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.
Annual Progress Report

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

UNIVERSITY OF GEORGIA
Griffin, GA

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 experimental cultivars 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 ft² 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 cm² 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 ft² 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 ft² 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 ft² 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 ft² 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 P₂O₅ per 1000 ft² 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 n or v. 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°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\(_2\)O wk\(^{-1}\) (Table 28). Beard [J. B. Beard, 1985. An assessment of water use by turfgrasses. In V. A. Gilbeault 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. Penetrometer 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:

<table>
<thead>
<tr>
<th>Soil Depth (cm)</th>
<th>No Traffic</th>
<th>Compaction</th>
<th>Wear + Compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N cm(^{-2})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>247</td>
<td>259</td>
<td>241</td>
</tr>
<tr>
<td>10</td>
<td>278</td>
<td>310</td>
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</tr>
<tr>
<td>15</td>
<td>324</td>
<td>347</td>
<td>324</td>
</tr>
<tr>
<td>20</td>
<td>350</td>
<td>361</td>
<td>343</td>
</tr>
<tr>
<td>25</td>
<td>387</td>
<td>400</td>
<td>361</td>
</tr>
</tbody>
</table>

**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 ft²/yr and by 8501 at 3.75 lb N; lowest has been 8501 across all N levels.

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

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<table>
<thead>
<tr>
<th>Cultivar</th>
<th>1991</th>
<th>1992</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 August</td>
<td>29 August</td>
<td>24 October</td>
<td>15 May</td>
</tr>
<tr>
<td>Meyer</td>
<td>24b</td>
<td>41d</td>
<td>82</td>
<td>92bc</td>
</tr>
<tr>
<td>DALZ 8701</td>
<td>22cb²</td>
<td>32ef</td>
<td>78c</td>
<td>69e</td>
</tr>
<tr>
<td>DALZ 8502</td>
<td>19cb</td>
<td>27f</td>
<td>58e</td>
<td>80d</td>
</tr>
<tr>
<td>El Toro</td>
<td>43a</td>
<td>74a</td>
<td>94a</td>
<td>100a</td>
</tr>
<tr>
<td>DALZ 8507</td>
<td>23b</td>
<td>39de</td>
<td>78c</td>
<td>94ab</td>
</tr>
<tr>
<td>DALZ 8512</td>
<td>44a</td>
<td>55c</td>
<td>93ab</td>
<td>98ab</td>
</tr>
<tr>
<td>DALZ 8516</td>
<td>17c</td>
<td>28f</td>
<td>54e</td>
<td>79d</td>
</tr>
<tr>
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<td>34def</td>
<td>76cd</td>
<td>86cd</td>
</tr>
<tr>
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<td>34def</td>
<td>69d</td>
<td>85cd</td>
</tr>
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<td>92bc</td>
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<td>33def</td>
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<td>93ab</td>
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<tr>
<td>DALZ 8514</td>
<td>47a</td>
<td>65b</td>
<td>97a</td>
<td>96ab</td>
</tr>
</tbody>
</table>

LSD (.05) = 5.5 8.0 9.1 7.2 5.2
Sign. F-test ** ** ** ** **
CV (%) 12 11 7 5 3

² 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.

<table>
<thead>
<tr>
<th></th>
<th>Spring Greenup</th>
<th>Turf Color</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9 Apr.</td>
<td>14 Apr.</td>
</tr>
<tr>
<td>Meyer</td>
<td>85ab</td>
<td>94abc</td>
</tr>
<tr>
<td>DALZ 8701</td>
<td>32d</td>
<td>78e</td>
</tr>
<tr>
<td>DALZ 8502</td>
<td>88a</td>
<td>86cde</td>
</tr>
<tr>
<td>El Toro</td>
<td>32d</td>
<td>79e</td>
</tr>
<tr>
<td>DALZ 8507</td>
<td>75b</td>
<td>92abc</td>
</tr>
<tr>
<td>DALZ 8512</td>
<td>52c</td>
<td>87abc</td>
</tr>
<tr>
<td>DALZ 8516</td>
<td>93a</td>
<td>100a</td>
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<tr>
<td>DALZ 8501</td>
<td>35d</td>
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<td>73b</td>
<td>93abc</td>
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<tr>
<td>DALZ 8508</td>
<td>85ab</td>
<td>96ab</td>
</tr>
<tr>
<td>DALZ 9006</td>
<td>88a</td>
<td>96ab</td>
</tr>
<tr>
<td>DALZ 8514</td>
<td>30d</td>
<td>82de</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>30 Mar</th>
<th>7 Apr</th>
<th>20 Apr</th>
<th>5 May</th>
<th>27 May</th>
<th>23 Jun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meyer</td>
<td>49ab</td>
<td>67a</td>
<td>75a</td>
<td>83a</td>
<td>83a</td>
<td>83ab</td>
</tr>
<tr>
<td>DALZ 8701</td>
<td>0e</td>
<td>0e</td>
<td>3f</td>
<td>14g</td>
<td>23e</td>
<td>47d</td>
</tr>
<tr>
<td>DALZ 8502</td>
<td>0e</td>
<td>2e</td>
<td>1f</td>
<td>8g</td>
<td>24e</td>
<td>46d</td>
</tr>
<tr>
<td>El Toro</td>
<td>18cd</td>
<td>24cd</td>
<td>43cd</td>
<td>57bcd</td>
<td>64bc</td>
<td>82ab</td>
</tr>
<tr>
<td>DALZ 8507</td>
<td>19cd</td>
<td>31bc</td>
<td>47bc</td>
<td>50cdef</td>
<td>63bc</td>
<td>87ab</td>
</tr>
<tr>
<td>DALZ 8512</td>
<td>31bc</td>
<td>38b</td>
<td>58b</td>
<td>63bc</td>
<td>69b</td>
<td>87ab</td>
</tr>
<tr>
<td>DALZ 8516</td>
<td>60a</td>
<td>63a</td>
<td>74a</td>
<td>73ab</td>
<td>73ab</td>
<td>81ab</td>
</tr>
<tr>
<td>DALZ 8501</td>
<td>0e</td>
<td>0e</td>
<td>0f</td>
<td>5g</td>
<td>17e</td>
<td>40d</td>
</tr>
<tr>
<td>Emerald</td>
<td>42b</td>
<td>37b</td>
<td>50bc</td>
<td>56cde</td>
<td>72ab</td>
<td>95a</td>
</tr>
<tr>
<td>DALZ 8508</td>
<td>9de</td>
<td>19cd</td>
<td>29de</td>
<td>40ef</td>
<td>49d</td>
<td>65c</td>
</tr>
<tr>
<td>DALZ 9006</td>
<td>9de</td>
<td>18d</td>
<td>26e</td>
<td>37f</td>
<td>49d</td>
<td>74bc</td>
</tr>
<tr>
<td>DALZ 8514</td>
<td>22cd</td>
<td>16d</td>
<td>32de</td>
<td>44def</td>
<td>51cd</td>
<td>75bc</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Spring Turf Color</th>
<th>Turf Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 Mar</td>
<td>7 Apr</td>
</tr>
<tr>
<td>Meyer</td>
<td>3.3a</td>
<td>3.6a</td>
</tr>
<tr>
<td>DALZ 8701</td>
<td>1.0c</td>
<td>1.0d</td>
</tr>
<tr>
<td>DALZ 8502</td>
<td>1.0c</td>
<td>1.0d</td>
</tr>
<tr>
<td>El Toro</td>
<td>1.8b</td>
<td>1.7bcd</td>
</tr>
<tr>
<td>DALZ 8507</td>
<td>1.8b</td>
<td>1.8bc</td>
</tr>
<tr>
<td>DALZ 8512</td>
<td>2.7a</td>
<td>2.1b</td>
</tr>
<tr>
<td>DALZ 8516</td>
<td>3.3a</td>
<td>2.9a</td>
</tr>
<tr>
<td>DALZ 8501</td>
<td>1.0c</td>
<td>1.0d</td>
</tr>
<tr>
<td>Emerald</td>
<td>2.7a</td>
<td>2.0bc</td>
</tr>
<tr>
<td>DALZ 8508</td>
<td>1.7bc</td>
<td>1.4cd</td>
</tr>
<tr>
<td>DALZ 9006</td>
<td>1.7bc</td>
<td>1.4cd</td>
</tr>
<tr>
<td>DALZ 8514</td>
<td>1.7bc</td>
<td>1.4cd</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>24 June</th>
<th>3 August</th>
<th>26 August</th>
<th>3 September</th>
<th>6 October</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meyer</td>
<td>7.0abc</td>
<td>7.9ab</td>
<td>7.6ab</td>
<td>7.7a</td>
<td>7.5ab</td>
</tr>
<tr>
<td>DALZ 8701</td>
<td>5.6e</td>
<td>7.6abcd</td>
<td>7.6ab</td>
<td>7.6ab</td>
<td>7.3ab</td>
</tr>
<tr>
<td>DALZ 8502</td>
<td>6.6bcd</td>
<td>8.1a</td>
<td>7.6ab</td>
<td>7.4ab</td>
<td>7.0bc</td>
</tr>
<tr>
<td>El Toro</td>
<td>7.6a</td>
<td>7.3cde</td>
<td>7.8a</td>
<td>7.6ab</td>
<td>7.4ab</td>
</tr>
<tr>
<td>DALZ 8507</td>
<td>7.4ab</td>
<td>7.7abc</td>
<td>7.5ab</td>
<td>7.5ab</td>
<td>7.6ab</td>
</tr>
<tr>
<td>DALZ 8512</td>
<td>7.4ab</td>
<td>7.6abcd</td>
<td>7.5ab</td>
<td>7.5ab</td>
<td>7.4ab</td>
</tr>
<tr>
<td>DALZ 8516</td>
<td>5.8de</td>
<td>6.8e</td>
<td>6.6e</td>
<td>6.7c</td>
<td>6.6c</td>
</tr>
<tr>
<td>DALZ 8501</td>
<td>7.0abc</td>
<td>7.4cd</td>
<td>6.8de</td>
<td>6.7c</td>
<td>5.9d</td>
</tr>
<tr>
<td>Emerald</td>
<td>6.4cde</td>
<td>7.4cd</td>
<td>7.4ab</td>
<td>7.3abc</td>
<td>7.7a</td>
</tr>
<tr>
<td>DALZ 8508</td>
<td>7.3ab</td>
<td>7.5bcd</td>
<td>7.3bc</td>
<td>7.1bc</td>
<td>7.5ab</td>
</tr>
<tr>
<td>DALZ 9006</td>
<td>7.6a</td>
<td>7.2de</td>
<td>7.0cd</td>
<td>7.1bc</td>
<td>7.4ab</td>
</tr>
<tr>
<td>DALZ 8514</td>
<td>7.5a</td>
<td>7.6decd</td>
<td>7.7ab</td>
<td>7.5ab</td>
<td>7.4ab</td>
</tr>
</tbody>
</table>

