ($P>0.05$). Number of eggs per plot was greatly affected by turf cultivar host (Table 1). Oviposition was greatest on Meyer zoysia and DALZ 8508. Although DALZ 8516 was the most severely damaged cultivar in this study, oviposition was comparatively low. The five cultivars showing the least amount of injury (DALZ 8502, DALZ 8514, Emerald, DALZ 8701, and DALZ 8507) also supported the least amount of oviposition.



Shoot Dry Weight
Mean % Uninfested Controls
120
100
80
60
40
20
0
8502
8514
Emerald
8701
8507
8508
El Toro
8512
8501
Meyer
9006
8516
Cultivar
Week 2
Week 4
Total


Oviposition by S. vicinus
Mean # of eggs per 4 weeks
0
10
20
30
40
c
c
c
c
c
ab
c
bc
bc
a
bc
c
8502
8514
Emerald
8701
8507
8508
El Toro
8512
8501
Meyer
9006
8516
Zoysiagrass Cultivar

Executive Summary
Annual Report
1992

The Use of Mycorrhizae in the Establishment and Maintenance of Greens Turf

University of Rhode Island
Kingston, Rhode Island
1990 Grant Awarded: $40,000

Drs. Noel Jackson
R. E. Koske & J. N. Gemma
Principal Investigators

This report covers research completed through October, 1992. The project consists of several related studies: identifying the species of mycorrhizal fungi that are associated with velvet and creeping bentgrass and Poa annua, culturing these fungi, and the testing the fungi to promote establishment of greensturf, minimize application of P fertilizers, offer protection against root pathogens, enhance resistance of greens to invasion by Poa annua, and increase drought tolerance.

Major accomplishments to date include:

1. Twenty-nine species of mycorrhizal fungi associated with velvet and creeping bentgrass and *Poa annua* have been identified.
2. Mycorrhizal fungi isolated from sandy soils are more effective than are isolates from loamy soils in stimulating greensturf in the USGA sand green medium.
3. Seven species of mycorrhizal fungi have been identified as having potential in terms of enhancing turfgrasses vigor and ease of inoculum production.
4. Response of velvet and creeping bentgrass to mycorrhizal fungi is maximal at low P concentrations.
5. Establishment of young turf is enhanced by inoculation with mycorrhizal fungi, and established turf grows more vigorously when inoculated.
6. Inoculated turf is greener (has a greater chlorophyll concentration) than is uninoculated turf.
7. Inoculated turf is more resistant to drought than is uninoculated turf, and it recovers from drought much quicker.
8. At low levels of soil P, mycorrhizae appear to provide some protection against the take-all fungus, *Gaeumannomyces graminis*.
9. Methods of producing inoculum are being assessed. A large supplier of a sphagnum-based inoculum has been identified.
10. A method was developed to inoculate bentgrasses with mycorrhizal fungi under sterile laboratory conditions.