UNIVERSITY OF GEORGIA

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

1993 Research Grant: $21,455
(Third Year of support)

Dr. Robert N. Carrow
Principal Investigator

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. Objectives of the current study were to evaluate nine zoysiagrass experimentals from the Texas A&M University (Dr. Milt Engelke) zoysiagrass breeding program versus three commercial cultivars under 3 N-levels and 3 traffic programs for:

a) ET, spatial rooting/water extraction patterns, and drought avoidance/tolerance responses
b) basic cultural requirements (fertility, disease, insect, traffic tolerance)
c) determination of the stability of these grasses to environment, disease, and insect pressures

Observations to date:

a) Most rapid to cover during plugging were 8514, El Toro, and 8512, while least were 8516 and 8502.
b) Cultivars exhibiting substantial cold induced winter injury at this location are 8501, 8502, and 8701.
c) Consistently highest visual quality has been expressed by 8507, Emerald, and 8512 at 1.25 and 2.50 lb N/1000 ft^2/yr and by 8501 at 3.75 lb N; lowest has been 8501 across all N levels.
d) All cultivars substantially improved in quality from 1.25 to 2.50 lb N with some improvement from 2.50 to 3.75, but of lesser magnitude.
e) Differential cultivar responses are starting to develop under the three traffic treatments.
f) Evapotranspiration (ET) rates over all dates ranged from 3.93 (Meyer) to 2.77 mm d^{-2} (8507). Cultivars exhibiting lowest ET and very little wilt during a moderately severe dry-down were 8501, 8512, El Toro, and 8502.
g) Cultivars demonstrating moderately severe wilt in late summer dry-down are 8516, 8507, 8508, and 9006.
h) Rooting data under cultivar and traffic regimes are currently being processed.
i) Dr. Kris Braman has found least tawny mole cricket injury and suitability for oviposition for 8502 and 8514, while 8516 exhibited greatest damage.

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UNIVERSITY OF GEORGIA
Griffin, GA

Dr. Robert N. Carrow
Principal Investigator

1993 Research Grant: $21,455
(final year of support)

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 normally 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. Meyer also has a very high evapotranspiration (ET) rate 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 (Meyer, Emerald, El Toro) 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 and 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 was attained for all cultivars, the following treatments were 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. Fertility treatments were initiated in August 1992.

b) Traffic.
   * None (N), except mowing.
   * Compaction (C), using a Brouwer Model 230 riding roller with rollers filled with sand plus water to exert a static pressure of 1.0 kg cm^{-2} (14.2 psi). The roller has a smooth surface.
   * Wear + compaction (WC), 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); our unit is a riding unit using two studded rollers of 30 inch width that applied 270 lbs per square inch of top surface area of stud versus 296 for the Canaway device. Studs are on a random pattern with 1 stud every 40 cm^2 using a 14 mm length stud of 10 mm diameter (top) and 20 mm diameter (bottom). Average static pressure over the stud and roller contact surface is 0.38 kg cm^{-2} versus 0.33 kg cm^{-2} for the Canaway device. Our device uses a 1:33:1 ratio of gears to develop slip and drag. The front roller drive gear is 6 inch radius, while the rear is 8 inch radius.

Traffic treatments were initiated on 27 July, 1993. All treatments were conducted when the surface soil moisture was between field capacity and saturation. Treatment schedule for C and WC traffic was: 8X (i.e., 8 passes per area) on 27 July; 2X on 18 Aug.; 6X on 16 Sept., and 6X on 13 Oct. 1993. Traffic treatments were originally scheduled for early spring 1993, but winterkill of some cultivars caused delay until greater than 80% coverage for all cultivars except 8501 was achieved.

Plots were treated with Ronstar 2G at 1.75 lbs ai/acre for preemergence annual grass control immediately after plugging and in March 1992 and 1993. 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, thereafter, 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. In 1993, applications were made at 0.42, 0.83, and 1.25 lb N/1000 ft^2 for low, medium, and high N levels on each date of 12 April, 15 June, and 17 August using 33-0-0. Additionally, 1 lb P_2O_5 per 1000 ft^2 was applied in early April as 0-46-0.

The soil is Cecil sandy loam of 67.4% sand, 18.1% silt, and 14.5% clay. Soil pH was 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) in October 1991 (Table 29).

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.

Boxes for soil moisture probes were installed in the medium N-level plots for all three traffic treatments. Water use data in 1993 and through 19 July 1993 were only from the "none" traffic plots, and thereafter, from all three traffic treatments.

Water extraction, ET, and rooting data after 19 July 1993 were obtained at the middle N rate of 122 kg ha^{-1}, but under the three traffic treatments. These data are analyzed as a 12 (cultivar) x 3 (traffic) factorial in a split plot design. Paired comparisons of each cultivar are made versus Meyer at each traffic treatment.

All other data were obtained on the full treatment set of 12 (cultivar) x 3 (N level) x 3 (traffic) factorial in a split-strip plot design. Paired comparisons of each cultivar are made versus Meyer at each traffic and N level. Additionally, a N trend analysis was conducted at the "none" traffic treatment for N linear and quadratic responses. A linear response to increasing N level could be / or \ in nature, while a quadratic would normally be ∩ or ∪. A response with significant linear and quadratic components is normally /‾ in nature.

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

Establishment

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%) had > 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 exhibited in April 1992 is shown by the turf color ratings in 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

Winter Injury. Going into the 1992-93 winter period, all grasses had 100% turf coverage. In the spring of 1993, all zoysiagrasses exhibited some winterkill, since by 5 May, the highest percent coverage was for Meyer (83%) and 8516 (73%) (Table 3). Winterkill was greatest for 8501, 8502, and 8701 with recovery from these cultivars coming from rhizome tissue. By late June, all cultivars except 8501, 8701, and 8502 had >65% coverage (Table 3). Turf coverage measurements on 4 August revealed that all cultivars had >80% coverage except 8501, which was at about 60% cover (Table 8).

The winter injury appeared to be a combination of 8 consecutive days below 32°F (16 to 30°F) after initial greenup, 5 lb/1000 ft^2 S application made in late March during a several-day warm period, and several nights in April with temperatures between 28 to 32°F. The S may have delayed greenup of all cultivars since this area and one other site receiving S exhibited slow greenup. Actual surface pH at 0 to 1 inch measured in October 1992 was somewhat less acid than in October 1991.

Turf spring greenup and quality responses for 1993 in Table 4 reflect a combination of the genetic ability of each cultivar for early spring greenup, and influence of winter injury on cultivars. Thus, some grasses with rapid spring greenup in 1992 (a year without winterkill except for 8701) had slow apparent greenup in 1993 due to winter injury and not a genetic-based slow greenup basis. By late June, cultivars with highest visual quality were Emerald and 8512 (Table 4).

Shoot Responses 1992 (prior to traffic treatments). Cultivars with visual quality ratings within the highest group throughout all rating dates were Meyer, 8507, 8512, and 8514 (Table 5). 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 12). 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 16). 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 16). 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^{o}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 20). 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. This was not observed in 1993.

Mottling, due to a color decline in irregular patches, was noted in early September 1992, but not in 1993. 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) scalp on 8502, 8508, 9006, 8501, and Emerald, and c) 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 20). 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 21) 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 21). 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. Rhizome determinations in September 1993 at 26 months after establishment revealed greatest rhizome development for Emerald, 8502 and 8507, and least for Meyer and 9006. Verdure measurements obtained on the same date in 1993 showed greatest verdure for 8516 (Table 21).

Shoot Responses 1993 (after imposing traffic treatments). Main treatment effects (i.e., cultivar, N, traffic) were significant in most instances for all shoot responses (Table 6). Cultivar x traffic interactions were common for most shoot responses, indicating the potential for differences among cultivars as to traffic tolerance. Occasionally, other interactions (CxN; CxNxT) were significant, but no significant NxT interaction occurred.

At 61 kg N ha^{-1} yr^{-1} (i.e., low N), cultivars that performed better than Meyer at all traffic regimes were 8507 and Emerald (Table 9), while 8512 rated higher except under the WC treatment. The only cultivar exhibiting lower quality on a consistent basis was 8501. Similar results for 8507, Emerald, and 8512 occurred at 122 kg N ha^{-1} level. Interestingly, 9006 demonstrated better quality than Meyer, but only under the no-traffic regime (Table 10). At the high N level, 8507 tended to do better than Meyer at the WC treatment, but fewer quality differences relative to Meyer were apparent for most cultivars (Table 11). DALZ 8501 continued to exhibit the lowest quality.