| LSD (0.5)  | 0.86    | 0.51     | 0.38      | 0.53        | 0.54      |
| Sign F-test| **      | **       | **        | **          | **        |
| CV (%)     | 7       | 4        | 3         | 4           | 4         |

*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.

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

**,** † 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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Response ‡</th>
<th>Significance of N-level Trend Response §</th>
<th>Density</th>
<th>Cover</th>
<th>Wilt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Aug</td>
<td>Aug</td>
<td>Sep</td>
</tr>
<tr>
<td>Meyer</td>
<td>N-linear</td>
<td>** * * .21 .21 ** † .42 .42 .64 .99</td>
<td>27</td>
<td>29</td>
<td>27</td>
</tr>
<tr>
<td>8502</td>
<td>N-linear</td>
<td>.99 * .99 * .99 .85 .85 .85 .81 .81 .81 .72 .72 .72</td>
<td>4</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>8507</td>
<td>N-linear</td>
<td>.45 * .45 * .45 .16 .16 .16 .21 .21 .21 .36 .36 .36</td>
<td>4</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>8512</td>
<td>N-linear</td>
<td>.86 .86 .86 .67 .67 .67 .47 .47 .47 .36 .36 .36</td>
<td>4</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>8516</td>
<td>N-linear</td>
<td>.19 .19 .19 .32 .32 .32 † .37 .37 .37 .29 .29 .29</td>
<td>4</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>8501</td>
<td>N-linear</td>
<td>.49 .49 .49 .55 .55 .55 .37 .37 .37 .29 .29 .29</td>
<td>4</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>Emerald</td>
<td>N-linear</td>
<td>.13 * .13 * .13 .37 .37 .37 † .41 .41 .41 .19 .19 .19</td>
<td>4</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>8508</td>
<td>N-linear</td>
<td>.38 .38 .38 .26 .26 .26 † .37 .37 .37 .15 .15 .15</td>
<td>4</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>9006</td>
<td>N-linear</td>
<td>† † † † † † † † † † † † †</td>
<td>4</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>8514</td>
<td>N-linear</td>
<td>.23 * .23 * .23 † .20 .20 .20 † .60 .60 .60 .99 .99 .99</td>
<td>4</td>
<td>27</td>
<td>29</td>
</tr>
</tbody>
</table>

‡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).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Annual N kg ha⁻¹</th>
<th>Cover (4 Aug)</th>
<th>Wilt (31 Aug)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>C</td>
<td>WC</td>
</tr>
<tr>
<td>Meyer vs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8701</td>
<td>61</td>
<td>87</td>
<td>86</td>
</tr>
<tr>
<td>8502</td>
<td>61</td>
<td>86</td>
<td>78</td>
</tr>
<tr>
<td>El Toro</td>
<td>61</td>
<td>81</td>
<td>92*</td>
</tr>
<tr>
<td>8507</td>
<td>61</td>
<td>94</td>
<td>87</td>
</tr>
<tr>
<td>8512</td>
<td>61</td>
<td>96*</td>
<td>95*</td>
</tr>
<tr>
<td>8516</td>
<td>61</td>
<td>86</td>
<td>82*</td>
</tr>
<tr>
<td>8501</td>
<td>61</td>
<td>62*</td>
<td>65**</td>
</tr>
<tr>
<td>Emerald</td>
<td>61</td>
<td>96</td>
<td>95*</td>
</tr>
<tr>
<td>8508</td>
<td>61</td>
<td>81</td>
<td>79*</td>
</tr>
<tr>
<td>9006</td>
<td>61</td>
<td>89</td>
<td>80</td>
</tr>
<tr>
<td>8514</td>
<td>61</td>
<td>87</td>
<td>88</td>
</tr>
<tr>
<td>Meyer vs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8701</td>
<td>122</td>
<td>90</td>
<td>88</td>
</tr>
<tr>
<td>8502</td>
<td>122</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>El Toro</td>
<td>122</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td>8507</td>
<td>122</td>
<td>92</td>
<td>90</td>
</tr>
<tr>
<td>8512</td>
<td>122</td>
<td>96</td>
<td>93</td>
</tr>
<tr>
<td>8516</td>
<td>122</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td>8501</td>
<td>122</td>
<td>60*</td>
<td>58*</td>
</tr>
<tr>
<td>Emerald</td>
<td>122</td>
<td>95</td>
<td>96</td>
</tr>
<tr>
<td>8508</td>
<td>122</td>
<td>83</td>
<td>82</td>
</tr>
<tr>
<td>9006</td>
<td>122</td>
<td>93</td>
<td>87</td>
</tr>
<tr>
<td>8514</td>
<td>122</td>
<td>88</td>
<td>89</td>
</tr>
<tr>
<td>Meyer vs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8701</td>
<td>183</td>
<td>88</td>
<td>86</td>
</tr>
<tr>
<td>8502</td>
<td>183</td>
<td>87</td>
<td>82</td>
</tr>
<tr>
<td>El Toro</td>
<td>183</td>
<td>83</td>
<td>77</td>
</tr>
<tr>
<td>8507</td>
<td>183</td>
<td>93*</td>
<td>90</td>
</tr>
<tr>
<td>8512</td>
<td>183</td>
<td>97*</td>
<td>89</td>
</tr>
<tr>
<td>8516</td>
<td>183</td>
<td>84</td>
<td>85</td>
</tr>
<tr>
<td>8501</td>
<td>183</td>
<td>52**</td>
<td>58**</td>
</tr>
<tr>
<td>Emerald</td>
<td>183</td>
<td>96*</td>
<td>95*</td>
</tr>
<tr>
<td>8508</td>
<td>183</td>
<td>78*</td>
<td>75</td>
</tr>
<tr>
<td>9006</td>
<td>183</td>
<td>90</td>
<td>84</td>
</tr>
<tr>
<td>8514</td>
<td>183</td>
<td>88</td>
<td>83</td>
</tr>
</tbody>
</table>

