UNIVERSITY OF GEORGIA

SEEDED BERMUDAGRASS WATER USE, ROOT AND SHOOT GROWTH UNDER SOIL STRESSES

1994 Research Grant: $12,359
(Second Year of Support)

Dr. Robert N. Carrow
Principal Investigator

Bermudagrasses (*Cynodon* spp.) are drought resistant grasses in many areas of the southern United States. In the Piedmont region, as well as Utisol and Oxisol soils world-wide, turfgrass root growth can be inhibited by the soil stresses a) high soil strength, and b) acid soil complex, a combination of element toxicities with nutrient deficiencies. Genotypes of bermudagrass may differ in tolerance to these stresses. Objectives of this project were to evaluate eight seeded bermudagrass genotypes from Dr. C. M. Taliaferro's USGA supported breeding program at Oklahoma State University versus two commercial cultivars (AZ common, Primavera) under 3 traffic levels and 3 N-regimes for:

a) ET, drought resistance, rooting/water extraction patterns and shoot responses will be determined under field conditions. These data are essential if the USGA is to substantiate that their turfgrasses are truly superior in these characteristics.

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

Results to date:

1. The most rapid establishment was observed for Primavera, 91-2, 91-1, and AZ common, while least were 91-14, 91-12, and 91-3.

2. AZ common and Primavera exhibited some winterkill (i.e., 5-10%), while no winter injury was noted on the experimentals.

Data has been obtained in 1994 on genotype responses under the traffic and N treatments for shoot aspects, rooting, water use, water extraction by root depth, and rhizome production. Further data will be obtained in 1995 before conclusions are developed.

October 1994

Progress Report

SEEDED BERMUDAGRASS WATER USE, ROOTING AND SHOOT GROWTH UNDER SOIL STRESSES

University of Georgia
Griffin, GA

Dr. Robert N. Carrow
Principal Investigator

1994 Research Grant: $12, 359
(Second Year of Support)

The primary objective of the USGA-supported turfgrass breeding programs is to develop grasses with high drought resistance including low evapotranspiration (ET). Also, the USGA states as a goal the development of basic cultural program/adaptation data on turfgrasses to be released. This would insure rapid acceptance of these grasses by golf course superintendents and other growers. The seeded bermudagrass project objectives will result in data directly related to the above-mentioned USGA goals.

a) ET, drought resistance, rooting/water extraction patterns and shoot responses will be determined under field conditions. These data are essential if the USGA is to substantiate that their turfgrasses are truly superior in these characteristics.

b) Basic cultural programs (fertility, disease/insect, traffic tolerance) will be 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 Oklahoma to determine environmental stability of these grasses with respect to environment, disease, and insect pressures.

In this project, a soil is used that imposes two of the major soil stresses that may inhibit root growth on sensitive genotypes; namely, high soil strength and the acid soil complex (i.e. combination of element toxicities, such as Al and Mn, and/or nutrient deficiencies of Mg, P, and/or K). These stresses are very common on Utisols and Oxisols. Any bermudagrass genotype able to develop and maintain a deep, extensive root system will have a major drought avoidance advantage.

Nine seeded bermudagrass (Cynodon spp.) experimentals from Dr. C. M. Taliaferro's USGA supported breeding program, and two commercial seeded bermudagrass cultivars (AZ common, Primavera) were seeded at l.25 lb/1000 ft^2 PLS on 8 June 1993. The experimental cultivars were: 91-1, 91-2, 91-3, 91-4, 91-10, 91-12, 91-14, and 91-15. During establishment in 1993, the grasses received fertilization as follows: 0.5 lb N/1000 ft^2 as 33-0-0 at seeding, 1.0 lb N 1 July (10-10-10), 1.0 lb N (33-0-0) 1 August, 1.0 lb N (10-10-10) 2 September, and l.0 lb N (10-10-10) on 29 March 1994. Mowing was at 1.0 inch with clippings returned in 1993, but lowered to 0.63 inch in 1994. In October 1993, boxes were installed for TDR soil moisture probes to determine water uptake by the roots from different soil zones and total water uptake (i.e. ET).