In terms of traffic treatments, WC caused slightly more decline in quality than C treatment, especially at the low N level (Tables 9,10,11). As N level increased, the greatest response in quality occurred from 61 to 122 kg N ha^{-1} yr^{-1} (Tables 9,10,11). Further discussion of cultivar x traffic interactions at different N levels will be developed at the conclusion of the study.

Shoot density responses of cultivars to traffic and N treatments were similar to the visual quality trends with 8507 and Emerald demonstrating better density than Meyer at the low and medium N level and under all traffic (Tables 13,14,15). At high N, 8507 continued to provide excellent density relative to Meyer even under C and WC traffic (Table 15).

At low N, cultivars that showed similar color as Meyer were 8502, 8516, Emerald, 8508, 9006, and 8514, while 8701, El Toro, and 8501 often had inferior color ratings (Table 17). Comparisons to Meyer at the medium and high N levels, revealed no cultivar with better color, but 8514, 8516, 8508, and 9006 were similar (Tables 18,19).

Roots. The most important root growth factors are a) absolute RLD values for the 30 to 60 cm soil zone, and b) percent changes in rooting from early July to mid-September. Under good conditions, a warm-season grass would be expected to continue root development over the summer. However, genotypes that are sensitive to the low pH/high soil strength stresses may exhibit limited growth or root dieback as dry periods in the summer accentuate these stresses.

By 7 July 1992, cultivars with the highest RLD in the 30 to 60 cm zone were 8512, 8507, and El Toro (Table 22). By mid-September, highest deep RLD values were apparent for 8512, 8701, 8516, and 8508. Cultivars that demonstrated increased RLD throughout the summer at both depths were 8701, 8502, Emerald, 8508, and 8514. Loss or no change in RLD at both soil depths were noted for El Toro, 8507, and 9006.

Roots were sampled in 1993 on 22 June and 15 September. These have been washed and are being determined for RLD and weight.

Water Relations. Water extraction and ET data for a 6-day period in late summer 1992 are presented in Table 23 for routine (none) traffic. Lowest ET was found for 8701 and highest for El Toro, 9006, and 8507. El Toro exhibited the greatest deep soil water extraction, while least were 8701 and 8508, even though these two cultivars had high deep RLD values. This would indicate that they have an inherent low ET and not a low ET imposed by restricted rooting. El Toro did not have high RLD in the 20 to 60 cm zone, but extracted considerable water. This, along with the high ET, may indicate that El Toro can use excessive water when soil conditions are relatively non-limiting.

Until the 1993 rooting data is available, it is difficult to interpret the root water extraction data in Tables 25, 26, and 27, as well as the ET data in Table 28. However, the ET rates averaged over all dates and treatments reveal a range of 2.49 to 3.88 mm d^{-1} for cultivars. The important question is which cultivars exhibit an inherent low ET versus ones that have a low ET induced by limit rooting/water uptake. During the 6-day dry-down of 24 to 30 August, several cultivars exhibited moderate wilt symptoms (Table 8). These are identified in Table 28 with a ‡ notation. Wilt would indicate that soil moisture extraction was limited on 8507, 8516, 8508, and 9006, since these had low average ET and wilt. In contrast, 8501, 8512, El Toro, and 8502 demonstrated relatively low ET, but without substantial wilt.

Over 1992 and 1993, ET ranged from a high of 5.58 to a low of 0.91 at any single measurement period. When 1992 and 1993 ET data were averaged for cultivars across all traffic treatments, the range was 3.93 (Meyer) to 2.27 mm d^{-1} (8507) or 1.08 to 0.76 inch H_2O wk^{-1} (Table 28). Beard [J. B. Beard, 1985. An assessment of water use by turfgrasses. In 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.

Traffic had a major influence on ET rates. Based on the 27 July to 3 August and 24 to 30 August data, soil compaction reduced ET relative to the No-traffic treatment by 23-26%, while wear + compaction reduced ET by 26-30%. This is consistent with results observed by the author for compaction on ET in other studies. However, it does indicate that actual field ET rates can be substantially lower than observed for a cultivar when the "baseline" is determined under arid, non-traffic conditions.

Soil Data. Soil chemical analyses data from samples obtained in October 1991 and 1992 are in Table 29. Samples have been taken in October 1993 and are being processed. Penetrameter data was obtained in October 1993 within 2 hours of saturation from two cultivars (Emerald, 8701). Since no differences between cultivars were noted, the average values are:

	Traffic		
Soil Depth (cm)	No Traffic	Compaction	Wear + Compaction
	------ $N\ cm^{-2}$ ------		
5	247	259	241
10	278	310	278
15	324	347	324
20	350	361	343
25	387	400	361

Insects. In Appendix A (following Table 29) is a report of progress 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. This report has been accepted for publication in 1994 in the Florida Entomologist.

Conclusions:

Observations to date are:

a) Most rapid to cover during plugging were 8514, El Toro, and 8512, while least were 8516 and 8502.

b) Cultivars exhibiting substantial cold induced winter injury at this location are 8501, 8502, and 8701.

c) Consistently highest visual quality has been expressed by 8507, Emerald, and 8512 at 1.25 and 2.50 lb N/1000 ft^2/yr and by 8501 at 3.75 lb N; lowest has been 8501 across all N levels.

d) All cultivars substantially improved in quality from 1.25 to 2.50 lb N with some improvement from 2.50 to 3.75 but of lesser magnitude.

e) Differential cultivar responses are starting to develop under the three traffic treatments.

f) Evapotranspiration (ET) rates over all dates ranged from 3.93 (Meyer) to 2.77 mm d^{-1} (8507). Cultivars exhibiting lowest ET and very little wilt during a moderately severe dry-down were 8501, 8512, El Toro, and 8502.

g) Cultivars demonstrating moderately severe wilt in late summer dry-down are 8516, 8507, 8508, and 9006.

h) Rooting data under cultivar and traffic regimes are currently being processed.

i) Dr. Kris Braman has found least tawny mole cricket injury and suitability for ovipoisition for 8502 and 8514, while 8516 exhibited greatest damage.

Table 1. Rate of establishment (1991-1992)

Cultivar	1991			1992	
	8 August	29 August	24 October	15 May	24 June
	% Turf Cover				
Meyer	24b	41d	82	92bc	95abc
DALZ 8701	22cb[z]	32ef	78c	69e	85e
DALZ 8502	19cb	27f	58e	80d	92bc
El Toro	43a	74a	94a	100a	100a
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 (.05) =	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%.

**,*,† Indicates significant difference at the 1, 5, and 10% levels, respectively.

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

	Spring Greenup		Turf Color	
	9 Apr.	14 Apr.	9 Apr.	14 Apr.
	------------------%------------------		-9 = dark green, 1 = no green	
Meyer	85ab	94abc	6.8bcd	7.2c
DALZ 8701	32d	78e	3.3f	5.8d
DALZ 8502	88a	86cde	6.2d	6.1d
El Toro	32d	79e	3.2f	5.5d
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 (.05) =	12.8	8.9	.76	.68
Sign. F-test =	**	**	**	**
CV(%) =	12	6	8	6

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 3. Turf coverage in 1993 during recovery from winter injury.

Cultivar	Turf Coverage					
	30 Mar	7 Apr	20 Apr	5 May	27 May	23 Jun
	%					
Meyer	49ab	67a	75a	83a	83a	83ab
DALZ 8701	0e	0e	3f	14g	23e	47d
DALZ 8502	0e	2e	1f	8g	24e	46d
El Toro	18cd	24cd	43cd	57bcd	64bc	82ab
DALZ 8507	19cd	31bc	47bc	50cdef	63bc	87ab
DALZ 8512	31bc	38b	58b	63bc	69b	87ab
DALZ 8516	60a	63a	74a	73ab	73ab	81ab
DALZ 8501	0e	0e	0f	5g	17e	40d
Emerald	42b	37b	50bc	56cde	72ab	95a
DALZ 8508	9de	19cd	29de	40ef	49d	65c
DALZ 9006	9de	18d	26e	37f	49d	74bc
DALZ 8514	22cd	16d	32de	44def	51cd	75bc
LSD (.05) =	18	12	15	16	14	15
Sign. F-test =	**	**	**	**	**	**
CV(%)	48	27	23	22	16	12

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 4. Spring color and quality in 1993 during recovery from winter injury.