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

‡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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Annual N</th>
<th>None</th>
<th>Compaction</th>
<th>Wear + Compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oct</td>
<td>Jul</td>
<td>Aug</td>
<td>Sep</td>
</tr>
<tr>
<td>Meyer vs.</td>
<td>61</td>
<td>6.4</td>
<td>5.8</td>
<td>6.7</td>
</tr>
<tr>
<td>8501</td>
<td>61</td>
<td>6.7</td>
<td>6.9*</td>
<td>7.2†</td>
</tr>
<tr>
<td>8502</td>
<td>61</td>
<td>6.7</td>
<td>6.7*</td>
<td>7.3*</td>
</tr>
<tr>
<td>El Toro</td>
<td>61</td>
<td>6.9</td>
<td>6.2</td>
<td>6.5</td>
</tr>
<tr>
<td>8507</td>
<td>61</td>
<td>7.3†</td>
<td>7.5**</td>
<td>7.3*</td>
</tr>
<tr>
<td>8512</td>
<td>61</td>
<td>7.3†</td>
<td>7.1**</td>
<td>7.2†</td>
</tr>
<tr>
<td>8516</td>
<td>61</td>
<td>7.0</td>
<td>6.9*</td>
<td>7.4*</td>
</tr>
<tr>
<td>8501</td>
<td>61</td>
<td>5.2**</td>
<td>6.1</td>
<td>6.7</td>
</tr>
<tr>
<td>Emerald</td>
<td>61</td>
<td>7.4*</td>
<td>7.1**</td>
<td>7.4*</td>
</tr>
<tr>
<td>9006</td>
<td>61</td>
<td>6.9</td>
<td>6.7*</td>
<td>7.4*</td>
</tr>
<tr>
<td>8514</td>
<td>61</td>
<td>6.3</td>
<td>6.2</td>
<td>6.8</td>
</tr>
<tr>
<td>Average</td>
<td>6.7</td>
<td>6.6</td>
<td>7.1</td>
<td>6.6</td>
</tr>
</tbody>
</table>

**,*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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Annual N</th>
<th>None</th>
<th>CompaCtion</th>
<th>Wear + Compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jul</td>
<td>Aug</td>
<td>Sep</td>
<td>Aug</td>
</tr>
<tr>
<td>26°</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>5.5</td>
<td>7.0</td>
<td>6.8</td>
<td>5.7</td>
</tr>
<tr>
<td>27</td>
<td>5.3</td>
<td>7.0</td>
<td>6.9</td>
<td>5.7</td>
</tr>
<tr>
<td>29</td>
<td>5.5</td>
<td>7.0</td>
<td>6.9</td>
<td>5.7</td>
</tr>
<tr>
<td>kg ha⁻¹</td>
<td>--------</td>
<td>9 = ideal density, color uniformity; 1 = no live turf</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Meyer vs.</td>
<td>122</td>
<td>6.9</td>
<td>7.3</td>
<td>7.1</td>
</tr>
<tr>
<td>8701</td>
<td>122</td>
<td>7.3</td>
<td>7.0</td>
<td>7.3</td>
</tr>
<tr>
<td>8502</td>
<td>122</td>
<td>7.4</td>
<td>7.5</td>
<td>7.6</td>
</tr>
<tr>
<td>El Toro</td>
<td>122</td>
<td>6.9</td>
<td>6.7</td>
<td>7.2</td>
</tr>
<tr>
<td>8507</td>
<td>122</td>
<td>7.5</td>
<td>7.6</td>
<td>7.6</td>
</tr>
<tr>
<td>8512</td>
<td>122</td>
<td>7.3</td>
<td>7.3**</td>
<td>7.6</td>
</tr>
<tr>
<td>8516</td>
<td>122</td>
<td>7.5</td>
<td>7.5**</td>
<td>7.5</td>
</tr>
<tr>
<td>8501</td>
<td>122</td>
<td>5.5**</td>
<td>6.5</td>
<td>6.7</td>
</tr>
<tr>
<td>Emerald</td>
<td>122</td>
<td>7.7</td>
<td>7.7**</td>
<td>7.6</td>
</tr>
<tr>
<td>8508</td>
<td>122</td>
<td>7.5</td>
<td>7.6**</td>
<td>7.5</td>
</tr>
<tr>
<td>9006</td>
<td>122</td>
<td>7.4</td>
<td>7.6**</td>
<td>7.5</td>
</tr>
<tr>
<td>8514</td>
<td>122</td>
<td>6.4</td>
<td>6.6</td>
<td>7.2</td>
</tr>
<tr>
<td>Average</td>
<td>7.1</td>
<td>7.2</td>
<td>7.4</td>
<td>7.1</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Annual N</th>
<th>None</th>
<th>Compaction</th>
<th>Wear + Compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Jul</td>
<td>Aug</td>
<td>Sep</td>
</tr>
<tr>
<td>Meyer vs.</td>
<td>183</td>
<td>7.3</td>
<td>6.9</td>
<td>7.6</td>
</tr>
<tr>
<td>8701</td>
<td>183</td>
<td>7.7</td>
<td>7.6</td>
<td>7.7</td>
</tr>
<tr>
<td>8502</td>
<td>183</td>
<td>6.6</td>
<td>6.7</td>
<td>7.8</td>
</tr>
<tr>
<td>El Toro</td>
<td>183</td>
<td>7.1</td>
<td>6.7</td>
<td>7.4</td>
</tr>
<tr>
<td>8507</td>
<td>183</td>
<td>7.5</td>
<td>7.6</td>
<td>7.7</td>
</tr>
<tr>
<td>8512</td>
<td>183</td>
<td>7.5</td>
<td>7.2</td>
<td>7.6</td>
</tr>
<tr>
<td>8516</td>
<td>183</td>
<td>7.8</td>
<td>7.4</td>
<td>7.8</td>
</tr>
<tr>
<td>8501</td>
<td>183</td>
<td>4.6**</td>
<td>5.5*</td>
<td>6.9**</td>
</tr>
<tr>
<td>Emerald</td>
<td>183</td>
<td>7.8</td>
<td>7.8</td>
<td>7.7</td>
</tr>
<tr>
<td>8508</td>
<td>183</td>
<td>7.6</td>
<td>7.1</td>
<td>7.6</td>
</tr>
<tr>
<td>9006</td>
<td>183</td>
<td>7.5</td>
<td>7.3</td>
<td>7.7</td>
</tr>
<tr>
<td>8514</td>
<td>183</td>
<td>6.5</td>
<td>6.7</td>
<td>7.3</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>7.1</td>
<td>7.0</td>
<td>7.6</td>
</tr>
</tbody>
</table>