Once full turf cover was attained for all cultivars, the following treatments were initiated:

a) N-Programs. Annual N levels of 2.00, 4.00, and 6.00 lb N/1000 ft^2 split into three equal applications at mid-April, mid-June, and mid-August. Fertility treatments were initiated in April 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. <u>J. Sports Turf Res. Inst.</u> 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 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.

In April 1994, the three annual N treatments were initiated with applications on 25 April (33-0-0), 2 June (l0-10-10), and 5 August (33-0-0). Also, 1.0 lb P_2O_5 per 1,000 ft^2 was applied on 13 April (0-46-0). Traffic treatments were: 6X (i.e. six passes over the plot when the soil moisture was between field capacity and saturated) 16 May, 10X 26 June, 8X 13 July, 10X 2 August, 8X 28 September.

The study is a 10 cultivar X 3 traffic X 3 N-level factorial in a strip-strip completely randomized block with 3 replications. Main plots (cultivar) were 22 X 4 m . Analyses of data were a) when only cultivar treatment was present - completely randomized block, b) when only cultivars and traffic treatments were sampled at the 4.0 lb N/1000 ft^2 level - a 10 X 3 factorial in a randomized complete strip block, and c) with all treatments, the strip-strip arrangement was used with paired comparisons of cultivars versus AZ common at different traffic and N level combinations.

ESTABLISHMENT PHASE

Coverage. The summer of 1993 was drier than normal and somewhat warmer. By October 1993 most rapid coverage occurred for Primavera, 91-2, 91-1, and AZ Common, while least were 91-14, 91-12, and 91-3 (Table 1). Coming out of winter, greatest coverage was evident for 91-1, 91-15, and 91-2. Some reduction in turf coverage in April 1994 compared to October 1993 was observed for AZ Common (10%) and Primavera (5%), apparently due to low temperature injury. Increased coverage was noted for 91-14 (19%), 91-12 (7%) and 91-15 (5%), while all others were within ± 3% in coverage.

Spring Greenup. In early March 1994, 91-15, 91-10, 91-14, 91-4 and 91-3 had a higher spring greenup than AZ Common (Table 1). Part of the slower greenup of AZ Common was due to some winter injury. By 23 March, only 91-15 was significantly better than AZ Common in terms of early spring greenup rate.

Shoot Aspects. Turfgrass quality in October 1993 was similar across cultivars (Table 2), but in spring 1994, 91-15 exhibited the best visual quality. In late March, 91-2 had better quality than AZ Common and 91-1 showed higher quality in late April. All other cultivars were similar to AZ Common.

Cultivar 91-15, the only *Cynodon transvaalensis*; had much higher shoot density than the *Cynodon dactylon* cultivars (Table 2). Other cultivars tending to have greater shoot density than AZ Common were 91-1, 91-2, and 91-10.

Mid and late fall color data are in Table 2. In mid-fall best green color occurred for 91-3, 94-4, and 91-14. By late fall, none of the experimentals had better color retention in cold weather than AZ Common and several went dormant earlier; namely, 91-1, 91-15, 91-2, and Primavera.

MATURE PHASE

Shoot Aspects. Traffic and N-level effects on turfgrass visual quality (Tables 4, 5, 6), shoot density (Tables 7, 8, 9) and color (Tables 10, 11, 12) were determined in the July to September 1994 period. This will be continued through fall 1995 to provide at least 2 year's data for comparison of genotypes for traffic tolerance and N-level response.

Rhizomes. Rhizome production is important for a) recovery from winter injury, and b) regrowth in sod fields after harvesting. At 1 year after seeding, rhizome samples were obtained and data are presented in Table 3. Plots will be sampled again in summer 1995. Rhizomes showed much variability even with 2 samples per plot.

Roots. Roots were sampled in all cultivars under the 3 traffic regimes and 4.0 lb N/1000 ft^2 N-level on 17 July and 19 September. These are under preparation for analysis.

