Evapotranspiration and Leaf Extension Rates of 24 Well-watered, Turf-type *Cynodon* Genotypes

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

Department of Soil and Crop Sciences, Texas A&M University, College Station, TX 77843-2474

Additional index words. bermudagrass, mowing frequency, water conservation

Abstract. Cultivar selection is one method used for the conservation of irrigation water. The primary objective of this research was to evaluate the evapotranspiration (ET) rates of 24 well-watered, turf-type bermudagrass (*Cynodon* spp.) genotypes under field conditions and established on a fritted clay root zone contained in plastic minilysimeter pots. A secondary objective was to correlate ET rate to leaf extension rate, a potential rapidly assessed predictor of the amount of leaf surface area present for ET. ET rates were determined by the water-balance method. Both the overall ET and leaf extension rate differed significantly among genotypes. ET rates were not correlated with leaf extension rates in individual years. Our data indicated a potential for water savings based on bermudagrass cultivar selection that was similar to the reported potential water savings based on warm-season turfgrass species selection.

Bermudagrasses are well adapted for use as turf on recreational areas, lawns, and industrial/utility grounds throughout the humid and arid regions of the southern and western United States (Beard, 1973). Although they are a popular turf for nonirrigated sites, due to a high level of drought resistance (Kim, 1987), the production of quality, functional bermudagrass turf requires supplemental irrigation. Because water conservation is an important concern, a combination of management practices is needed, coupled with the selection of turfgrass species and cultivars with low ET rates (Beard, 1985). Results from prior studies suggested a potential for water savings based on species and cultivar selection of warm-season turfgrasses (Kim and Beard, 1988) and cultivar selection of cool-season turfgrasses (Kopeck et al., 1988; Shearman, 1986, 1989). We found no reports on ET rates for a substantial collection of turf-type bermudagrasses.

There is a need to identify simple, rapidly assessed plant traits for the prediction of ET rates among turfgrasses. Kim and Beard (1988) suggested that leaf extension rate may be an indicator of the total amount of leaf surface area present for ET at the interspecies level. They and Johns (1980) suggested that grasses with comparatively lower ET rates under well-watered conditions were generally characterized by a small leaf surface area present for ET, including a slow leaf extension rate and narrow leaves.

The primary objective of this research was

to compare ET rates among 24 well-watered, turf-type bermudagrass genotypes under field conditions. A secondary objective was to correlate ET rates with leaf extension rates.

Genotypes evaluated were: *Cynodon dactylon* (L.) Pers. 'Arizona Common', 'Bayshore', 'Everglades', FB-119, 'Ormond', Texturf IF, Texturf 10, 'Tufcote', 'U-3', and 'Vamont'; *C. dactylon* × *C. transvaalensis* Burt-Davy and reciprocal A-22, A-29, 'Midiron', 'Midway', 'Pee Dee', 'Santa Ana', 'Tifdwarf', 'Tiffine', 'Tifgreen', 'Tifgreen II', 'Tiflawn', 'Tifway', and 'Tifway II'; and *C. magennissii* Hurcombe 'Sunturf'. Three replicate plugs, 210 mm in diameter, of each genotype were collected from mature turf plots located at the Turfgrass Field Research Laboratory of Texas A&M Univ., College Station, in May 1984; exceptions were A-22, A-29, 'Tifgreen II', and 'Tufcote', which were collected in Sept. 1984 and were not included in the 1984 evaluations. Roots were severed 25 mm below the soil surface of each plug, and the soil was removed by washing. Plugs were individually transplanted onto a growth medium of fritted clay (Van Bavel et al., 1978) contained in black plastic minilysimeter pots (Johns et al., 1983) that were 210 mm in diameter and 210 mm deep. The plugs were rooted under glasshouse conditions in which air maxima and minima did not exceed 35 and 24°C, respectively. Turfs were fertilized biweekly with a nutrient solution (20.0N-8.8P-16.6K plus micronutrients) at 5.0 g N/m² per month. They were mowed weekly at a 25mm cutting height by use of a reel mower, and clippings were removed. The turfs were watered to prevent visual wilt symptoms during the entire study.