---

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

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

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>3 August</th>
<th>26 August</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meyer</td>
<td>8.0def</td>
<td>8.4b</td>
</tr>
<tr>
<td>DALZ 8701</td>
<td>7.9ef</td>
<td>8.4b</td>
</tr>
<tr>
<td>DALZ 8502</td>
<td>8.8a</td>
<td>8.8a</td>
</tr>
<tr>
<td>El Toro</td>
<td>7.8f</td>
<td>8.5ab</td>
</tr>
<tr>
<td>DALZ 8507</td>
<td>8.4b</td>
<td>8.6ab</td>
</tr>
<tr>
<td>DALZ 8512</td>
<td>7.9ef</td>
<td>8.4b</td>
</tr>
<tr>
<td>DALZ 8516</td>
<td>7.8f</td>
<td>8.0c</td>
</tr>
<tr>
<td>DALZ 8501</td>
<td>8.3bc</td>
<td>8.4b</td>
</tr>
<tr>
<td>Emerald</td>
<td>8.1cdef</td>
<td>8.5ab</td>
</tr>
<tr>
<td>DALZ 8508</td>
<td>8.2bcd</td>
<td>8.5ab</td>
</tr>
<tr>
<td>DALZ 9006</td>
<td>8.1bcde</td>
<td>8.6ab</td>
</tr>
<tr>
<td>DALZ 8514</td>
<td>7.9ef</td>
<td>8.5ab</td>
</tr>
</tbody>
</table>

LSD (0.5) = .28
Sign F-test = **
CV (%) = 2

*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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Annual N</th>
<th>Shoot Density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jul</td>
</tr>
<tr>
<td>kg ha⁻¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meyer vs.</td>
<td>61</td>
<td>6.9</td>
</tr>
<tr>
<td>8701</td>
<td>61</td>
<td>7.0</td>
</tr>
<tr>
<td>8502</td>
<td>61</td>
<td>7.0</td>
</tr>
<tr>
<td>El Toro</td>
<td>61</td>
<td>7.0</td>
</tr>
<tr>
<td>8507</td>
<td>61</td>
<td>7.5*</td>
</tr>
<tr>
<td>8512</td>
<td>61</td>
<td>7.3</td>
</tr>
<tr>
<td>8516</td>
<td>61</td>
<td>7.3</td>
</tr>
<tr>
<td>8501</td>
<td>61</td>
<td>5.4**</td>
</tr>
<tr>
<td>Emerald</td>
<td>61</td>
<td>7.6*</td>
</tr>
<tr>
<td>8508</td>
<td>61</td>
<td>7.2</td>
</tr>
<tr>
<td>9006</td>
<td>61</td>
<td>7.1</td>
</tr>
<tr>
<td>8514</td>
<td>61</td>
<td>6.4</td>
</tr>
</tbody>
</table>

**,** 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.

| Cultivar    | Annual N |                |                |                |                |                |                |
|-------------|----------|----------------|----------------|----------------|----------------|----------------|
|             |          | Jul 27 29      | Aug 27 29      | Aug 27 29      | Aug 27 29      | Aug 27 29      |
| Contrast    |          | Shot Density   | Shot Density   | Shot Density   | Shot Density   | Shot Density   |
| Meyer vs.   | 122      | 7.1 7.3 7.3    | 7.1 7.0        | 7.1 6.9        | 7.4 7.1 7.1    | 7.4 6.7        |
| 8701        | 122      | 7.4 7.4 7.7†   | 7.2 7.1        | 7.3 6.9        | 7.4 6.7        | 7.4 6.7        |
| 8502        | 122      | 7.6 8.0** 7.1  | 7.4 6.9        | 7.4 6.7        | 7.4 6.7        | 7.4 6.7        |
| El Toro     | 122      | 7.2 7.4 7.2    | 7.2 7.1        | 6.9 6.9        | 7.4 6.7        | 7.4 6.7        |
| 8507        | 122      | 7.8† 7.8* 7.8* | 7.5* 7.6*      | 7.6† 7.7†      | 7.6† 7.7†      | 7.6† 7.7†      |
| 8512        | 122      | 7.5 7.7† 7.5   | 7.6* 7.2       | 7.4 7.2        | 7.4 7.2        | 7.4 7.2        |
| 8516        | 122      | 7.7† 7.8* 7.0  | 7.5* 6.7       | 7.6 6.6        | 7.6 6.6        | 7.6 6.6        |
| 8501        | 122      | 5.9** 7.1 5.8**| 6.8 5.8**      | 6.7 5.5**      | 7.6† 7.6       | 7.6† 7.6       |
| Emerald     | 122      | 7.9* 7.8* 7.9**| 7.7* 7.4       | 7.6† 7.6       | 7.6† 7.6       | 7.6† 7.6       |
| 8508        | 122      | 7.7 7.8* 7.8*  | 7.5* 7.4       | 7.6† 7.6       | 7.6† 7.6       | 7.6† 7.6       |
| 9006        | 122      | 7.6 7.8* 7.6   | 7.4 6.5        | 7.1 6.3        | 7.1 6.3        | 7.1 6.3        |
| 8514        | 122      | 6.5 7.3 7.4    | 7.1 7.2        | 6.3** 6.3      | 6.3** 6.3      | 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.

<table>
<thead>
<tr>
<th>Contrast</th>
<th>Shoot Density</th>
<th>26 Jul</th>
<th>27 Aug</th>
<th>29 Sep</th>
<th>27 Aug</th>
<th>29 Sep</th>
<th>27 Aug</th>
<th>29 Sep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivar</td>
<td>183 kg ha(^{-1})</td>
<td>9 = ideal density; 1 = no live turf</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meyer vs.</td>
<td>183</td>
<td>7.4</td>
<td>7.7</td>
<td>7.6</td>
<td>7.5</td>
<td>7.1</td>
<td>7.5</td>
<td>7.0</td>
</tr>
<tr>
<td>8701</td>
<td>183</td>
<td>7.9</td>
<td>8.0(t)</td>
<td>8.0</td>
<td>7.6</td>
<td>7.3</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>8502</td>
<td>183</td>
<td>6.6</td>
<td>8.0(t)</td>
<td>6.7(t)</td>
<td>7.6</td>
<td>7.0</td>
<td>7.5</td>
<td>6.5</td>
</tr>
<tr>
<td>El Toro</td>
<td>183</td>
<td>7.1</td>
<td>7.4</td>
<td>7.4</td>
<td>7.3</td>
<td>7.0</td>
<td>7.2</td>
<td>7.0</td>
</tr>
<tr>
<td>8507</td>
<td>183</td>
<td>7.8</td>
<td>7.9</td>
<td>8.2</td>
<td>7.6</td>
<td>7.7(t)</td>
<td>7.6</td>
<td>7.9(t)</td>
</tr>
<tr>
<td>8512</td>
<td>183</td>
<td>7.6</td>
<td>7.7</td>
<td>7.6</td>
<td>7.7</td>
<td>7.6</td>
<td>7.6</td>
<td>7.2</td>
</tr>
<tr>
<td>8516</td>
<td>183</td>
<td>7.9</td>
<td>7.9</td>
<td>7.3</td>
<td>7.6</td>
<td>6.6</td>
<td>7.7</td>
<td>7.1</td>
</tr>
<tr>
<td>8501</td>
<td>183</td>
<td>4.9(**)</td>
<td>7.0(**)</td>
<td>4.9(**)</td>
<td>6.8(**)</td>
<td>5.8(**)</td>
<td>6.7(**)</td>
<td>4.7(**)</td>
</tr>
<tr>
<td>Emerald</td>
<td>183</td>
<td>8.1</td>
<td>8.0</td>
<td>8.2</td>
<td>7.6</td>
<td>7.4</td>
<td>7.7</td>
<td>7.5</td>
</tr>
<tr>
<td>8508</td>
<td>183</td>
<td>7.7</td>
<td>7.9</td>
<td>7.7</td>
<td>7.6</td>
<td>7.4</td>
<td>7.5</td>
<td>7.2</td>
</tr>
<tr>
<td>9006</td>
<td>183</td>
<td>7.6</td>
<td>7.0</td>
<td>7.0</td>
<td>7.8</td>
<td>7.8</td>
<td>7.5</td>
<td>7.4</td>
</tr>
<tr>
<td>8514</td>
<td>183</td>
<td>6.6</td>
<td>7.5</td>
<td>7.5</td>
<td>7.2</td>
<td>7.2</td>
<td>7.2</td>
<td>7.2</td>
</tr>
</tbody>
</table>