Water Relations. The summer of 1994 was a record year for rainfall, especially in July. Only one dry-down period occurred for determining water extraction by depth and evapotranspiration (ET). The dry-down in late August - early September allowed for leaf firing (Table 10, 11, 12), ET (Table 13), and water extraction by root depth (Table 14) data to be obtained.

Table 1. Coverage (1993, 1994), and spring greenup (1994) of seeded bermudagrasses.

Contrast and Cultivar	Coverage 1993 18 Oct	Coverage 1994 20 Apr	Spring Greenup‡ 1994 11 Mar	Spring Greenup‡ 1994 23 Mar
	———%———		———% Plot———	
AZ Common vs.	92	82	30	67
Primavera (FMC-1-90)	96	91	27	70
91-1	92	94*	37	73
91-2	96	93†	32	70
91-3	78*	79	38†	77
91-4	82†	85	40*	78
91-10	88	89	42*	73
91-12	72**	79	32	72
91-14	68**	87	40*	83
91-15	89	94*	63**	90*
Sign F test	**	†	**	.48
CV (%)	8	8	16	16

†,*,** Significant difference at .10, .05 and .01 probability levels.
‡ No winter injury was observed; thus ratings reflect inherent greenup rates.

Table 2. Quality, shoot density, and color ratings of seeded bermudagrasses in 1993-1994.

Contrast and Cultivar	Quality[z] 1993 18 Oct	Quality[z] 1994 23 Mar	Quality[z] 1994 20 Apr	Shoot Density[y] 1993 18 Oct	Shoot Density[y] 1994 23 Mar	Shoot Density[y] 1994 20 Apr	Color[x] 1993 18 Oct	Color[x] 1993 22 Nov
AZ Common vs.	6.3	5.0	5.1	7.4	5.2	5.3	5.5	4.0
Primavera	6.1	5.4	5.2	7.6	5.6	5.4	5.2	3.1*
91-1	6.1	5.4	5.9*	7.6	5.8†	6.3*	5.3	2.7**
91-2	6.5	5.6†	5.2	7.8†	6.3*	5.6	5.6	3.0*
91-3	6.6	5.2	5.0	7.5	5.5	5.2	6.1*	4.1
91-4	6.3	5.3	5.3	7.3	5.3	5.7	5.9†	4.0
91-10	6.0	5.3	5.3	7.5	5.7†	5.8	5.7	3.6
91-12	5.9	4.9	5.0	6.9*	4.8	5.3	5.8	4.1
91-14	5.9	4.6	5.4	7.1	4.7	5.7	5.9†	4.2
91-15	6.0	6.6**	6.8**	8.0*	7.7**	7.7**	5.1	3.1*
Sign. F-test	.72	*	**	*	**	**	*	**
CV(%)	8	9	9	4	7	9	6	13

†,*,**Significant difference at .10, .05, and .01 probability levels.

[z]Quality: 9 = ideal density, color, uniformity; 1 = no live turf.

[y]Shoot density: 9 = ideal; 1 = no live turf.

[x]Color: 9 = dark green; 1 = all brown.

Table 3. Rhizome volume and weight of 10 seeded bermudagrasses sampled 8 August 1994.

Contrast and Cultivar	Rhizome Volume‡	Rhizome Weight
	- cm^3 -	$mg \cdot 100\ cm^{-3}$
AZ Common vs.	.05	19
Primavera	.07	4
91-1	.18	70
91-2	.33	73
91-3	.11	34
91-4	.02	8
91-10	.23	50
91-12	.23	57
91-14	.17	52
91-15	.11	30
Sign. F-test	.77	.74
CV (%)	158	155

**,*,† Significant difference at .01, .05, and .10 probability levels, respectively.

‡Per 100 cm^3 soil volume. Sample depth to 6.0 cm.

Table 4. Turfgrass visual quality at 3 N-levels under the "none" traffic treatment in 1994.