This study was conducted from May 1984 to Aug. 1986 with minilysimeters maintained in the field from May through October and in a glasshouse from November through April; the exception was 1984, when minilysimeters were not transferred to the field

until July. They received 5.0 g N/m² per month as biweekly applications of a granular fertilizer (21.0N-0.0P-0.0K) when in the field and as biweekly applications of a nutrient solution (20.0N-8.8P-16.6K plus micronutrients) when in the glasshouse. There was no noticeable shoot thinning nor disease or insect problems for the duration of the study. A visual inspection following completion of the study indicated no concentrated root mass at the bottom or sides of the minilysimeters.

Evaluations of ET rates and leaf extension rates were conducted Sept. 1984, June 1985, and July and Aug. 1986. Three or four measurements (subsamples) of ET and leaf extension rate were taken each year. A measurement consisted of determining ET rates by the water-balance method (Johns et al., 1983) between the 24th and 48th hours following mowing and saturation with water. Leaf extension rates were determined during the 48 h following mowing and saturation with water and then were converted to a 24-h basis. ET rates were evaluated under well-watered conditions to minimize ET rate being confounded by possible genotypic differences in rooting and consequently the capability to extract moisture from the soil. Under these conditions, it was assumed that ET rates were not limited by soil moisture. The minilysimeters were placed in individual, mature-turfed field plots, 1.8 × 3.0 m (width/length), which were arranged in three complete blocks. The field-plot construction (Kim and Beard, 1988) allowed for the lysimeter turf canopy to be contiguous with the surrounding turf canopy of the field plot. Leaf extension rates were determined by measuring the height of 10 leaf blades per minilysimeter immediately following mowing and measuring a second subsample, consisting of 10 leaf blades, 48 h later. Some oasis effect would be expected from placing minilysimeters in field plots. We assumed that the relative differences in ET and leaf extension rates among the genotypes would be similar. Daily maximum and minimum air temperatures 1.5 m above the soil surface, pan evaporation, wind speed at 0.3 m above the soil surface, and solar radiation at 3.0 m above the soil surface were measured at a class A National Weather Service Station located 41 m from the ET experimental site during ET rate measurements (Table 1).

Analysis of variance (ANOVA) was conducted on ET and leaf extension rate subsample means for individual years using a randomized complete-block design with three replications and over all years in a repeated-measures design with genotypes as main plots and years as the repeated-measures factor. A general linear model (GLM) procedure was used for the overall ANOVA because four genotypes were missing in 1984. The arithmetic means of the overall ET and leaf extension rates were presented because the least-squares means of the four genotypes we used could not be estimated by a least-squares means option of the GLM procedure. Therefore, some caution should be exercised when comparing overall arithmetic means, because cell sizes were not equal. Pearson cor-

Received for publication 2 July 1991. Accepted for publication 6 May 1992. Texas Agr. Expt. Sta. Journal Article no. TA 29095. A major portion of this investigation has been made possible by a grant from the U.S. Golf Assn. Green Section. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

Table 1. Average daily environmental measurements taken during selected months between 1984 and 1986 during the evapotranspiration rate measurements.

Year ^c	Air temp (°C) ^b				Pan evaporation (mm·day ⁻¹)		Wind speed ^a (m·s ⁻¹)		Photoperiod (h)		Solar radiation (MJ·m ⁻² ·d a y ⁻¹)	
	Max		Min		X	SE	X	SE	X	SE	X	SE
	X	SE	X	SE								
1984	32.8 ^c	0.6	19.7 ^c	0.9	7.0 ^c	0.9	2.5 ^c	0.2	12.34	0.04	20.9 ^c	1.0
1985	32.5	1.9	20.0	3.3	10.2	2.5	3.5	0.9	13.94	0.01	26.4	1.5
1986	36.0	1.0	22.6	0.3	10.1	0.7	0.9	0.2	12.56	0.05	15.8	3.2

^aSept. 1984; June 1985; July-Aug. 1986.^bMaximum and minimum air temperatures measured 1.5 m above soil surface.^cWind speed measured 0.3 m above soil surface.^dSolar radiation measured 3.0 m above soil surface.^eMeans are the average of 6 to 8 days (2 days per ET rate subsample × three to four subsamples) measured for 24 h at a class A National Weather Service Station located 41 m from the ET experimental site.Table 2. Evapotranspiration and leaf extension rates for 24 well-watered, turf-type *Cynodon* genotypes evaluated under field conditions during selected months between 1984 and 1986 at College Station, Texas.