\(**\)\(t\): Indicates significant difference at the 1, 5, and 10% levels, respectively.
Table 16. Zoysiagrass color in 1991 and 1992 prior to imposing N level and traffic treatments.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Turf Color</th>
<th>Turf Color</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aug 91</td>
<td>Aug 91</td>
</tr>
<tr>
<td>Meyer</td>
<td>7.9bc 8.2</td>
<td>8.0cd 7.2c</td>
</tr>
<tr>
<td>DALZ 8701</td>
<td>7.8cd 8.0</td>
<td>7.7d 5.8d</td>
</tr>
<tr>
<td>DALZ 8502</td>
<td>8.0ab 8.0</td>
<td>7.9d 6.1d</td>
</tr>
<tr>
<td>El Toro</td>
<td>7.8cd 8.1</td>
<td>7.8d 5.5d</td>
</tr>
<tr>
<td>DALZ 8507</td>
<td>7.8cd 8.1</td>
<td>7.9d 7.4bc</td>
</tr>
<tr>
<td>DALZ 8512</td>
<td>7.8cd 7.9</td>
<td>7.6de 6.0d</td>
</tr>
<tr>
<td>DALZ 8516</td>
<td>8.2a 8.4</td>
<td>8.8a 8.4a</td>
</tr>
<tr>
<td>DALZ 8501</td>
<td>7.8cd 7.9</td>
<td>7.3d 5.7d</td>
</tr>
<tr>
<td>Emerald</td>
<td>7.9bc 8.3</td>
<td>7.9d 7.1c</td>
</tr>
<tr>
<td>DALZ 8508</td>
<td>8.0ab 8.2</td>
<td>8.2bc 7.7abc</td>
</tr>
<tr>
<td>DALZ 9006</td>
<td>8.0ab 8.1</td>
<td>8.4b 8.0ab</td>
</tr>
<tr>
<td>DALZ 8514</td>
<td>7.7d 8.1</td>
<td>7.7d 5.9d</td>
</tr>
<tr>
<td>LSD (0.5)</td>
<td>.21 .34</td>
<td>.34 .68</td>
</tr>
<tr>
<td>Sign F-test</td>
<td>** .25**</td>
<td>** ** **</td>
</tr>
<tr>
<td>CV(%)</td>
<td>2 3 3 6</td>
<td>2 2 2 3</td>
</tr>
</tbody>
</table>

---

**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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Contrast</th>
<th>None</th>
<th>Compaction</th>
<th>Wear + Compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual N</td>
<td>Jul</td>
<td>Aug</td>
<td>Aug</td>
</tr>
<tr>
<td>Meyer vs.</td>
<td>61</td>
<td>7.5</td>
<td>7.4</td>
<td>7.5</td>
</tr>
<tr>
<td>8701</td>
<td>61</td>
<td>7.3*</td>
<td>7.4</td>
<td>7.4*</td>
</tr>
<tr>
<td>8502</td>
<td>61</td>
<td>7.5</td>
<td>7.6*</td>
<td>7.5</td>
</tr>
<tr>
<td>El Toro</td>
<td>61</td>
<td>7.2**</td>
<td>7.4</td>
<td>7.4*</td>
</tr>
<tr>
<td>8507</td>
<td>61</td>
<td>7.4</td>
<td>7.6*</td>
<td>7.4*</td>
</tr>
<tr>
<td>8512</td>
<td>61</td>
<td>7.3*</td>
<td>7.4</td>
<td>7.4*</td>
</tr>
<tr>
<td>8516</td>
<td>61</td>
<td>7.6</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>8501</td>
<td>61</td>
<td>7.2**</td>
<td>7.4</td>
<td>7.4*</td>
</tr>
<tr>
<td>Emerald</td>
<td>61</td>
<td>7.5</td>
<td>7.6*</td>
<td>7.8</td>
</tr>
<tr>
<td>8508</td>
<td>61</td>
<td>7.5</td>
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<td>7.6</td>
</tr>
<tr>
<td>9006</td>
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</tr>
<tr>
<td>8514</td>
<td>61</td>
<td>7.3*</td>
<td>7.4</td>
<td>7.5</td>
</tr>
</tbody>
</table>

*Indicates significant difference at the 10% level. **Indicates significant difference at the 5% level.
<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Annual N kg ha⁻¹</th>
<th>26</th>
<th>4</th>
<th>7</th>
<th>29</th>
<th>4</th>
<th>27</th>
<th>29</th>
<th>4</th>
<th>27</th>
<th>29</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meyer vs.</td>
<td>122</td>
<td>7.6</td>
<td>7.5</td>
<td>8.0</td>
<td>7.6</td>
<td>7.2</td>
<td>8.0</td>
<td>7.5</td>
<td>7.4</td>
<td>7.9</td>
<td>7.5</td>
</tr>
<tr>
<td>8701</td>
<td>122</td>
<td>7.5</td>
<td>7.5</td>
<td>7.6*</td>
<td>7.6</td>
<td>7.3</td>
<td>7.7*</td>
<td>7.5</td>
<td>7.3</td>
<td>7.6*</td>
<td>7.5</td>
</tr>
<tr>
<td>8502</td>
<td>122</td>
<td>7.7</td>
<td>7.6</td>
<td>7.6*</td>
<td>7.7</td>
<td>7.4</td>
<td>7.6*</td>
<td>7.4</td>
<td>7.4</td>
<td>7.6*</td>
<td>7.4</td>
</tr>
<tr>
<td>El Toro</td>
<td>122</td>
<td>7.4†</td>
<td>7.5</td>
<td>7.7†</td>
<td>7.6</td>
<td>7.5</td>
<td>7.7†</td>
<td>7.4</td>
<td>7.3</td>
<td>7.7†</td>
<td>7.4</td>
</tr>
<tr>
<td>8507</td>
<td>122</td>
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<td>7.5</td>
<td>7.6*</td>
<td>7.6</td>
<td>7.3</td>
<td>7.6*</td>
<td>7.5</td>
<td>7.4</td>
<td>7.5**</td>
<td>7.4</td>
</tr>
<tr>
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<td>7.5</td>
<td>7.4</td>
<td>7.6*</td>
<td>7.6</td>
<td>7.4</td>
<td>7.5**</td>
<td>7.5</td>
<td>7.4</td>
<td>7.5**</td>
<td>7.5</td>
</tr>
<tr>
<td>8516</td>
<td>122</td>
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<td>7.6*</td>
<td>7.7</td>
<td>7.4</td>
<td>7.7†</td>
<td>7.5</td>
<td>7.5</td>
<td>7.7†</td>
<td>7.5</td>
</tr>
<tr>
<td>8501</td>
<td>122</td>
<td>7.4†</td>
<td>7.3*</td>
<td>7.6*</td>
<td>7.4*</td>
<td>6.7**</td>
<td>7.7*</td>
<td>7.3*</td>
<td>7.1</td>
<td>7.5**</td>
<td>7.2*</td>
</tr>
<tr>
<td>Emerald</td>
<td>122</td>
<td>7.6</td>
<td>7.6</td>
<td>7.7†</td>
<td>7.6</td>
<td>7.5*</td>
<td>7.7*</td>
<td>7.5</td>
<td>7.5</td>
<td>7.7</td>
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</tr>
<tr>
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<td>122</td>
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<td>7.6</td>
<td>7.7†</td>
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<td>7.3</td>
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<td>7.1</td>
<td>7.7</td>
<td>7.4</td>
</tr>
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<td>122</td>
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<td>7.6*</td>
<td>7.5</td>
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<td>7.8</td>
<td>7.5</td>
<td>7.5</td>
<td>7.8</td>
<td>7.5</td>
</tr>
<tr>
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<td>122</td>
<td>7.5</td>
<td>7.5</td>
<td>7.7†</td>
<td>7.7</td>
<td>7.3</td>
<td>7.8</td>
<td>7.6</td>
<td>7.3</td>
<td>7.7</td>
<td>7.5</td>
</tr>
</tbody>
</table>