Contrast		98 kg N ha^{-1}			196kg N ha^{-1}			294kg N ha^{-1}		
Cultivar	Traffic	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep
		—— 9 = ideal shoot density, color, uniformity; 1 = no live turf ——								
AZ Com. vs.	None	5.4	5.7	6.1	5.7	5.5	5.9	6.3	6.6	6.6
Primavera	"	5.7	6.0	5.8	5.2*	5.9	5.6	6.0	6.4	5.8**
91-1	"	5.9	5.8	6.2	6.0	5.9	6.2	6.4	6.4	6.5
91-2	"	5.8	5.9	5.8	5.9	6.1	6.3†	6.4	6.6	6.5
91-3	"	6.0†	6.4**	5.6†	6.0	6.6**	5.8	6.6	7.1†	5.9*
91-4	"	5.6	5.7	5.9	6.0	6.3*	5.9	6.5	6.8	6.1†
91-10	"	5.6	5.7	5.4**	5.2†	5.7	5.6	6.3	6.3	6.2
91-12	"	5.7	5.9	4.7**	5.7	5.8	4.7**	6.4	6.3	5.2**
91-14	"	5.6	6.3*	5.3**	5.9	5.7	5.2*	6.0	6.2	5.2**
91-15	"	6.1*	6.8**	6.5†	5.7	6.5*	6.7	6.6	6.9	7.0
Average =		5.7	6.0	5.7	5.7	6.0	5.8	6.4	6.6	6.1

**, *, † Indicates significant difference at 0.01, 0.05, and 0.10 probability levels, respectively.

Table 5. Turfgrass visual quality at 3 N-levels under the "soil compaction" traffic treatment in 1994.

Contrast		98 kg N ha^{-1}			196kg N ha^{-1}			294kg N ha^{-1}		
Cultivar	Traffic	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep
		—— 9 = ideal shoot density, color, uniformity; 1 = no live turf ——								
AZ Com. vs.	Compaction	5.3	5.5	5.7	5.0	6.0	5.5	5.7	6.2	6.3
Primavera	"	5.5	5.9	5.9	4.9	5.7	4.8*	5.4	6.2	5.6*
91-1	"	5.7	5.8	6.0	5.5*	5.8	6.0	5.5	6.0	6.0
91-2	"	5.6	5.7	5.7	5.7*	6.0	6.0	5.6	6.4	6.2
91-3	"	6.0*	6.1*	5.2	5.9**	6.4	5.3	5.9	6.5	5.5*
91-4	"	5.8	5.9	5.6	5.4†	5.9	5.4	6.1	6.4	6.0
91-10	"	5.3	5.8	5.7	5.1	5.8	5.3	5.3	6.1	5.8
91-12	"	5.8	5.7	4.7**	5.4†	5.6	4.7*	5.9	5.8	4.9**
91-14	"	5.7	5.8	4.9*	5.4†	5.4	4.8*	5.6	5.9	5.1**
91-15	"	5.5	6.3**	6.2	5.4†	5.6	6.7**	5.1*	6.5	7.0*
Average =		5.6	5.9	5.6	5.4	5.8	5.5	5.6	6.2	5.8

**, *, † Indicates significant difference at 0.01, 0.05, and 0.10 probability levels, respectively.

Table 6. Turfgrass visual quality at 3 N-levels under the "wear + soil compaction" traffic treatment in 1994.

Contrast		98 kg N ha^{-1}			196kg N ha^{-1}			294kg N ha^{-1}		
Cultivar	Traffic	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep
		—— 9 = ideal shoot density, color, uniformity; 1 = no live turf ——								
AZ Com. vs.	W + C‡	4.3	4.1	5.0	4.2	4.4	4.9	4.7	4.7	5.7
Primavera	"	4.2	4.2	4.5†	4.4	4.1	4.4	4.6	4.4	4.9†
91-1	"	4.6	4.7*	5.2	4.5†	4.7	5.8†	4.7	4.6	5.4
91-2	"	4.4	4.3	4.7	4.6*	5.0*	5.5	4.6	4.8	5.8
91-3	"	4.5	4.5†	4.5†	4.5†	4.8†	5.0	4.7	5.1	5.2
91-4	"	4.4	4.3	4.6	4.8**	5.0*	4.8	4.7	5.1	5.5
91-10	"	4.3	4.2	4.7	4.3	4.6	5.3	4.3	4.5	5.2
91-12	"	4.7*	4.2	4.1**	4.5†	4.4	4.2	4.6	4.2	4.4**
91-14	"	4.4	4.2	4.1**	4.5†	4.4	4.2	4.6	4.2	4.6*
91-15	"	4.2	4.2	5.6*	4.2	4.2	5.4	4.5	4.6	6.7*
Average =		4.4	4.3	4.7	4.5	4.6	5.0	4.6	4.6	5.3