Genotype	ET rate (mm·day ⁻¹) ^a				Leaf extension rate (mm·day ⁻¹) ^a			
	1984	1985	1986	Overall ^b	1984	1985	1986	Overall ^b
A-29	---	5.6	2.8	4.2	---	2.5	5.0	4.0
A-22	---	5.2	3.1	4.2	---	3.7	4.6	4.2
Tufcote	---	5.2	3.2	4.2	---	2.8	5.0	3.9
Texturf 10	3.7	5.7	3.6	4.3	2.6	4.5	4.0	3.7
Tifgreen II	---	5.7	3.1	4.4	---	1.9	4.1	3.0
Arizona Common	4.4	5.0	4.2	4.5	5.3	8.1	5.3	6.2
FB-119	4.4	5.4	3.5	4.5	2.9	4.3	5.7	4.3
Tifdwarf	4.2	5.5	4.0	4.5	2.0	2.6	2.9	2.5
Bayshore	4.2	5.4	4.1	4.6	3.5	3.8	4.7	4.0
Midway	4.6	5.4	3.8	4.6	4.3	4.5	5.2	4.6
Vamont	4.2	5.4	4.3	4.6	2.4	2.4	5.1	3.4
Everglades	4.6	5.0	4.7	4.8	3.3	4.1	5.0	4.1
Midiron	4.2	5.2	5.0	4.8	3.5	4.5	5.0	4.3
Pee Dee	4.8	5.2	4.4	4.8	3.4	3.2	4.9	3.8
Tifway II	4.6	5.8	3.9	4.8	2.9	4.1	4.0	3.7
Ormond	4.8	5.8	4.1	4.9	2.6	3.4	3.9	3.3
Tiffine	4.9	5.3	4.4	4.9	3.6	3.3	4.2	3.7
Tiflawn	4.3	6.2	4.1	4.9	3.1	5.6	3.3	3.5
Tifway	4.5	6.1	4.1	4.9	3.0	3.8	4.6	3.8
U-3	5.3	5.4	4.0	4.9	2.4	2.5	4.0	2.9
Texturf 1F	5.1	5.6	4.2	5.0	3.3	3.6	5.1	4.0
Santa Ana	4.6	5.8	4.9	5.1	3.5	3.9	4.2	3.9
Tifgreen	5.3	5.4	4.4	5.1	2.7	3.2	4.4	3.4
Sunturf	4.9	6.0	4.6	5.2	3.7	2.9	3.9	3.5
LSD _{P=0.05}	---	0.6	0.7	0.5	1.4	2.6	1.0	1.0
Mean	4.6	5.5	4.0	4.7	3.2	3.7	4.5	3.9
cv (%)	13.6	6.2	11.1	10.6	27.3	38.2	13.4	25.8
ANOVA ^c								
Genotype (G)	NS	**	***	***	*	*	***	***
Year (Y)				***				***
G × Y				**				NS

^aThree or four ET rate and leaf extension rate measurements taken during each year: Sept. 1984; June 1985; and July and Aug. 1986.^bCaution should be exercised when comparing overall arithmetic means due to missing data in 1984.^cANOVA for individual years was a randomized complete-block design with three replications, and ANOVA for overall years was a repeated-measures design where genotypes = main plots and years = repeated measures factor.*, **, ***, NS: Significant at $P = 0.05$, 0.01 , and 0.001 , or nonsignificant, respectively.

relation coefficients were calculated between the ET and leaf extension rate subsample means for individual years.