**.† 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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Annual N</th>
<th>Color</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
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<td></td>
<td></td>
<td>None</td>
<td>26</td>
<td>4</td>
<td>27</td>
<td>29</td>
<td>4</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Jul</td>
<td>Aug</td>
<td>Aug</td>
<td>Sep</td>
<td>Aug</td>
<td>Aug</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meyer vs.</td>
<td>183</td>
<td>7.8</td>
<td>7.7</td>
<td>8.2</td>
<td>7.7</td>
<td>7.6</td>
<td>8.2</td>
<td>7.5</td>
</tr>
<tr>
<td>8701</td>
<td>183</td>
<td>7.7</td>
<td>7.5</td>
<td>7.8*</td>
<td>7.5</td>
<td>7.3</td>
<td>7.8*</td>
<td>7.5</td>
</tr>
<tr>
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<td>183</td>
<td>7.9</td>
<td>7.6</td>
<td>7.8*</td>
<td>7.4†</td>
<td>7.3</td>
<td>7.8*</td>
<td>7.4</td>
</tr>
<tr>
<td>El Toro</td>
<td>183</td>
<td>7.5*</td>
<td>7.5†</td>
<td>8.0</td>
<td>7.6</td>
<td>7.4</td>
<td>8.0</td>
<td>7.5</td>
</tr>
<tr>
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<td>7.7</td>
<td>7.6**</td>
<td>7.5</td>
<td>7.5</td>
<td>7.7**</td>
<td>7.4</td>
</tr>
<tr>
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<td>183</td>
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<td>7.4†</td>
<td>7.7*</td>
<td>7.7</td>
<td>7.3</td>
<td>7.8*</td>
<td>7.6</td>
</tr>
<tr>
<td>8516</td>
<td>183</td>
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<td>7.9</td>
<td>7.7</td>
<td>7.7</td>
<td>7.4</td>
<td>7.9†</td>
<td>7.6</td>
</tr>
<tr>
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<td>183</td>
<td>7.4*</td>
<td>7.7*</td>
<td>7.7*</td>
<td>7.8†</td>
<td>7.1*</td>
<td>7.8*</td>
<td>7.1*</td>
</tr>
<tr>
<td>Emerald</td>
<td>183</td>
<td>7.7</td>
<td>7.6</td>
<td>7.8*</td>
<td>7.4†</td>
<td>7.4</td>
<td>7.8*</td>
<td>7.6</td>
</tr>
<tr>
<td>8508</td>
<td>183</td>
<td>7.7</td>
<td>7.7</td>
<td>8.0</td>
<td>7.6</td>
<td>7.1*</td>
<td>8.0</td>
<td>7.3</td>
</tr>
<tr>
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<td>7.6</td>
<td>7.9</td>
<td>7.5</td>
<td>7.5</td>
<td>8.0</td>
<td>7.4</td>
</tr>
<tr>
<td>8514</td>
<td>183</td>
<td>7.6†</td>
<td>7.5</td>
<td>8.0</td>
<td>7.7</td>
<td>7.2</td>
<td>7.8*</td>
<td>7.6</td>
</tr>
</tbody>
</table>

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

**kg ha\(^{-1}\) = dark green; 1 = no green**
Table 20. Chlorosis, mottling and scalping in 1992 prior to imposing N level or traffic treatments.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Chlorosis 3 August (% Plot)</th>
<th>Mottling 3 September (% Plot)</th>
<th>Scalp 3 September</th>
<th>Scalp 6 October</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meyer</td>
<td>0.7b</td>
<td>1.3bc</td>
<td>9.0a</td>
<td>9.0a</td>
</tr>
<tr>
<td>DALZ 8701</td>
<td>0b</td>
<td>0c</td>
<td>8.7ab</td>
<td>8.7ab</td>
</tr>
<tr>
<td>DALZ 8502</td>
<td>0b</td>
<td>5.0bc</td>
<td>7.4c</td>
<td>7.2c</td>
</tr>
<tr>
<td>El Toro</td>
<td>1.7b</td>
<td>0c</td>
<td>9.0a</td>
<td>9.0a</td>
</tr>
<tr>
<td>DALZ 8507</td>
<td>1.7b</td>
<td>4.3bc</td>
<td>9.0a</td>
<td>9.0a</td>
</tr>
<tr>
<td>DALZ 8512</td>
<td>5.0b</td>
<td>0.7bc</td>
<td>9.0a</td>
<td>9.0a</td>
</tr>
<tr>
<td>DALZ 8516</td>
<td>48.3a</td>
<td>49.3a</td>
<td>9.0a</td>
<td>9.0a</td>
</tr>
<tr>
<td>DALZ 8501</td>
<td>0b</td>
<td>0c</td>
<td>5.5d</td>
<td>5.2d</td>
</tr>
<tr>
<td>Emerald</td>
<td>10.7b</td>
<td>11.7b</td>
<td>8.3b</td>
<td>9.0a</td>
</tr>
<tr>
<td>DALZ 8508</td>
<td>0.7b</td>
<td>3.3bc</td>
<td>7.1c</td>
<td>8.7ab</td>
</tr>
<tr>
<td>DALZ 9006</td>
<td>11.7b</td>
<td>6.7bc</td>
<td>7.4c</td>
<td>8.2b</td>
</tr>
<tr>
<td>DALZ 8514</td>
<td>7.3b</td>
<td>0c</td>
<td>9.0a</td>
<td>9.0a</td>
</tr>
<tr>
<td>LSD (0.5) =</td>
<td>18.5</td>
<td>11.2</td>
<td>.25</td>
<td>.31</td>
</tr>
<tr>
<td>Sign F-test</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>CV (%) =</td>
<td>150</td>
<td>96</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

*Mottling. Due to rust (Meyer), unknown (8516), or tendency to scalp (8502, 8508, 9006, 8501, and Emerald).

*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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Leaf Texture</th>
<th>Rhizomes</th>
<th>Weight</th>
<th>Verdure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aug</td>
<td>Aug</td>
<td>Jul 92</td>
<td>Sep 93</td>
</tr>
<tr>
<td>Meyer</td>
<td>4.4b</td>
<td>3.1a</td>
<td>0.6c</td>
<td>1.7b</td>
</tr>
<tr>
<td>8701</td>
<td>3.0e</td>
<td>2.1b</td>
<td>5.3b</td>
<td>7.4b</td>
</tr>
<tr>
<td>8502</td>
<td>2.5f</td>
<td>1.0c</td>
<td>9.5a</td>
<td>10.0ab</td>
</tr>
<tr>
<td>El Toro</td>
<td>5.0a</td>
<td>3.4a</td>
<td>2.3bc</td>
<td>3.9b</td>
</tr>
<tr>
<td>8507</td>
<td>2.9ef</td>
<td>1.2c</td>
<td>2.3bc</td>
<td>8.8ab</td>
</tr>
<tr>
<td>8512</td>
<td>5.0a</td>
<td>3.4a</td>
<td>3.7bc</td>
<td>4.4b</td>
</tr>
<tr>
<td>8516</td>
<td>3.6c</td>
<td>2.6b</td>
<td>2.2bc</td>
<td>3.7b</td>
</tr>
<tr>
<td>8501</td>
<td>3.5cd</td>
<td>1.1c</td>
<td>2.8bc</td>
<td>2.9b</td>
</tr>
<tr>
<td>Emerald</td>
<td>3.1de</td>
<td>1.4c</td>
<td>4.3bc</td>
<td>19.3a</td>
</tr>
<tr>
<td>8508</td>
<td>2.9e</td>
<td>1.3c</td>
<td>2.7bc</td>
<td>2.0b</td>
</tr>
<tr>
<td>9006</td>
<td>2.8ef</td>
<td>1.2c</td>
<td>3.0bc</td>
<td>1.5b</td>
</tr>
<tr>
<td>8514</td>
<td>5.0a</td>
<td>3.3a</td>
<td>1.7bc</td>
<td>3.9b</td>
</tr>
<tr>
<td>LSD (.05)</td>
<td>0.4</td>
<td>0.4</td>
<td>4.0</td>
<td>10.6</td>
</tr>
<tr>
<td>Sign F-test</td>
<td>**</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CV(%)</td>
<td>13</td>
<td>10</td>
<td>70</td>
<td>108</td>
</tr>
</tbody>
</table>

*Volume per 1646 cm² 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.