**, *, † Indicates significant difference at 0.01, 0.05, and 0.10 probability levels, respectively.

‡ W + C = Wear + soil compaction.

Table 7. Turfgrass shoot density at 3 N-levels and under the "none" traffic treatment in 1994.

Contrast		98 kg N ha^{-1}			196kg N ha^{-1}			294kg N ha^{-1}		
Cultivar	Traffic	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep
		9 = ideal shoot density; 1 = no live turf								
AZ Com. vs.	None	5.7	6.0	6.2	5.8	5.7	6.1	6.6	7.0	6.8
Primavera	"	5.9	6.5†	6.2	5.5	6.3	5.8	6.3	6.9	6.0*
91-1	"	6.3*	6.3	6.3	6.2	6.3	6.5	6.9	6.7	6.6
91-2	"	6.1†	6.5†	6.1	6.1	6.5	6.7†	6.7	7.0	6.8
91-3	"	6.4*	6.9**	6.0	6.3†	7.0**	6.0	6.9	7.4	6.1*
91-4	"	5.9	6.2	6.0	6.3†	6.7*	6.1	6.8	7.2	6.3
91-10	"	5.9	6.1	5.6*	5.5	6.2	5.6	6.5	6.6	6.4
91-12	"	6.1	6.1	4.7**	5.9	6.3	4.8**	6.8	6.6	5.3**
91-14	"	5.9	6.8**	5.5**	6.2	6.0	5.2*	6.4	6.5	5.3**
91-15	"	6.8**	7.5**	7.3**	6.0	7.4**	7.2**	7.0	7.7*	7.5*
Average =		6.0	6.5	6.0	6.0	6.4	6.0	6.7	7.0	6.3

**, *, † Indicates significant difference at 0.01, 0.05, and 0.10 probability levels, respectively.

Table 8. Turfgrass shoot density at 3 N-levels and under the "soil compaction" traffic treatment in 1994.

Contrast		98 kg N ha^{-1}			196kg N ha^{-1}			294kg N ha^{-1}		
Cultivar	Traffic	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep
		9 = ideal shoot density; 1 = no live turf								
AZ Com. vs.	Compaction	5.5	5.9	5.8	5.2	6.3	5.9	6.1	6.4	6.4
Primavera	"	5.9	6.3	6.1	5.2	5.8	4.9*	5.7	6.6	5.8†
91-1	"	6.1†	6.3	6.2	5.8**	6.2	6.2	5.9	6.4	6.3
91-2	"	5.9	6.2	6.1	5.8**	6.3	6.1	6.7	7.0*	6.8
91-3	"	6.4*	6.7*	5.5	6.1**	6.9	5.4	6.5	6.8	5.7*
91-4	"	6.1†	6.2	5.8	5.8**	6.3	5.5	6.5	6.9†	6.2
91-10	"	5.6	6.1	5.7	5.4	6.2	5.3	5.7	6.4	6.0
91-12	"	6.2*	6.1	4.9*	5.7*	6.0	4.7**	6.2	6.2	4.9**
91-14	"	6.0	6.1	5.0*	5.7*	5.6	4.8**	6.0	6.3	5.1**
91-15	"	6.2*	7.2**	7.0**	5.9**	6.2	7.1**	5.7	7.2*	7.3**
Average =		6.0	6.3	5.8	5.7	6.2	5.6	6.1	6.6	6.1

**, *, † Indicates significant difference at 0.01, 0.05, and 0.10 probability levels, respectively.

Table 9. Turfgrass shoot density at 3 N-levels and under the "wear + soil compaction" traffic treatment in 1994.