Cultivar	Spring Turf Color 30 Mar	7 Apr	27 May	23 Jun	Turf Quality‡ 27 May	23 Jun
	------------------ 9 = dark green; 1 = no green ---------------					
Meyer	3.3a	3.6a	7.1d	7.5abc	5.4a	5.1bc
DALZ 8701	1.0c	1.0d	7.7a	7.8a	1.9d	3.2e
DALZ 8502	1.0c	1.0d	7.5abc	7.5abc	1.9d	3.2e
El Toro	1.8b	1.7bcd	7.5abc	7.3cd	4.7ab	5.4bc
DALZ 8507	1.8b	1.8bc	7.3bcd	7.4bcd	4.6abc	5.5bc
DALZ 8512	2.7a	2.1b	7.2cd	7.4bcd	4.8a	6.0ab
DALZ 8516	3.3a	2.9a	7.7a	7.8a	5.2a	5.2bc
DALZ 8501	1.0c	1.0d	7.6ab	7.1d	1.7d	2.9e
Emerald	2.7a	2.0bc	7.3bcd	7.6abc	5.3a	7.0a
DALZ 8508	1.7bc	1.4cd	7.6ab	7.7ab	3.6c	3.9de
DALZ 9006	1.7bc	1.4cd	7.7a	7.7ab	3.7c	4.6cd
DALZ 8514	1.7bc	1.4cd	7.5abc	7.5abc	3.8bc	4.6cd
LSD (.05) =	.78	.73	.35	.34	.96	1.11
Sign. F-test =	**	**	*	**	**	**
CV(%)	23	24	3	3	15	14

‡ Turf quality: 9 = ideal density, color, uniformity; 1 = no live turf.

**,*,† Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 5. Turf quality in 1992 prior to imposing N-level and traffic treatments.

Cultivars	Turf Quality[z]				
	24 June	3 August	26 August	3 September	6 October
Meyer	7.0abc	7.9ab	7.6ab	7.7a	7.5ab
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
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.

**,*,† Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 6. ANOVA analysis for 12 cultivars under 3 N levels and 3 traffic treatments.

ANOVA Source	Quality 4 Aug	Quality 27 Aug	Quality 29 Sep	Density 27 Aug	Density 29 Sep	Color 4 Aug	Color 27 Aug	Color 29 Sep	Cover 4 Aug	Wilt 31 Aug
Cultivar(C)	**	**	**	**	**	.17	.14	**	**	†
Nitrogen(N)	**	**	**	**	**	*	**	**	.77	*
Traffic(T)	**	**	**	**	**	**	.14	**	*	†
CxN	.44	.43	**	.77	.15	.56	.33	.71	.12	.19
CxT	**	**	**	**	**	**	.92	.12	†	.33
NxT	.74	.52	.51	.34	.76	.92	.18	.48	.56	.92
CxNxT	.53	*	.12	.19	*	.28	.66	.47	.33	.24

**,*,† Indicates significant treatment difference at the 1, 5 , and 10% levels, respectively.

Table 7. Nitrogen level trend analysis for 12 cultivars under the "none" traffic treatment.

		Significance of N-level Trend Response‡									
		Quality			Density		Color			Cover	Wilt
Cultivar	Response‡	4 Aug	27 Aug	29 Sep	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep	4 Aug	31 Aug
Meyer	N-linear	**	**	*	*	†	*	**	†	.42	.64
8701	N-linear	.14	*	**	*	*	.21	*	*	.13	.99
8502	N-linear	.99	**	.99	*	.85	.48	*	.81	.72	†
El Toro	N-linear	.43	*	**	.13	**	.12	**	.13	.39	**
8507	N-linear	.45	*	†	*	*	†	*	†	.21	.36
8512	N-linear	.86	*	*	*	.16	.67	*	†	.47	†
8516	N-linear	.19	**	*	*	†	.32	**	†	.60	.29
8501	N-linear	.49	.29	.52	.55	.37	.59	†	†	.37	**
Emerald	N-linear	.13	*	†	*	*	.37	.17	.41	.99	.19
8508	N-linear	.38	*	.26	†	†	*	*	.17	.49	.15
9006	N-linear	†	**	*	*	†	.20	*	.14	.60	†
8514	N-linear	.23	**	*	**	*	†	**	**	.67	.99
Meyer	N-quad	.94	.99	.62	.83	.82	.69	.38	.71	.14	.43
8701	N-quad	.49	.16	*	.16	.35	.62	.86	*	.96	.23
8502	N-quad	.16	.43	.48	.26	.51	.68	.57	.30	.70	.23
El Toro	N-quad	.58	.49	†	.48	.23	.64	.54	.31	.81	**
8507	N-quad	.88	.23	.52	.40	.61	*	.19	.13	.46	†
8512	N-quad	.53	.26	.12	.33	.37	.80	.85	.99	.70	.52
8516	N-quad	.12	.43	.59	.69	.87	.76	.13	.67	.83	.23
8501	N-quad	.31	.74	.50	.56	.22	.25	.89	.68	.71	**
Emerald	N-quad	.49	.86	.15	.99	.55	.16	.73	.62	*	.21
8508	N-quad	†	.83	.50	.42	.23	.29	.26	.65	.30	.20
9006	N-quad	.13	.25	.12	.21	.35	.42	.18	.35	.12	*
8514	N-quad	.59	.19	.36	.53	.26	.43	.74	.15	.71	.58

‡N-linear and N-quad trend analyses are at the None (control) traffic level.

**,*,†Indicates a significant N level trend at the 1, 5, and 10% levels, respectively.

Table 8. Turf coverage and wilt severity in August 1993 for 12 cultivars under N and traffic treatments (none; C=compaction; WC=wear + compaction.

Contrast		Cover (4 Aug)			Wilt (31 Aug)		
Cultivar	Annual N	None	C	WC	None	C	WC
	$kg\ ha^{-1}$	------- % plot ----			- 9 =none; 1 =severe -		
Meyer *vs*.	61	87	87	86	8.3‡	8.3	8.7
8701	61	78	80*	76	8.7	8.7	8.7
8502	61	86	86	78	8.7	8.0	8.3
El Toro	61	81	92†	92	8.7	8.7	8.7
8507	61	94	89	87	8.3	7.7	8.0
8512	61	96†	95*	93	8.7	8.3	7.7
8516	61	86	82†	78	7.3	7.3	7.7
8501	61	62†	65**	57*	8.7	8.7	8.3
Emerald	61	96	94*	95	8.7	8.3	8.3
8508	61	81	79*	65†	7.7	6.7*	7.0*
9006	61	89	90	80	7.7	7.7	7.0*
8514	61	87	88	84	8.0	8.3	8.7
Meyer *vs*.	122	90	88	84	7.7	8.0	8.0
8701	122	82	82	79	8.3	7.7	8.0
8502	122	87	84	82	8.7	8.3	8.3
El Toro	122	84	86	85	8.7	8.3	8.7
8507	122	92	90	89	5.7*	6.3*	7.0
8512	122	96	93	95	8.3	8.0	8.3
8516	122	84	84	85	7.6	6.7†	7.0
8501	122	60*	58*	54*	8.6	8.3	8.3
Emerald	122	95	96	95	9.0†	8.7	8.7
8508	122	83	82	83	8.0	6.7†	7.0
9006	122	93	87	84	8.3	6.0*	6.3*
8514	122	88	89	81	8.3	7.7	7.3
Meyer *vs*.	183	88	86	82	8.0	8.0	8.0
8701	183	87	87	82	8.7	7.7	8.0
8502	183	83	83	77	8.0	7.7	8.0
El Toro	183	93*	90	91	8.5	8.7	8.3
8507	183	97*	89	88	7.3	7.0	7.3
8512	183	94*	96	94	7.3	7.0	7.3
8516	183	84	85	88	6.6†	6.3*	7.0
8501	183	52**	58**	53**	8.7	7.3	8.0
Emerald	183	96*	95	95*	7.7	6.7	8.0
8508	183	78*	83	75	6.3*	6.7	6.0**
9006	183	90	88	84	6.3*	6.3*	5.7**
8514	183	88	88	83	8.0	8.0	7.7

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectfully.

‡Wilt of 6.0 represented >80% plot wilt but no apparent leaf firing.

Table 9. Turfgrass quality at 61 kg ha^{-1} annual N of 12 cultivars under three traffic treatments in 1993.