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

<sup>2</sup>Total Root Length: cm of roots per cm² 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.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Water Extraction</th>
<th>Evapotranspiration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28 August to 3 September</td>
<td>28 August to 3 September</td>
</tr>
<tr>
<td></td>
<td>0 to 10cm</td>
<td>10 to 20cm</td>
</tr>
<tr>
<td>Meyer</td>
<td>8.7ab</td>
<td>5.8ab</td>
</tr>
<tr>
<td>DALZ 8701</td>
<td>6.2b</td>
<td>5.4ab</td>
</tr>
<tr>
<td>DALZ 8502</td>
<td>7.3ab</td>
<td>4.6b</td>
</tr>
<tr>
<td>El Toro</td>
<td>7.2ab</td>
<td>5.2ab</td>
</tr>
<tr>
<td>DALZ 8507</td>
<td>8.2ab</td>
<td>4.9ab</td>
</tr>
<tr>
<td>DALZ 8512</td>
<td>9.8a</td>
<td>5.0ab</td>
</tr>
<tr>
<td>DALZ 8516</td>
<td>7.9ab</td>
<td>5.8ab</td>
</tr>
<tr>
<td>DALZ 8501</td>
<td>8.7ab</td>
<td>5.9a</td>
</tr>
<tr>
<td>Emerald</td>
<td>7.0b</td>
<td>5.9a</td>
</tr>
<tr>
<td>DALZ 8508</td>
<td>6.9b</td>
<td>5.5ab</td>
</tr>
<tr>
<td>DALZ 9006</td>
<td>7.9ab</td>
<td>5.8ab</td>
</tr>
<tr>
<td>DALZ 8514</td>
<td>7.0b</td>
<td>5.7ab</td>
</tr>
<tr>
<td>LSD (0.5) =</td>
<td>2.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Sign F-test =</td>
<td>.70</td>
<td>.66</td>
</tr>
<tr>
<td>CV (%)</td>
<td>26</td>
<td>16</td>
</tr>
</tbody>
</table>

**Note:** 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.

<table>
<thead>
<tr>
<th>Source</th>
<th>Evapotranspiration</th>
<th>Root Water Extraction by Soil Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13 to 27 Jul</td>
<td>24 to 19 Jul</td>
</tr>
<tr>
<td></td>
<td>19 Jul to 3 Aug</td>
<td>30 Aug</td>
</tr>
<tr>
<td>Cultivar(C)</td>
<td>NS²</td>
<td>*</td>
</tr>
<tr>
<td>Traffic (T)</td>
<td>-</td>
<td>*</td>
</tr>
<tr>
<td>CxT</td>
<td>-</td>
<td>NS</td>
</tr>
</tbody>
</table>

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

*Note:* 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\(^{-1}\).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Traffic</th>
<th>0 to 10 Jul</th>
<th>10 to 20 Jul</th>
<th>20 to 60 Jul</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meyer at No vs</td>
<td>10 cm</td>
<td>11.73</td>
<td>7.00</td>
<td>7.60</td>
</tr>
<tr>
<td>10 cm</td>
<td>9.03</td>
<td>6.47</td>
<td>6.27</td>
<td>9.67</td>
</tr>
<tr>
<td>20 cm</td>
<td>10.80</td>
<td>7.23</td>
<td>6.00</td>
<td>10.27</td>
</tr>
<tr>
<td>60 cm</td>
<td>10.77</td>
<td>8.33</td>
<td>4.80</td>
<td>8.27</td>
</tr>
<tr>
<td>El Toro</td>
<td>10.90</td>
<td>6.03</td>
<td>8.93</td>
<td>9.30</td>
</tr>
<tr>
<td>8507</td>
<td>9.13</td>
<td>5.43</td>
<td>12.13*</td>
<td>8.77</td>
</tr>
<tr>
<td>8512</td>
<td>10.87</td>
<td>6.03</td>
<td>4.27‡</td>
<td>9.03</td>
</tr>
<tr>
<td>8516</td>
<td>11.07</td>
<td>6.77</td>
<td>10.67</td>
<td>9.57</td>
</tr>
<tr>
<td>8501</td>
<td>10.10</td>
<td>8.13</td>
<td>9.47</td>
<td>9.57</td>
</tr>
<tr>
<td>8508</td>
<td>11.07</td>
<td>7.33</td>
<td>3.87*</td>
<td>11.23</td>
</tr>
<tr>
<td>9006</td>
<td>11.10</td>
<td>7.27</td>
<td>5.47</td>
<td>9.03</td>
</tr>
<tr>
<td>8514</td>
<td>12.17</td>
<td>6.13</td>
<td>15.20*</td>
<td>12.97</td>
</tr>
</tbody>
</table>

Sign F-test = .99 .79 .32 .78 .21 .35 .67 .23 .58
CV(%) = 30 28 28 30 55 130 43 46 125

**,**,* 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\(^{-1}\).

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

** † ‡ ‡‡ † 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\(^{-1}\).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Traffic</th>
<th>27 Jul to 3 Aug</th>
<th>24 to 30 Aug</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 to 10 cm</td>
<td>10 to 20 cm</td>
<td>20 to 60 cm</td>
</tr>
<tr>
<td>Meyer at WC vs</td>
<td>8.90</td>
<td>2.33</td>
<td>2.27</td>
</tr>
<tr>
<td>8701</td>
<td>5.80*</td>
<td>1.80</td>
<td>8.53</td>
</tr>
<tr>
<td>8502</td>
<td>8.40</td>
<td>2.90</td>
<td>11.80**</td>
</tr>
<tr>
<td>El Toro</td>
<td>7.97</td>
<td>2.70</td>
<td>5.60</td>
</tr>
<tr>
<td>8507</td>
<td>10.33</td>
<td>3.43</td>
<td>8.00</td>
</tr>
<tr>
<td>8512</td>
<td>8.76</td>
<td>1.83</td>
<td>10.13†</td>
</tr>
<tr>
<td>8516</td>
<td>6.13†</td>
<td>2.67</td>
<td>4.13</td>
</tr>
<tr>
<td>8501</td>
<td>7.33</td>
<td>1.63</td>
<td>.84</td>
</tr>
<tr>
<td>Emerald</td>
<td>10.00</td>
<td>2.20</td>
<td>4.27</td>
</tr>
<tr>
<td>8508</td>
<td>3.33**</td>
<td>2.93</td>
<td>0</td>
</tr>
<tr>
<td>9006</td>
<td>4.60*</td>
<td>3.07</td>
<td>11.77**</td>
</tr>
<tr>
<td>8514</td>
<td>4.80*</td>
<td>3.77</td>
<td>6.40</td>
</tr>
</tbody>
</table>

Sign F-test: **, †Indicates significant difference at the 1, 5, and 10% levels, respectively.
Table 28. Evapotranspiration under traffic treatments and at the 122 kg ha⁻¹ annual N level in 1993, and ET averages.