Contrast		98 kg N ha^{-1}			196kg N ha^{-1}			294kg N ha^{-1}		
Cultivar	Traffic	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep	1 Jul	9 Aug	15 Sep
		9 = ideal shoot density; 1 = no live turf								
AZ Com. <u>vs.</u> W + C‡		4.3	4.2	5.1	4.3	4.5	5.0	4.7	4.8	5.9
Primavera	"	4.4	4.2	4.6	4.5	4.2	4.5	4.7	4.6	5.0*
91-1	"	4.7*	4.8	5.3	4.7*	4.8	6.0†	5.0	4.6	5.3
91-2	"	4.6†	4.4	4.8	4.7*	5.2*	5.7	4.7	4.9	5.9
91-3	"	4.7*	4.6	4.5*	4.7*	5.0	4.9	4.9	5.4†	5.2
91-4	"	4.5	4.4	4.7	4.9**	5.2*	4.9	4.9	5.2	5.7
91-10	"	4.3	5.3*	4.7	4.4	4.6	5.4	4.4	4.6	5.3
91-12	"	4.9**	4.2	4.1**	4.7*	4.3	4.3	4.9	4.3	4.4**
91-14	"	4.5	4.3	4.1**	4.6	4.4	4.2	4.7	4.3	4.6**
91-15	"	4.4	4.3	6.5**	4.3	4.2	5.8	4.7	4.8	7.4**
Average =		4.5	4.5	4.8	4.6	4.6	5.1	4.8	4.8	5.5

**, *, † Indicates significant difference at 0.01, 0.05, and 0.10 probability levels, respectively.
‡ W + C = Wear + soil compaction.

Table 10. Turfgrass color and leaf firing ratings at 3-N levels (kg N ha^{-1}) under the "none" traffic treatment in 1994.

Contrast		Color (9 Aug)			Leaf Firing (15 Sep)		
Cultivar	Traffic	98	196	294	98	196	294
		- 9 = dark green; 1= no green -			% Plot		
AZ Com. vs.	None	6.9	7.1	7.1	16	11	5
Primavera	"	7.1	7.1	7.3	12	9	12
91-1	"	7.0	7.0	7.3	7	4	6
91-2	"	7.2†	7.4*	7.4*	15	15	12
91-3	"	7.3*	7.4*	7.6**	17	9	12
91-4	"	7.3*	7.4*	7.6**	11	8	14
91-10	"	7.0	7.1	7.4*	12	9	5
91-12	"	7.4**	7.4*	7.6**	13	15	10
91-14	"	7.2†	7.4*	7.5*	17	15	15†
91-15	"	7.0	6.9	7.0	0*	0*	0
Average		7.1	7.2	7.4	12	10	9

**, *, † Indicates significant difference at 0.01, 0.05, and 0.10 probability levels, respectively.

Table 11. Turfgrass color and leaf firing ratings at 3-N levels (kg N ha^{-1}) under the "soil compaction" traffic treatment in 1994.

Contrast		Color (9 Aug)			Leaf Firing (15 Sep)		
Cultivar	Traffic	98	196	294	98	196	294
		- 9 = dark green; 1= no green -			% Plot		
AZ Com. vs. Compaction		7.0	7.0	7.2	16	13	6
Primavera	"	7.1	7.1	7.3	11	10	12
91-1	"	7.1	7.1	7.4	11	8	10
91-2	"	7.0	7.3†	7.3	19	11	13
91-3	"	7.3	7.4*	7.6**	16	15	9
91-4	"	7.3	7.4*	7.6**	13	17	13
91-10	"	7.0	7.2	7.3	14	14	6
91-12	"	7.2	7.5*	7.5*	11	20	13
91-14	"	7.2	7.3	7.5*	18	14	13
91-15	"	6.8	6.9	7.0	0	0	0
Average		7.1	7.2	7.4	13	12	10

**, *, † Indicates significant difference at 0.01, 0.05, and 0.10 probability levels, respectively.

Table 12. Turfgrass color and leaf firing ratings at 3-N levels (kg N ha^{-1}) under the "wear + soil compaction" traffic treatment in 1994.