Contrast		Turf Quality									
		None				Compaction			Wear + Compaction		
Cultivar	Annual N	26‡ Jul	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep
	kg ha^{-1}	9 = ideal density, color uniformity; 1 = no live turf									
Meyer *vs*.	61	6.4	5.8	6.7	6.4	5.2	6.5	5.5	5.1	6.5	5.5
8701	61	6.7	6.9*	7.2†	6.1	5.5	6.8	5.7	5.3	6.6	5.4
8502	61	6.7	6.7*	7.3*	6.5	5.5	7.1*	5.9	5.2	7.0	5.4
El Toro	61	6.9	6.2	6.5	6.7	5.8	6.5	6.7**	5.4	6.1	6.2†
8507	61	7.3†	7.5**	7.3*	7.3*	6.7**	7.2*	7.2**	6.4**	7.0	7.2**
8512	61	7.3†	7.1**	7.2†	7.4*	6.3*	7.0*	6.8**	5.6	6.9	6.8**
8516	61	7.0	6.9*	7.4*	6.4	6.1†	7.1*	6.3*	6.1**	7.1	5.7
8501	61	5.2**	6.1	6.7	5.1**	5.1	6.4	4.8†	4.6†	6.0	4.4**
Emerald	61	7.4*	7.1**	7.4*	7.6**	6.4*	7.2*	7.1**	6.6**	7.3†	7.1**
8508	61	6.9	6.7*	7.4*	6.8	5.9	7.1*	6.4**	4.6†	6.8	6.0
9006	61	6.8	6.1	7.0	6.7	5.7	6.9	6.5**	5.0	6.5	5.9
8514	61	6.3	6.2	6.8	6.5	5.8	6.7	6.7**	5.1	6.5	6.5*
Average		6.7	6.6	7.1	6.6	5.8	6.9	6.3	5.0	6.7	6.0

**,*,† Indicates significant difference at the 1, 5, and 10% levels, respectively.

‡ Traffic treatments initiated 27 July 1993.

Table 10. Turfgrass quality at 122 kg ha^{-1} annual N of 12 cultivars under three traffic treatments in 1993.

Contrast		Turf Quality									
		None				Compaction			Wear + Compaction		
Cultivar	Annual N	26‡ Jul	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep
	kg ha^{-1}	9 = ideal density, color uniformity; 1 = no live turf									
Meyer <u>vs</u>.	122	6.9	6.3	7.2	7.1	5.5	7.0	6.8	5.7	7.1	6.4
8701	122	7.3	7.0*	7.3	7.5*	5.7	7.0	6.9	6.0	7.2	7.0
8502	122	7.4	7.5**	7.6*	6.9	6.4	7.2	6.7	6.5†	7.3	6.3
El Toro	122	6.9	6.7	7.2	7.2	5.7	7.0	7.1	5.4	6.6	6.8
8507	122	7.5	7.6**	7.6*	7.6**	6.7†	7.2	7.4*	7.2**	7.4	7.3†
8512	122	7.3	7.3**	7.6*	7.4	6.7†	7.5*	7.1	6.9**	7.4	7.0
8516	122	7.5	7.6**	7.5†	6.7*	6.7†	7.4*	6.6	7.3**	7.4	6.4
8501	122	5.5**	6.5	6.7*	5.3**	5.0	6.6†	5.7**	5.1	6.4†	5.1*
Emerald	122	7.7†	7.7**	7.6*	7.6**	7.5**	7.5*	7.2†	7.4**	7.5	7.3†
8508	122	7.5	7.6**	7.5†	7.4	6.4	7.4*	7.3†	6.3	7.5	7.1
9006	122	7.4	7.6**	7.5†	7.4†	5.8	7.2	6.4†	5.8	7.1	6.0
8514	122	6.4	6.6	7.2	7.3	5.9	7.0	7.1	5.2	6.2**	6.0
Average		7.1	7.2	7.4	7.1	6.2	7.2	6.9	6.2	7.1	6.6

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

‡Traffic treatments initiated 27 July 1993.

Table 11. Turfgrass quality at 183 kg ha^{-1} annual N of 12 cultivars under three traffic treatments in 1993.

Contrast		Turf Quality									
		None				Compaction			Wear + Compaction		
Cultivar	Annual N	26‡ Jul	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep
	kg ha^{-1}	9 = ideal density, color uniformity; 1 = no live turf									
Meyer vs.	183	7.3	6.9	7.6	7.4	5.5	7.4	6.9	5.7	7.4	6.8
8701	183	7.7	7.6	7.7	7.6	6.0	7.5	6.9	6.1	7.3	7.3
8502	183	6.6	6.7	7.8	6.5*	6.1	7.6	6.5	5.2	7.3	6.2†
El Toro	183	7.1	6.7	7.4†	7.3	6.3†	7.3	7.0	5.6	7.2	7.0
8507	183	7.5	7.6	7.7	7.7	6.5*	7.5	7.4	6.8†	7.5	7.5*
8512	183	7.5	7.2	7.6	7.6	7.2**	7.5	7.1	6.5	7.5	7.1
8516	183	7.8	7.4	7.8	7.2	6.2†	7.5	6.5	7.3*	7.5	6.9
8501	183	4.6**	5.5*	6.9**	4.6**	5.2	6.7**	5.3**	4.8	6.6**	4.4*
Emerald	183	7.8	7.8	7.7	7.9	6.9**	7.5	7.2	7.4**	7.6	7.4
8508	183	7.6	7.1	7.6	7.4	6.3†	7.5	7.2	5.6	7.4	7.0
9006	183	7.5	7.3	7.7	7.4	6.5*	7.4	7.2	5.3	7.2	7.1
8514	183	6.5	6.7	7.3†	7.5	6.3†	7.2	7.2	5.5	7.1	7.2
Average		7.1	7.0	7.6	7.2	6.3	7.4	6.9	6.0	7.3	6.8

**,*,† Indicates significant difference at the 1, 5, and 10% levels, respectively.

‡ Traffic treatments initiated 27 July 1993.

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Table 12. Turfgrass shoot density in 1992 prior to imposing N level and traffic treatments.

Cultivar	Turf Density[z] 3 August	Turf Density[z] 26 August
Meyer	8.0def	8.4b
DALZ 8701	7.9ef	8.4b
DALZ 8502	8.8a	8.8a
El Toro	7.8f	8.5ab
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.

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 13. Shoot density at 61 kg ha^{-1} annual N of 12 cultivars under three traffic treatments in 1993.

Contrast		Shoot Density						
		None			Compaction		Wear + Compaction	
Cultivar	Annual N	26 Jul	27 Aug	29 Sep	27 Aug	29 Sep	27 Aug	29 Sep
	kg ha^{-1}	9 = ideal density; 1 = no live turf						
Meyer vs.	61	6.9	7.0	6.8	6.7	5.9	6.7	6.1
8701	61	7.0	7.4	6.8	6.9	6.5	6.7	6.1
8502	61	7.0	7.5†	6.6	7.4*	6.6†	7.1	6.1
El Toro	61	7.0	6.8	6.8	6.7	6.8*	6.3	6.5
8507	61	7.5†	7.4	7.7*	7.3*	7.5**	7.1	7.5**
8512	61	7.3	7.3	7.5†	7.1	7.1**	7.0	7.1**
8516	61	7.3	7.6*	6.7	7.3*	6.5	7.3†	6.3
8501	61	5.4**	6.9	5.4**	6.5	5.3†	6.3	4.8**
Emerald	61	7.6*	7.6*	7.8*	7.3*	7.2**	7.4*	7.3**
8508	61	7.2	7.7*	6.9	7.3*	6.7*	7.0	6.3
9006	61	7.1	7.2	6.9	7.0	6.6†	6.6	6.0
8514	61	6.4	6.9	6.6	6.8	6.8*	6.6	6.6

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 14. Shoot density at 122 kg ha^{-1} annual N of 12 cultivars under three traffic treatments in 1993.

Contrast		Shoot Density						
		None			Compaction		Wear + Compaction	
Cultivar	Annual N	26 Jul	27 Aug	29 Sep	27 Aug	29 Sep	27 Aug	29 Sep
	kg ha^{-1}	9 = ideal density; 1 = no live turf						
Meyer *vs*.	122	7.1	7.3	7.3	7.1	7.0	7.1	6.9
8701	122	7.4	7.4	7.7†	7.2	7.1	7.3	6.9
8502	122	7.6	8.0**	7.1	7.4	6.9	7.4	6.7
El Toro	122	7.2	7.4	7.2	7.2	7.1	6.9	6.9
8507	122	7.8†	7.8*	7.8*	7.5*	7.6*	7.6†	7.7†
8512	122	7.5	7.7†	7.5	7.6*	7.2	7.4	7.2
8516	122	7.7†	7.8*	7.0	7.5*	6.7	7.6	6.6
8501	122	5.9**	7.1	5.8**	6.8	5.8**	6.7	5.5**
Emerald	122	7.9*	7.8*	7.9**	7.7*	7.4	7.6†	7.6
8508	122	7.7	7.8*	7.8*	7.5*	7.4	7.6†	7.2
9006	122	7.6	7.8*	7.6	7.4	6.5	7.1	6.3
8514	122	6.5	7.3	7.4	7.1	7.2	6.3**	6.3

**,*,† Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 15. Shoot density at 183 kg ha^{-1} annual N of 12 cultivars under three traffic treatments in 1993.