<table>
<thead>
<tr>
<th>Contrasts</th>
<th>No Traffic</th>
<th>Evapotranspiration</th>
<th>Wear + Compaction</th>
<th>Avg. 1993</th>
<th>Avg. 92+93</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13 to 19 Jul</td>
<td>27 Jul to 3 Aug</td>
<td>24 to 30 Aug</td>
<td>27 Jul to 3 Aug</td>
<td>24 to 30 Aug</td>
</tr>
<tr>
<td>Meyer vs.</td>
<td>4.39</td>
<td>3.75</td>
<td>5.58</td>
<td>3.82</td>
<td>3.23</td>
</tr>
<tr>
<td>8701</td>
<td>3.63</td>
<td>3.81</td>
<td>3.96</td>
<td>2.40</td>
<td>3.19</td>
</tr>
<tr>
<td>8502</td>
<td>4.01</td>
<td>3.97</td>
<td>4.54</td>
<td>1.91†</td>
<td>1.41†</td>
</tr>
<tr>
<td>El Toro</td>
<td>3.98</td>
<td>2.70</td>
<td>3.50</td>
<td>2.22</td>
<td>3.52</td>
</tr>
<tr>
<td>8507</td>
<td>4.31</td>
<td>3.40</td>
<td>2.04**‡</td>
<td>1.78*</td>
<td>1.52‡</td>
</tr>
<tr>
<td>8512</td>
<td>4.45</td>
<td>2.09</td>
<td>3.77</td>
<td>2.80</td>
<td>2.11</td>
</tr>
<tr>
<td>8516</td>
<td>3.53</td>
<td>2.33</td>
<td>3.69</td>
<td>2.00†</td>
<td>5.42‡</td>
</tr>
<tr>
<td>8501</td>
<td>4.75</td>
<td>2.30</td>
<td>3.81</td>
<td>1.81*</td>
<td>1.92</td>
</tr>
<tr>
<td>Emerald</td>
<td>4.62</td>
<td>3.02</td>
<td>5.01</td>
<td>2.51</td>
<td>2.86</td>
</tr>
<tr>
<td>8508</td>
<td>3.71</td>
<td>1.97</td>
<td>4.30</td>
<td>1.72*</td>
<td>3.57‡</td>
</tr>
<tr>
<td>9006</td>
<td>3.97</td>
<td>3.14</td>
<td>3.03</td>
<td>3.05</td>
<td>2.61‡</td>
</tr>
<tr>
<td>8514</td>
<td>5.58</td>
<td>4.75</td>
<td>4.71</td>
<td>2.50</td>
<td>4.30</td>
</tr>
<tr>
<td>Sign F-Test</td>
<td>.73</td>
<td>.43</td>
<td>.71</td>
<td>.38</td>
<td>.56**</td>
</tr>
<tr>
<td>CV(%)</td>
<td>.28</td>
<td>.58</td>
<td>.61</td>
<td>.53</td>
<td>.115</td>
</tr>
<tr>
<td>Average</td>
<td>-</td>
<td>3.10</td>
<td>4.00</td>
<td>2.38</td>
<td>2.97</td>
</tr>
</tbody>
</table>

**†**: 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.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 to 10 cm 10 cm 20 cm 30 cm 40 cm</td>
<td>0 to 10 cm 20 cm 30 cm 40 cm 60 cm</td>
</tr>
<tr>
<td>Soil pH</td>
<td>4.50 5.04 5.65 5.75</td>
<td>4.74 5.23 5.71 6.05 6.20</td>
</tr>
<tr>
<td>Base Cations (meq. 100 g⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>1.71 1.90 2.26 2.15</td>
<td>.97 1.56 1.83 1.92 2.04</td>
</tr>
<tr>
<td>Mg</td>
<td>.39 .36 .49 .53</td>
<td>.13 .23 .34 .50 .57</td>
</tr>
<tr>
<td>K</td>
<td>.33 .27 .29 .25</td>
<td>.22 .22 .28 .34 .21</td>
</tr>
<tr>
<td>Na</td>
<td>.04 .02 .01 .01</td>
<td>.18 .05 .05 .05 .17</td>
</tr>
<tr>
<td>Acid Cations (meq. 100 g⁻¹)</td>
<td>4.24 3.84 2.56 3.44</td>
<td>3.92 2.95 2.56 2.96 2.79</td>
</tr>
<tr>
<td>Al</td>
<td>.23 .06 .02 .01</td>
<td>.58 .14 .03 .01 .01</td>
</tr>
<tr>
<td>Cation Exchange Capacity (meq. 100 g⁻¹)</td>
<td>6.93 6.44 5.63 6.38</td>
<td>6.00 5.15 5.09 5.78 5.79</td>
</tr>
<tr>
<td>Base Saturation (%)</td>
<td>36 40 54 46</td>
<td>25 40 49 49 52</td>
</tr>
<tr>
<td>Extractable Nutrients (ppm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>56VH 35H 23H 7L</td>
<td>57VH 43VH 27H 2L 1L</td>
</tr>
<tr>
<td>K</td>
<td>100M 83M 64M 71M</td>
<td>68M 69M 83M 92M 55M</td>
</tr>
<tr>
<td>Ca</td>
<td>399H 446H 530H 450H</td>
<td>263H 381H 417H 367H 370H</td>
</tr>
<tr>
<td>Mg</td>
<td>111L 10L 14L 15L</td>
<td>17L 29L 41L 62 69</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>.08 .07 .03 .04</td>
<td>- - - -</td>
</tr>
<tr>
<td>Organic Matter Content (%)</td>
<td>.98 .76 .47 .52</td>
<td>1.46 .99 .74 .30 .26</td>
</tr>
</tbody>
</table>

¹L = 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

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POTENTIAL RESISTANCE IN ZOYSIAGRASSES
TO TAWNY MOLE CRICKETS (ORTHOPTERA: GRYLLOTALPIDAE)

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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 m² 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 cm² 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 m². Georgia Cooperative Extension Service recommendations suggest that chemical intervention to protect turf may be required at adult densities of 1 cricket per 0.09 m². 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.
ACKNOWLEDGMENT

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REFERENCES CITED


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

Running head: Braman et al.: Zoysiagrass susceptibility to S. vicinus
**TABLE 1. ZOYSIAGRASS RESPONSE TO ADULT S. VICINUS**

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Shoot dry weight</th>
<th>Root dry weight</th>
<th>Shoot density per 18 cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 wk</td>
<td>4 wk</td>
<td>total</td>
</tr>
<tr>
<td>DALZ8502</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DALZ8514</td>
<td>73.0 a</td>
<td>41.6 ab</td>
<td>55.0 ab</td>
</tr>
<tr>
<td>Emerald</td>
<td>100 a</td>
<td>41.0 ab</td>
<td>54.7 ab</td>
</tr>
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<td>DALZ8701</td>
<td>72.4 a</td>
<td>42.2 ab</td>
<td>52.9 ab</td>
</tr>
<tr>
<td>DALZ8507</td>
<td>75.5 a</td>
<td>34.1 abc</td>
<td>50.7 ab</td>
</tr>
<tr>
<td>DALZ8508</td>
<td>75.6 a</td>
<td>23.0 bc</td>
<td>41.6 abc</td>
</tr>
<tr>
<td>El Toro</td>
<td>59.4 a</td>
<td>27.6 bc</td>
<td>41.3 abc</td>
</tr>
<tr>
<td>DALZ8512</td>
<td>60.6 a</td>
<td>25.1 bc</td>
<td>38.8 bc</td>
</tr>
<tr>
<td>DALZ8501</td>
<td>58.2 a</td>
<td>21.5 bc</td>
<td>37.4 bc</td>
</tr>
<tr>
<td>Meyer</td>
<td>55.5 a</td>
<td>19.1 bc</td>
<td>34.9 bc</td>
</tr>
<tr>
<td>DALZ9006</td>
<td>48.6 a</td>
<td>25.1 bc</td>
<td>34.7 bc</td>
</tr>
<tr>
<td>DALZ8516</td>
<td>49.0 a</td>
<td>10.1 bc</td>
<td>25.2 c</td>
</tr>
</tbody>
</table>

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

Mean # of eggs per 4 weeks

Zoysiagrass Cultivar

8502 8514 8701 8507 8508 8512 8501 Meyer 9006 8516