ANOVA for overall ET rates showed that the genotype, year, and genotype × year effects were significant (Table 2). Differences in environmental conditions (Table 1) may have contributed to the significant year effect. Pearson correlation coefficients across 3 years were calculated between the daily environmental measurements and the daily ET rate average over all genotypes (a total of 10 observations). During the entire study, ET rates were most closely associated with

wind speed ($r = 0.84$; $P = 0.02$) and solar radiation ($r = 0.62$; $P = 0.10$). Net radiation (Kim and Beard, 1988) and solar radiation (Feldhake et al., 1983) have been reported to be closely associated with turfgrass ET rates. ANOVA for ET rates in individual years showed that the genotype effect was significant in 1985 and 1986. Overall ET rates ranged from a low of 4.2 mm·day⁻¹ for A-29, A-22, and 'Tufcote' to a high of 5.2 mm·day⁻¹ for 'Sunturf'.

The 1.0-mm·day⁻¹ range in overall ET rates among the 24 well-watered bermudagrass genotypes is similar to the 1.2-mm·day⁻¹

range in overall ET rates among nine well-watered, warm-season turfgrasses tested by Kim and Beard (1988). However, some caution should be exercised concerning this comparison because it was not statistically validated, and the two studies were not conducted under exactly the same environmental conditions. Our data may indicate a potential for water savings based on bermudagrass cultivar selection that is similar to the potential water savings based on warm-season turfgrass species selection. Shearman (1989) made similar conclusions concerning water savings based on cultivar selections of per-

ennial ryegrass (*Lolium perenne* L.). He reported significant ET rate variation among 12 well-watered perennial ryegrass cultivars evaluated under field conditions for two consecutive years and using methodology similar to ours. Significant intraspecific ET rate variations also have been reported among 20 well-watered Kentucky bluegrass (*Poa pratensis* L.) cultivars (Shearman, 1986) and six tall fescue (*Festuca arundinacea* Schreb.) cultivars (Kopeck et al., 1988), which also would indicate potential water savings by cultivar selection. Research evaluating intraspecific ET rate variations of two other species was not as promising. Green et al. (1991) reported no differences in ET rates among 11 well-watered zoysiagrass (*Zoysia* spp.) genotypes, and Atkins et al. (1991) reported the same for 10 well-watered St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze] genotypes. Both studies were field evaluations over three consecutive years using the same methodology we used.

Overall leaf extension rates were influenced by genotype and year (Table 2). Genotype significantly affected leaf extension rates in all years. Overall leaf extension rates ranged from a low of 2.5 mm-day⁻¹ for 'Tifdwarf' to a high of 6.2 mm-day⁻¹ for 'Arizona Common'. Variation in leaf extension rates among the genotypes would require adjustment of mowing frequency.

We found no correlation between the ET and the leaf extension rate among 24 well-watered bermudagrass genotypes in individual years. Other field studies, using the same methodology as this study, have reported similar results among 11 well-watered *Zoysia* genotypes (Green et al., 1991) and among 10 well-watered St. Augustinegrass genotypes (Atkins et al., 1991), while a significant correlation ($r = 0.93$) between the ET rate and leaf extension rate was reported among 12 well-watered perennial ryegrass cultivars (Shearman, 1989). Shearman also reported a significant correlation ($r = -0.89$) between ET rate and verdure dry weight, but the latter criterion has higher cost and time requirements for assessment than measurement of leaf extension rates.

Higher turfgrass ET rates have been associated with higher clipping dry weights ($r = 0.82$) among 20 well-watered tall fescue cultivars (Bowman and Macaulay, 1991) and higher leaf area indices of a well-watered St. Augustinegrass with passage of time following mowing (Johns, 1980). Higher turfgrass ET rates or water consumption also have been associated with higher amounts of

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

Although water usage has been positively associated with the amount of shoot growth or leaf area index, our data and those of others suggest that measurements of leaf extension rates, although easily taken, were not a reliable predictor of the ET rate among collections of bermudagrasses, St. Augustinegrasses (Atkins et al., 1991), or zoysiagrasses (Green et al., 1991). An aspect of our study that could influence our conclusions on the association between ET rate and leaf extension rate was that coefficients of variation for leaf extension rate measurements were relatively high (Table 2). This variability might have been reduced by taking larger subsamples and measuring the same leaves during subsampling, immediately after mowing and 48 h later. However, these types of measurements are more time consuming and may not be practical for rapidly assessing many genotypes. Also, lower coefficients of variation (6.8% to 17.5%) for leaf extension rate measurements were reported for zoysiagrasses (Green et al., 1991), yet leaf extension rates generally were not correlated with ET rates.