Contrast		Color (9 Aug)			Leaf Firing (15 Sep)		
Cultivar	Traffic	98	196	294	98	196	294
		- 9 = dark green; 1= no green -			% Plot		
AZ Com. vs. W + C‡		7.1	7.1	7.4	10	11	1
Primavera	"	7.3	7.2	7.5	13	12	11
91-1	"	7.2	7.3	7.5	9	8	13
91-2	"	7.3	7.3	7.5	14	13	15
91-3	"	7.5†	7.3	7.6	14	15	20
91-4	"	7.2	7.4†	7.5	16	17	10
91-10	"	7.1	7.3	7.3	17	10	10
91-12	"	7.4	7.4†	7.6	14	14	8
91-14	"	7.4	7.4†	7.4	14	16	14
91-15	"	7.2	7.1	7.4	0	0	0
Average =		7.3	7.3	7.5	12	12	10

**, *, † Indicates significant difference at 0.01, 0.05, and 0.10 probability levels, respectively.
‡ W + C = Wear + soil compaction.

Table 13. Evapotranspiration for a dry-down during 23 August to 1 September 1994 (at 196 kg N ha^{-1} yr^{-1}).

Treatments		Daily Average ET		
Cultivar	Traffic	23 to 29 Aug	29 Aug - 1 Sep	23 Aug - 1 Sep
		mm d^{-1}		
AZ Common vs.	None‡	6.14	3.48	5.08
Primavera		7.84	3.82	6.23
91-1		10.36	2.82	7.34
91-2		6.26	2.77	4.86
91-3		3.48	2.68	3.16
91-4		7.20	3.53	5.73
91-10		6.99	3.22	5.48
91-12		7.14	3.87	5.83
91-14		6.73	3.52	5.45
91-15		8.60	4.45	6.94
AZ Common vs.	Soil Compaction	5.09	2.82	4.18
Primavera		8.30	3.57	6.41
91-1		8.51	2.02	5.91
91-2		5.21	3.05	4.35
91-3		7.86	3.47	6.10
91-4		4.99	2.97	4.18
91-10		6.40	4.77*	5.75
91-12		4.40	2.48	3.63
91-14		6.91	3.83	5.68
91-15		7.36	2.42	5.38
AZ Common vs.	Wear + Soil	8.08	2.47	5.83
Primavera	Compaction	9.13	3.47	6.87
91-1		7.19	2.85	5.45
91-2		5.84	2.92	4.67
91-3		6.39	2.73	4.93
91-4		5.42	2.93	4.43
91-10		6.06	3.62	5.08
91-12		7.69	2.93	5.79
91-14		9.12	2.92	6.64
91-15		6.98	3.37†	5.53
CV (%)		37	23	29
ANOVA				
Cultivar		.16	*	†
Traffic		.55	†	.50
CxT		.68	†	.53

**,*,†Significant difference at the 0.01, 0.05, and 0.10 probability levels, respectively.

‡Paired comparisons are within a traffic level.

Table 14. Water extraction by soil depth of 10 seeded bermudagrasses under 3 traffic regimes for the period 23 August to 1 September 1994 (at 196 kg N ha^{-1} yr^{-1}).