Contrast		Shoot Density						
		None			Compaction		Wear + Compaction	
Cultivar	Annual N	26 Jul	27 Aug	29 Sep	27 Aug	29 Sep	27 Aug	29 Sep
	kg ha^{-1}	9 = ideal density; 1 = no live turf						
Meyer *vs*.	183	7.4	7.7	7.6	7.5	7.1	7.5	7.0
8701	183	7.9	8.0†	8.0	7.6	7.3	7.5	7.5
8502	183	6.6	8.0†	6.7*	7.6	7.0	7.5	6.5
El Toro	183	7.1	7.4	7.4	7.3	7.0	7.2	7.0
8507	183	7.8	7.9	8.2	7.6	7.7†	7.6	7.9*
8512	183	7.6	7.7	7.6	7.7	7.6	7.6	7.2
8516	183	7.9	7.9	7.3	7.6	6.6	7.7	7.1
8501	183	4.9**	7.0**	4.9**	6.8**	5.8**	6.7**	4.7**
Emerald	183	8.1	8.0	8.2	7.6	7.4	7.7	7.5
8508	183	7.7	7.9	7.7	7.6	7.4	7.5	7.2
9006	183	7.6	7.8	7.8	7.8	7.8	7.5	7.4
8514	183	6.6	7.5	7.5	7.2	7.2	7.2	7.2

**,*,† Indicates significant difference at the 1, 5, and 10% levels, respectively.

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Table 16. Zoysiagrass color in 1991 and 1992 prior to imposing N level and traffic treatments.

	Turf Color									
	1991			1992						
Cultivar	8 Aug	29 Aug	24 Oct	14 Apr	24 Jun	3 Aug	26 Aug	3 Sep	6 Oct	29 Oct
	9 = dark green; 1 = no live turf									
Meyer	7.9bc	8.2	8.0cd	7.2c	7.7ab	7.8abc	7.6a	7.6a	7.6a	6.2bc
DALZ 8701	7.8cd	8.0	7.7d	5.8d	7.4cd	7.7bcd	7.5a	7.4ab	7.2c	6.3bc
DALZ 8502	8.0ab	8.0	7.9d	6.1d	7.9a	8.1a	7.6a	7.5a	7.5ab	6.2bc
El Toro	7.8cd	8.1	7.8d	5.5d	7.8ab	7.4de	7.6a	7.5a	7.2c	6.4b
DALZ 8507	7.8cd	8.1	7.9d	7.4bc	7.5bc	7.6cde	7.5a	7.6a	7.5ab	6.2bc
DALZ 8512	7.8cd	7.9	7.6de	6.0d	7.5bc	7.6cde	7.1bc	7.5a	7.2bc	6.4b
DALZ 8516	8.2a	8.4	8.8a	8.4a	7.9a	7.9ab	7.0bc	7.1c	7.4abc	6.9a
DALZ 8501	7.8cd	7.9	7.3e	5.7d	7.2d	7.3e	6.6d	6.9c	6.8d	4.0e
Emerald	7.9bc	8.3	7.9d	7.1c	7.7abc	7.6bcd	7.5a	7.4ab	7.6a	6.5ab
DALZ 8508	8.0ab	8.2	8.2bc	7.7abc	7.6abc	7.5de	7.2b	7.2b	7.4abc	5.7d
DALZ 9006	8.0ab	8.1	8.4b	8.0ab	7.8ab	7.4de	6.9c	7.2b	7.4abc	5.9cd
DALZ 8514	7.7d	8.1	7.7d	5.9d	7.6bc	7.5de	7.6a	7.4ab	7.4abc	6.6ab
LSD (0.5)	.21	.34	.34	.68	.31	.30	.23	.30	.32	.48
Sign F-test	**	.25	**	**	**	**	**	**	**	**
CV(%)	2	3	3	6	2	2	2	2	3	5

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 17. Turf color at 61 kg ha^{-1} annual N of 12 cultivars under three traffic treatments in 1993.

Contrast		Color									
		None				Compaction			Wear + Compaction		
Cultivar	Annual N	26 Jul	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep
	kg ha^{-1}	9 = dark green; 1 = no green									
Meyer *vs*.	61	7.5	7.4	7.6	7.5	7.2	7.6	7.0	7.3	7.6	7.2
8701	61	7.3*	7.4	7.4†	7.3*	7.2	7.4*	7.0	7.2	7.4	7.2
8502	61	7.5	7.6†	7.5	7.4	7.4	7.5†	7.0	7.3	7.5	7.0
El Toro	61	7.2**	7.4	7.4†	7.3*	7.3	7.5†	7.3*	7.2	7.4	7.2
8507	61	7.4	7.6†	7.4†	7.2*	7.3	7.5†	7.3*	7.3	7.5	7.2
8512	61	7.3*	7.4	7.4†	7.5	7.2	7.4*	7.4*	7.2	7.5	7.4
8516	61	7.6	7.5	7.5	7.6	7.4	7.5†	7.4*	7.5	7.6	7.5†
8501	61	7.2**	7.4	7.4†	7.3*	6.9*	7.3**	6.8**	6.5**	7.4†	7.2
Emerald	61	7.5	7.6†	7.8	7.6	7.4	7.7	7.4*	7.3	7.7	7.4
8508	61	7.5	7.5	7.6	7.5	7.3	7.7	7.3*	7.2	7.7	7.2
9006	61	7.5	7.5	7.6	7.4	7.3	7.7	7.4*	7.3	7.7	7.1
8514	61	7.3*	7.4	7.5	7.5	7.2	7.6	7.5**	7.2	7.6	7.4

**,*,† Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 18. Turf color at 122 kg ha^{-1} annual N of 12 cultivars under three traffic treatments in 1993.

Contrast		Color									
		None				Compaction			Wear + Compaction		
Cultivar	Annual N	26 Jul	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep
	kg ha^{-1}	9 = dark green; 1 = no green									
Meyer vs.	122	7.6	7.5	8.0	7.6	7.2	8.0	7.5	7.4	7.9	7.5
8701	122	7.5	7.5	7.6*	7.6	7.3	7.7†	7.5	7.3	7.6*	7.5
8502	122	7.7	7.6	7.6*	7.7	7.4	7.6*	7.4	7.4	7.6*	7.4
El Toro	122	7.4†	7.5	7.7†	7.6	7.5	7.7†	7.4	7.3	7.7†	7.4
8507	122	7.6	7.5	7.6*	7.6	7.3	7.6*	7.5	7.4	7.5**	7.4
8512	122	7.5	7.4	7.6*	7.6	7.4	7.5**	7.5	7.4	7.5**	7.5
8516	122	7.7	7.6	7.6*	7.7	7.4	7.7†	7.5	7.5	7.7†	7.5
8501	122	7.4†	7.3*	7.6*	7.4*	6.7**	7.7†	7.3*	7.1	7.5**	7.2*
Emerald	122	7.6	7.6	7.7†	7.6	7.5*	7.7†	7.5	7.5	7.7	7.6
8508	122	7.6	7.6	7.7†	7.6	7.3	7.7†	7.5	7.1	7.7	7.4
9006	122	7.7	7.6	7.6*	7.5	7.4	7.8	7.5	7.5	7.8	7.5
8514	122	7.5	7.5	7.7†	7.7	7.3	7.8	7.6	7.3	7.7	7.5

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 19. Turf color at 183 kg ha^{-1} annual N of 12 cultivars under three traffic treatments in 1993.