Among the bermudagrasses, other above-ground morphological traits, such as shoot and leaf density, leaf width, and others, should be evaluated for their potential association with the ET rate under well-watered conditions. Additional work also is needed to study the ET rate and the effects of morphological and physiological traits on ET rates during progressively lower soil moisture conditions.

Literature Cited

- Atkins, C.E., R.L. Green, S.I. Sifers, and J.B. Beard. 1991. Evapotranspiration rates of 10 St. Augustinegrass genotypes. *HortScience* 26:1488-1491.
- Beard, J.B. 1973. Turfgrass: Science and culture. Prentice-Hall, Inc., Englewood Cliffs, NJ.
- Beard, J.B. 1985. An assessment of water use by turfgrass, p. 47-60. In: V.A. Gibeault and S.T. Cockerham (eds.). *Turfgrass Water Conservation*, Univ. of California, Div. of Agr. and Natural Resources Publ. 21405.
- Biran, I., B. Bravdo, I. Bushkin-Harav, and E. Rawitz. 1981. Water consumption and growth rate of 11 turfgrasses as affected by mowing height, irrigation frequency, and soil moisture. *Agron. J.* 75:85-90.
- Bowman, D.C. and L. Macaulay. 1991. Comparative evapotranspiration rates of tall fescue cultivars. *HortScience* 26:122-123.
- Levitt, D.A. and R.L. Morris. 1989. Growth of common bermudagrass as influenced by plant growth regulators, soil type and nitrogen fertility. *J. Environ. Hort.* 7:1-8.
- Feldhake, C.M., R.F. Danielson, and J.D. Butler. 1983. Turfgrass evapotranspiration. I. Factors influencing rate in urban environments. *Agron. J.* 75:824-830.
- Green, R.L., K.S. Kim, and J.B. Beard. 1990. Effects of flurprimidol, mefluidide, and soil moisture on St. Augustinegrass evapotranspiration rate. *HortScience* 25:439-441.
- Green, R.L., S.I. Sifers, C.E. Atkins, and J.B. Beard. 1991. Evapotranspiration rates of eleven zoysiagrass genotypes. *HortScience* 26:264-266.
- Johns, D. 1980. Resistances to evapotranspiration from St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze] turf. PhD Diss., Texas A&M Univ., College Station.
- Johns, D., J.B. Beard, and C.H.M. van Bavel. 1983. Resistance to evapotranspiration from a St. Augustinegrass turf canopy. *Agron. J.* 75:419-422.
- Kim, K.S. 1987. Comparative drought resistance mechanisms of eleven major warm-season turfgrasses. PhD Diss., Texas A&M Univ., College Station.
- Kim, K.S. and J.B. Beard. 1988. Comparative turfgrass evapotranspiration rates and associated plant morphological characteristics. *Crop Sci.* 28:328-331.
- Kopeck, D.M., R.C. Shearman, and T.P. Riordan. 1988. Evapotranspiration of tall fescue. *HortScience* 23:300-301.
- Krogman, K.K. 1967. Evapotranspiration by irrigated grass as related to fertilizer. *Can. J. Plant Sci.* 47:281-287.
- Madison, J.H. and R.M. Hagan. 1962. Extraction of soil moisture by Merion bluegrass (*Poa pratensis* L. 'Merion') turf, as affected by irrigation frequency, mowing height, and other cultural operations. *Agron. J.* 54:157-160.
- Parr, T.W., R.W. Cox, and R.A. Plant. 1984. The effects of cutting height on root distribution and water use of ryegrass (*Lolium perenne* L. S23) turf. *J. Sports Turf Res. Inst.* 60:45-53.
- Shearman, R.C. 1986. Kentucky bluegrass cultivar evapotranspiration rates. *HortScience* 21:455-457.
- Shearman, R.C. 1989. Perennial ryegrass cultivar evapotranspiration rates. *HortScience* 24:767-769.
- Van Bavel, C.H.M., R. Lascano, and D.R. Wilson. 1978. Water relations of fritted clay. *Soil Sci. Soc. Amer. J.* 42:657-659.