Treatments		23 to 29 Aug			29 Aug - 1 Sep			23 Aug - 1 Sep		
Cultivar	Traffic	0-10 cm	10-20 cm	20-60 cm	0-10 cm	10-20 cm	20-60 cm	0-10 cm	10-20 cm	20-60 cm
		cm								
AZ Common vs.	None‡	1.12	.58	1.99	.62	.45	.32	1.74	1.03	2.31
Primavera		1.25	.84	2.61	.63	.54	.36	1.88	1.38	2.97
91-1		1.88	1.59†	2.75	.37	.45	.31	2.25	2.03	3.05
91-2		1.13	.80	1.83	.57	.47	.07	1.69	1.27	1.89
91-3		.94	.43	.72	.40	.45	.23	1.34	.87	.95
91-4		1.81	1.27	1.24	.59	.50	.32	2.41	1.77	1.56
91-10		1.81	.96	1.43	.45	.56	.28	2.25	1.52	1.71
91-12		1.59	.66	2.04	.68	.45	.41	2.27	1.11	2.45
91-14		1.53	.88	2.01	.56	.54	.31	2.09	.60	2.32
91-15		1.83	.97	2.36	.56	.54	.68*	2.39	1.51	3.04
AZ Common vs.	Soil Comp.	.97	.71	1.37	.47	.41	.25	1.44	1.11	1.63
Primavera		1.33	1.02	2.63	.47	.57	.39	1.81	1.59	3.01
91-1		1.73	1.67†	1.71	.31	.35	.15	2.05	2.01	1.85
91-2		1.18	.68	1.27	.42	.41	.39	1.60	1.09	1.65
91-3		1.68	.98	2.05	.49	.56	.33	2.17	1.54	2.39
91-4		1.22	.79	.98	.43	.34	.41	1.65	1.13	1.40
91-10		1.36	.85	1.63	.55	.61	.75*	1.91	1.46	2.37
91-12		1.31	.61	.72	.36	.38	.25	1.67	.99	.97
91-14		1.27	.90	2.69	.49	.58	.45	1.75	1.39	3.14
91-15		1.51	.91	2.00	.33	.51	.12	1.84	1.42	2.12
AZ Common vs.	Wear+Comp.	1.63	.81	2.40	.49	.32	.17	2.13	1.13	2.57
Primavera		1.17	.75	3.56	.55	.51	.32	1.72	1.27	3.88
91-1		1.63	.93	1.76	.47	.43	.24	2.09	1.36	2.00
91-2		1.21	.63	1.67	.39	.47	.31	1.59	1.11	1.97
91-3		1.13	.59	2.12	.37	.42	.31	1.49	1.01	2.42
91-4		1.31	.74	1.20	.38	.46	.33	1.69	1.20	1.53
91-10		1.33	1.01	1.29	.56	.66*	.23	1.89	1.67	1.52
91-12		1.55	.71	2.36	.41	.36	.40	1.96	1.07	2.76
91-14		1.33	1.31	4.20	.40	.39	.37	1.73	1.37	4.57
91-15		1.02†	.69	2.48	.35	.44	.56*	1.37*	1.13	3.04
CV (%)		32	51	63	30	23	67	26	35	53
ANOVA										
Cultivar		.25	*	.13	.26	**	.45	.50	*	†
Traffic		.34	.53	.21	**	.23	.89	†	.40	.23
CxT		.46	.82	.93	.44	.50	.14	.40	.84	.81

**,*,†Significant difference at the 0.01, 0.05, and 0.10 probability levels, respectively.

‡Paired comparisons are within a traffic level.

Table 15. Analysis of variance for turf quality, shoot density, color, and leaf firing from 1 July to 15 September, 1994.

Cultivar	Turf Quality 1 Jul	Turf Quality 3 Aug	Turf Quality 15 Sep	Shoot Density 1 Jul	Shoot Density 9 Aug	Shoot Density 15 Sep	Color 9 Aug	Leaf Firing 15 Sep
Cultivar (C)	**	**	**	**	**	**	**	**
N-level (N)	**	**	**	**	**	**	**	*
C x N	.94	**	**	.89	**	**	.68	.35
Traffic (T)	**	**	**	**	**	**	**	.56
N x T	**	**	*	**	*	**	.24	.42
C x T	.88	**	.79	.79	**	.79	†	.68
C x N x T	.99	.99	.56	.99	.76	.31	.61	.89
CV (%)	8	6	6	8	7	6	2	7

**, *, † Significant difference at the .01, .05, and .10 probability levels, respectively.