Contrast		Color									
		None				Compaction			Wear + Compaction		
Cultivar	Annual N	26 Jul	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep	4 Aug	27 Aug	29 Sep
	kg ha^{-1}	9 = dark green; 1 = no green									
Meyer vs.	183	7.8	7.7	8.2	7.7	7.6	8.2	7.5	7.5	8.2	7.6
8701	183	7.7	7.5	7.8*	7.5	7.3	7.8*	7.5	7.5	7.7**	7.5
8502	183	7.9	7.6	7.8*	7.4†	7.3	7.8*	7.4	7.4	7.7**	7.2*
El Toro	183	7.5*	7.5†	8.0	7.6	7.4	8.0	7.5	7.3	8.0	7.6
8507	183	7.7	7.7	7.6**	7.5	7.5	7.7**	7.4	7.3	7.6**	7.5
8512	183	7.5*	7.4†	7.7*	7.7	7.3	7.8*	7.6	7.4	7.7**	7.5
8516	183	7.8	7.7	7.9	7.7	7.4	7.9†	7.6	7.6	7.8**	7.6
8501	183	7.4*	7.4†	7.7*	7.5†	7.1*	7.8*	7.1*	6.9**	7.6**	7.2*
Emerald	183	7.7	7.6	7.8*	7.4†	7.4	7.8*	7.6	7.5	7.8**	7.6
8508	183	7.7	7.7	8.0	7.6	7.1*	8.0	7.3	7.1*	7.9*	7.5
9006	183	7.7	7.6	7.9	7.5	7.5	8.0	7.4	7.1*	8.0	7.5
8514	183	7.6†	7.5	8.0	7.7	7.2	7.8*	7.6	7.2	7.9*	7.6

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 20. Chlorosis, mottling and scalping in 1992 prior to imposing N level or traffic treatments.

Cultivar	Chlorosis 3 August	Mottling[z] 3 September	Scalp[y] 3 September	Scalp[y] 6 October
	- % Plot -	-% Plot-	9=none;1=all	turf scalpers
Meyer	0.7b	1.3bc	9.0a	9.0a
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
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), unknown (8516), or tendency to scalp (8502, 8508, 9006, 8501, and Emerald).

[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.

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 21. Leaf texture, rhizome, and verdure data on cultivars in the no-traffic plots.

	Leaf Texture		Rhizomes				Verdure
			Volume‡		Weight		
Cultivar	Aug 91	Aug 92	Jul 92	Sep 93	Jul 92	Sep 93	Sep 93
	------- mm ----		------ cm^3 -----		- mg 100 cm^{-3} -		g 100 cm^{-2}
Meyer	4.4b	3.1a	0.6c	1.7b	7c	25b	3.77b
8701	3.0e	2.1b	5.3b	7.4b	105ab	89b	3.41b
8502	2.5f	1.0c	9.5a	10.0ab	173a	172ab	4.53ab
El Toro	5.0a	3.4a	2.3bc	3.9b	32bc	57b	3.96b
8507	2.9ef	1.2c	2.3bc	8.8ab	38bc	196ab	4.01b
8512	5.0a	3.4a	3.7bc	4.4b	62bc	83b	4.14b
8516	3.6c	2.6b	2.2bc	3.7b	33bc	65b	7.69a
8501	3.5cd	1.1c	2.8bc	2.9b	61bc	45b	4.34b
Emerald	3.1de	1.4c	4.3bc	19.3a	86b	372a	5.45ab
8508	2.9e	1.3c	2.7bc	2.0b	44bc	30b	3.97b
9006	2.8ef	1.2c	3.0bc	1.5b	58bc	29b	4.80ab
8514	5.0a	3.3a	1.7bc	3.9b	29bc	46b	3.89b
LSD (.05)	0.4	0.4	4.0	10.6	76	201	3.35
Sign F-test	**	**	*	†	*	*	.47
CV(%)	13	10	70	108	14	118	44

‡Volume per 1646 cm^3 of soil (2 cores per plot of 5.08 cm radius, 10.2 cm depth)

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 22. Root growth of zoysiagrasses in 1992 prior to imposing N level or traffic treatments.

Cultivar	Root Length Density				Percent change in RLD (Jul to Sep)		Total Root Length[z]	
	7 Jul		18 Sep				7 July	18 Sept
	3 to 30 cm	30 to 60 cm	3 to 30 cm	30 to 60 cm	3 to 30 cm	3 to 60 cm	3 to 60 cm	3 to 60 cm
	$cm\bullet cm^{-3}$				%		$cm\bullet cm^{-2}$	
Meyer	.27ab	.03d	.23ab	.06c	-15	+100	4.39	4.79ab
DALZ 8701	.35ab	.06cd	.50a	.15ab	+43	+150	6.14	9.69a
DALZ 8502	.25ab	.03d	.30ab	.05c	+20	+67	4.20	5.30ab
El Toro	.52a	.09bc	.22ab	.07c	-58	-22	9.15	4.36b
DALZ 8507	.40ab	.11ab	.30ab	.08c	-25	-27	7.63	5.67ab
DALZ 8512	.49a	.14a	.31ab	.18a	-37	+29	9.48	7.40ab
DALZ 8516	.25ab	.06cd	.25ab	.11bc	0	+83	4.66	5.31ab
DALZ 8501	.19b	.03d	.15b	.05c	-20	+67	3.37	3.03b
Emerald	.19b	.04d	.28ab	.09bc	+47	+125	3.39	5.59ab
DALZ 8508	.37ab	.06cd	.45a	.11bc	+22	+83	6.50	8.12ab
DALZ 9006	.40ab	.05cd	.25ab	.05c	-37	0	6.78	4.57b
DALZ 8514	.27ab	.05cd	.29ab	.09bc	+7	+80	4.87	5.63ab
LSD (.05) =	.28	.046	.29	.059	-	-	6.47	5.10
Sign. F-test =	.28	**	.81	**	-	-	.60	.85
CV(%)	49	44	57	38	-	-	95	80

[z]Total Root Length: cm of roots per cm^2 of surface sod area.

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 23. Water extraction and evapotranspiration data (28 Aug to 3 Sep 1992) prior to imposing N level and traffic treatments.

Cultivar	Water Extraction 28 August to 3 September			Evapotranspiration 28 August to 3 September
	0 to 10cm	10 to 20cm	20 to 60 cm	
	-----------------	mm	----------------	---------- $mm\ d^{-1}$ ------
Meyer	8.7ab	5.8ab	11.3ab	4.3ab
DALZ 8701	6.2b	5.4ab	7.7b	3.2b
DALZ 8502	7.3ab	4.6b	11.1ab	3.8ab
El Toro	7.2ab	5.2ab	17.5a	5.0a
DALZ 8507	8.2ab	4.9ab	15.2ab	4.7a
DALZ 8512	9.8a	5.0ab	11.1ab	4.3ab
DALZ 8516	7.9ab	5.8ab	11.2ab	4.2ab
DALZ 8501	8.7ab	5.9a	11.9ab	4.4ab
Emerald	7.0b	5.9a	11.1ab	4.0ab
DALZ 8508	6.9b	5.5ab	10.4b	3.8ab
DALZ 9006	7.9ab	5.8ab	15.1ab	4.8a
DALZ 8514	7.0b	5.7ab	12.4ab	4.2ab
LSD (0.5) =	2.9	1.2	6.7	1.2
Sign F-test =	.70	.66	.55	.59
CV (%)	26	16	39	21

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 24. Significance of F-tests in the ANOVA for evapotranspiration and root water extraction data in 1993.

Source	Evapotranspiration			Root Water Extraction by Soil Depth: 13 to 19 Jul			27 Jul to 3 Aug			24 to 30 Aug		
	13 to 19 Jul	27 Jul to 3 Aug	24 to 30 Aug	0 to 10 cm	10 to 20 cm	20 to 60 cm	0 to 10 cm	10 to 20 cm	20 to 60 cm	0 to 10 cm	10 to 20 cm	20 to 60 cm
Cultivar(C)	NS‡	*	*	NS‡	NS‡	NS‡	NS	NS	**	*	**	NS
Traffic (T)	-	*	**	-	-	-	**	**	NS	**	**	†
CxT	-	NS	NS	-	-	-	†	NS	NS	NS	†	NS

**,*,† Significant at the 1, 5, and 10% levels, respectively.

‡ Traffic treatments were not imposed at this time period.

Table 25. Root water extraction by soil depth in 1993 under the no-traffic (control) at 122 kg N ha^{-1} yr^{-1}.

Contrasts	Root Water Extraction by Soil Depth								
	13 to 19 Jul			27 Jul to 3 Aug			24 to 30 Aug		
Cultivar Traffic	0 to 10 cm	10 to 20 cm	20 to 60 cm	0 to 10 cm	10 to 20 cm	20 to 60 cm	0 to 10 cm	10 to 20 cm	20 to 60 cm
	mm								
Meyer at No vs	11.73	7.00	7.60	11.60	5.97	8.67	7.53	3.53	22.40
8701	9.03	6.47	6.27	9.67	4.63	12.40	7.67	5.67	10.40
8502	10.80	7.23	6.00	10.27	5.40	12.13	6.30	5.07	15.87
El Toro	10.77	8.33	4.80	8.27	2.00†	8.66	7.07	6.30	7.60*
8507	10.90	6.03	8.93	9.30	4.63	9.87	5.73	4.37	2.13**
8512	9.13	5.43	12.13*	8.77	3.07	2.80	6.33	6.27	10.00
8516	10.87	6.03	4.27†	9.03	4.53	2.80	7.67	5.40	9.06
8501	11.07	6.77	10.67	9.57	4.30	2.27	6.40	6.03	10.40
Emerald	10.10	8.13	9.47	9.57	5.03	6.53	11.17	5.83	13.07
8508	11.07	7.33	3.87*	11.23	4.30	0 *	9.80	4.93	11.07
9006	11.10	7.27	5.47	9.03	7.03	5.93	8.43	3.10	6.67*
8514	12.17	6.13	15.20*	12.97	9.63†	10.67	10.27	10.10**	7.87*
Sign F-test =	.99	.79	.32	.78	.21	.35	.67	.23	.58
CV(%) =	30	28	28	30	55	130	43	46	123

**,*,† Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 26. Root water extraction by soil depth in 1993 under the compaction traffic treatment at 122 kg N ha^{-1} yr^{-1}.

Contrasts		Root Water Extraction by Soil Depth					
		27 Jul to 3 Aug			24 to 30 Aug		
Cultivar	Traffic	0 to 10 cm	10 to 20 cm	20 to 60 cm	0 to 10 cm	10 to 20 cm	20 to 60 cm
		mm					
Meyer at Compaction *vs*		8.80	4.47	13.47	6.17	3.83	9.39
8701		7.00	2.70	7.07	6.43	6.33	6.40
8502		5.67	3.07	4.67	3.80	2.13	2.53*
El Toro		7.60	.50†	7.47	6.30	6.43	8.40
8507		5.00	3.73	3.73†	3.73	2.00	3.37†
8512		9.93	2.83	6.80	5.00	5.67	2.00*
8516		7.00	2.90	4.13†	11.17*	10.00*	11.33
8501		6.07	3.80	2.80*	6.47	3.67	1.33*
Emerald		7.63	3.00	6.93	6.43	4.97	5.73
8508		6.62	5.42	0 **	8.60	6.13	6.67
9006		8.93	2.27	10.13	7.50	5.20	2.93*
8514		6.60	2.67	8.27	6.73	8.93*	10.13
Sign F-test		.88	.82	.48	.36	.11	.25
CV(%)		48	95	121	49	56	56

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

Table 27. Root water extraction by soil depth in 1993 under the wear + compaction traffic treatment at 122 kg N ha^{-1} yr^{-1}.

Contrasts		Root Water Extraction by Soil Depth					
		27 Jul to 3 Aug			24 to 30 Aug		
Cultivar	Traffic	0 to 10 cm	10 to 20 cm	20 to 60 cm	0 to 10 cm	10 to 20 cm	20 to 60 cm
		mm					
Meyer at WC vs		8.90	2.33	2.27	4.97	3.07	13.70
8701		5.80*	1.80	8.53	3.97	2.73	20.00
8502		8.40	2.90	11.80**	5.37	2.63	6.53†
El Toro		7.97	2.70	5.60	4.97	2.67	5.60†
8507		10.33	3.43	8.00	2.93	2.37	2.53*
8512		8.76	1.83	10.13†	3.73	3.33	3.07*
8516		6.13†	2.67	4.13	4.87	4.56	9.07
8501		7.33	1.63	.84	4.67	3.13	5.33†
Emerald		10.00	2.20	4.27	6.20	4.27	13.07
8508		3.33**	2.93	0	5.33	3.67	10.07
9006		4.60*	3.07	11.77**	4.83	3.23	5.33†
8514		4.80*	3.77	6.40	4.43	4.37	4.27*
Sign F-test		**	.96	**	.90	.92	.40
CV(%)		26	72	123	46	57	2.27

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

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Table 28. Evapotranspiration under traffic treatments and at the 122 kg ha^{-1} annual N level in 1993, and ET averages.

Contrasts	Evapotranspiration: No Traffic, 13 to 19 Jul	No Traffic, 27 Jul to 3 Aug	No Traffic, 24 to 30 Aug	Compaction, 27 Jul to 3 Aug	Compaction, 24 to 30 Aug	Wear + Compaction, 27 Jul to 3 Aug	Wear + Compaction, 24 to 30 Aug	Avg. 1993	Avg. 92+93
	mm d^{-1}								
Meyer *vs*.	4.39	3.75	5.58	3.82	3.23	1.93	4.45	3.88	3.93
8701	3.63	3.81	3.96	2.40	3.19	2.31	4.45	3.39	3.37
8502	4.01	3.97	4.54	1.91†	1.41	3.30*	2.42	3.08	3.17
El Toro	3.98	2.70	3.50	2.22	3.52	2.32	2.21	2.92	3.18
8507	4.31	3.40	2.04*‡	1.78*	1.52‡	3.10†	1.31†‡	2.49	2.77
8512	4.45	2.09	3.77	2.80	2.11	2.96†	1.68†	2.84	3.02
8516	3.53	2.33	3.69	2.00†	5.42‡	1.85	3.08‡	3.13	3.26
8501	4.75	2.30	3.81	1.81*	1.92	1.40	2.19	2.60	2.83
Emerald	4.62	3.02	5.01	2.51	2.86	2.35	3.92	3.47	3.54
8508	3.71	1.97	4.30	1.72*	3.57‡	.91†	3.34‡	2.79	2.92
9006	3.97	3.14	3.03	3.05	2.61‡	2.78	2.23‡	2.97	3.20
8514	5.58	4.75	4.71	2.50	4.30	2.14	2.18	3.74	3.80
Sign F-Test =	.73	.43	.71	.38	.56	**	.54	-	-
CV(%) =	28	.58	61	53	115	49	108	-	-
Average	-	3.10	4.00	2.38	2.97	2.28	2.79	-	-

**,*,†Indicates significant difference at the 1, 5, and 10% levels, respectively.

‡Indicates that substantial wilt (≤7.0) was present at the end of the 6-day dry-down period (see Table 8 for wilt data).

Table 29 . Soil chemical analyses by depth for the zoysiagrass study area in 1991 and 1992.

	30 Oct. 1991				20 Oct. 1992				
	Soil Depth				Soil Depth				
Measurement	0 to 10 cm	10 to 20 cm	20 to 30 cm	30 to 40 cm	0 to 10 cm	10 to 20 cm	20 to 30 cm	30 to 40 cm	40 to 60 cm
Soil pH	4.50	5.04	5.65	5.75	4.74	5.23	5.71	6.05	6.20
Base Cations (meq.100 g^{-1})									
Ca	1.71	1.90	2.26	2.15	.97	1.56	1.83	1.92	2.04
Mg	.39	.36	.49	.53	.13	.23	.34	.50	.57
K	.33	.27	.29	.25	.22	.22	.28	.34	.21
Na	.04	.02	.01	.01	.18	.05	.05	.05	.17
Acid Cations (meq. 100 g^{-1})	4.24	3.84	2.56	3.44	3.92	2.95	2.56	2.96	2.79
Al	.23	.06	.02	.01	.58	.14	.03	.01	.01
Cation Exchange Capacity (meq. 100 g^{-1})	6.93	6.44	5.63	6.38	6.00	5.15	5.09	5.78	5.79
Base Saturation (%)	36	40	54	46	25	40	49	49	52
Extractable Nutrients (ppm)									
P	56VH†	35H	23H	7L	57VH	43VH	27H	2L	1L
K	100M	83M	84M	71M	68M	69M	83M	92M	55M
Ca	399H	446H	530H	450H	263H	381H	417H	367H	370H
Mg	11L	10L	14L	15L	17L	29L	41L	62	69
Total N (%)	.08	.07	.03	.04	-	-	-	-	-
Organic Matter Content (%)	.98	.76	.47	.52	1.46	.99	.74	.30	.26

†L = low, M = medium, H = high, VH = very high based on current UGA soil test recommendations and lab procedures.

APPENDIX A

For Publication in: Florida Entomologist

Address Correspondence to:
S. Kristine Braman
Department of Entomology
University of Georgia
Georgia Station
Griffin, GA 30223-1797
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POTENTIAL RESISTANCE IN ZOYSIAGRASSES TO TAWNY MOLE CRICKETS (ORTHOPTERA: GRYLLOTALPIDAE)

S.K. Braman, A.F. Pendley, R.N. Carrow[1]
and M.C. Engelke[2]

University of Georgia, College of Agriculture
and Environmental Sciences Experiment Stations,
Georgia Station, Griffin, GA 30223

ABSTRACT

Reduction in growth of nine experimental and three commercially available zoysiagrasses by tawny mole crickets, *Scapteriscus vicinus* Scudder, at densities equivalent to 15 adults per 0.09 m^2 varied with cultivar. Root dry weights after a four week infestation period were similarly reduced for all cultivars, averaging 27.1% less than uninfested controls. Shoot dry weight reduction was most severe for DALZ 8516, DALZ 9006, and Meyer zoysia. The cultivars that retained the highest percentage of their normal growth were DALZ 8502, DALZ 8514, DALZ 8701, and Emerald zoysia. Cultivars that were least severely damaged also usually supported the lowest rate of oviposition. However, when the most severely injured selection (DALZ 8516) served as the host, a similarly low rate of oviposition was observed. Meyer zoysia and DALZ 8508 supported the highest rate of oviposition.

Key words: host plant resistance, *Scapteriscus* spp., zoysiagrass

Mole crickets in the genus *Scapteriscus* have become the most serious pests of turfgrasses in the southeastern United States since their entry into this country, probably in the ballast of ships, ca. 1900 (Walker and Nickle 1981, Nickle and Castner 1984, Walker 1984). The tawny mole cricket, *Scapteriscus vicinus* Scudder, is the more damaging of the two species common in Georgia. Management of these pests has involved chemical, cultural, and classical biological control efforts (Walker 1984, Hudson et al. 1988).

While laboratory and field screening has identified turfgrass genotypes that are relatively resistant, tolerant, or less preferred by various insects and mites (see reviews by Reinert 1982, Quisenberry 1990), limited work has focused on mole crickets and white grubs (Potter and Braman 1991). Resistant cultivars are needed to provide a safe, economical control strategy for these most serious subterranean turf pests. Here we report the results of a greenhouse evaluation of nine experimental and three commercially available zoysiagrass (*Zoysia* Willd.) cultivars for their susceptibility to mole cricket injury and ability to support oviposition activities.

MATERIALS AND METHODS

Zoysiagrass plugs (4.6 X 4.6 X 6.3 cm) of 12 cultivars were transplanted into granular calcinated clay (Turface, Applied Industrial Materials, Corp., Deerfield, IL) in 15 cm diam plastic pots in a greenhouse. Pots were watered daily and fertilized once per week with a solution containing 250 ppm NPK. Milorganite was applied (2.25 gm/pot) once per month. Turf was cut weekly to a height of 5 cm. Experimental cultivars included a range of leaf textures, colors , and growth rates (Carrow 1992). Six months post-transplant the 15 cm diam plugs were transferred to 38 cm tall, 15 cm diam PVC tubes containing sand held in wooden frames and equipped with drip irrigation. Watering and fertilizer regimes were maintained as before for one month prior to infestation with adult crickets.

Adult *S. vicinus* were collected in Tifton, GA during April, 1992 using a standard acoustic trap similar to that described by Walker (1982). A randomized complete block design of the 12 cultivars replicated seven times was infested with two female and one male mole crickets. Seven replicates of each cultivar within the design were left uninfested. Containers were covered with 32 mesh saran screen (Chicopee Manufacturing Co., Gainesville, GA) to prevent escape of crickets. Uninfested cages were also covered with screen to ensure equivalent light, temperature and humidity conditions. Water and fertilizer regimes were maintained as described. Greenhouse microplots were destructively sampled after four weeks exposure to crickets.

Two weeks after crickets were introduced to the PVC containers, top growth was clipped to a height of 5 cm. Clippings were placed in paper bags and oven dried for 7 days. Top growth clipping dry weights were again collected at four weeks post infestation. Number of green shoots per 18 cm^2 at the termination of the experiment was determined. Roots were washed, dried, and weighed.

Sand from all experimental PVC plots (1343 kg) was sifted to recover mole cricket adults and eggs. Adult survival and number of eggs were recorded and compared using the GLM procedure (SAS 1985). Mean separation following a significant analysis of variance was accomplished using a least significant difference test. Reduction in growth expressed as a percentage of uninfested controls of each cultivar for root and shoot weights and shoot density were similarly subjected to analysis of variance and mean separation.

RESULTS AND DISCUSSION

Reduction in top growth at two weeks post-infestation was statistically similar for all cultivars ($P>0.05$, Table 1). Growth of infested plants averaged 67.9% of uninfested plants at that time. Reduction in shoot dry weights at four weeks, however, differed significantly ($P<0.05$) with cultivar. DALZ 8516 infested achieved only 10.1% of its normal growth. DALZ 8502, however continued to maintain 55% of its normal growth even under this exceedingly high infestation level. The pest pressure employed here was equivalent to 15 adult crickets/0.09 m^2. Georgia Cooperative Extension Service recommendations suggest that chemical intervention to protect turf may be required at adult densities of 1 cricket per 0.09 m^2. Total reduction in top growth for the entire four week period ranged from 35.7 to 74.8% (inverse of the extremes presented in Table 1).

Shoot density followed a similar pattern to that exhibited by the clipping dry weights. Root weight reduction, however, was similar for all cultivars evaluated and averaged 72.9% of uninfested controls (Table 1). The majority of the damage observed was confined to the crown of each infested zoysiagrass plug. Dead turf was usually first visible at the center of each plug and expanded outward with increasing time of exposure.

Adult survival at the termination of the four week exposure period was not significantly affected by cultivar ($P>0.05$) and averaged 70.0% (data not given). Egg production during this time period was, however, significantly ($P<0.05$) influenced by cultivar (Fig.1). Mean number of eggs per cultivar ranged from 4.5 to 35.4. In general, cultivars that were least severely injured (DALZ 8502, DALZ 8514, Emerald, DALZ 8701, and DALZ 8507) also supported the lowest rate of oviposition. However, DALZ 8516, which was the most severely damaged, had a similarly low rate of oviposition. Meyer zoysia and DALZ 8508 supported the greatest rate of egg production.

Results of this no-choice evaluation of 12 cultivars of zoysiagrass under intense mole cricket pressure revealed distinct differences in susceptibility to injury and suitability for egg production by the tawny mole cricket. Previous work (e.g., Reinert and Busey 1984) has shown a preference by mole crickets for the finer textured varieties within a species of grass. Those authors discussed the need to carefully define the relative contribution of nonpreference and host plant tolerance. The results reported here indicate a similar tolerance of injury and reduced suitability for oviposition among fine textured (DALZ 8502) and wider bladed (DALZ 8514) selections. In large monocultures such as golf courses, parks, commercial properties, etc., nonpreference in the absence of other resistance mechanisms is of somewhat limited value. The potential for resistance among zoysiagrass cultivars to damage by tawny mole crickets demonstrated here offers characteristics in addition to nonpreference that should permit selected cultivars to be planted with reduced risk of mole cricket injury.

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[1] Department of Crop and Soil Sciences, University of Georgia, Griffin, Georgia 30223

[2] Texas A&M University, Research and Extension Center, 17360 Coit Rd., Dallas, Texas 75252

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TABLE 1. ZOYSIAGRASS RESPONSE TO ADULT *S. VICINUS*

	Mean % of uninfested controls				
	Shoot dry weight			Root dry	Shoot density
Cultivar	2 wk	4 wk	total	weight	per 18 cm^2
DALZ8502	87.7 a	55.4 a	64.3 a	72.0 a	49.8 b
DALZ8514	73.0 a	41.6 ab	55.0 ab	97.8 a	43.9 bc
Emerald	100 a	41.0 ab	54.7 ab	74.0 a	41.0 bc
DALZ8701	72.4 a	42.2 ab	52.9 ab	72.5 a	80.9 a
DALZ8507	75.5 a	34.1 abc	50.7 ab	75.9 a	30.9 bcd
DALZ8508	75.6 a	23.0 bc	41.6 abc	69.1 a	23.0 bcd
El Toro	59.4 a	27.6 bc	41.3 abc	72.3 a	43.5 bc
DALZ8512	60.6 a	25.1 bc	38.8 bc	76.2 a	20.2 cd
DALZ8501	58.2 a	21.5 bc	37.4 bc	69.5 a	28.7 bcd
Meyer	55.5 a	19.1 bc	34.9 bc	62.9 a	23.1 bcd
DALZ9006	48.6 a	25.1 bc	34.7 bc	60.5 a	34.7 bcd
DALZ8516	49.0 a	10.1 bc	25.2 c	72.1 a	9.0 d

Means within a column followed by the same letter are not significantly different (LSD test)

FIGURE CAPTIONS

Fig. 1. Oviposition rate, number of eggs per four weeks, on 12 zoysiagrass cultivars.

Oviposition by S. vicinus