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California Turfgrass: It's Use, Water Requirement and Irrigation

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This article is written from the perspective of turfgrass in man's planned landscape. It is recognized by the authors, and stressed to the reader, that turfgrass is one component of a landscape with trees, shrubs, groundcovers and flowers.

THE INDUSTRY

Turfgrass directly affects the way most Californians live. It provides the play medium on many recreational facilities; it modifies our environment to make life easier and more pleasant; it provides opportunity for a pleasing and functional home landscape; and, in turn, the turfgrass industry has a significant direct economic impact on our economy and indirect impact on our tourist economy.

Many recreational facilities depend on a uniform, vigorously growing and recuperating, well-maintained turf sward for many activities. Common examples include soccer, baseball and football fields, golf courses, bowling greens, lacrosse. and polo fields, general use and specialty parks, and school grounds. Turfgrasses provide a safety cushion that is especially beneficial in contact and intensely physical sports.

Because most Californians now live in urban and suburban centers where glass, steel, concrete, asphalt, buildings and cars prevail, turfgrasses directly influence our immediate environment in many positive ways. As examples, actively growing turfgrasses have been shown to reduce high summer ground surface temperatures because of transpirational cooling. Turfgrasses, often with trees, shrubs and groundcovers, reduce discomforting glare and traffic noise. Soil erosion is reduced from surfaces covered with turfgrass, dust is stabilized, and fire potential is reduced or eliminated. Turfgrasses increase infiltration of water into the soil profile and also increases the water quality when this water moves below the turfgrass system.

Turfgrasses are used extensively in California home landscapes. In many settings, they provide the functional cover for child and adult activities and household pets. A well-landscaped home adds to the economic value of the property with the recovery value at, or exceeding, 100 percent.

Lastly, the California turfgrass industry has a sizeable direct economic activity for individuals and organizations involved in the design, installation, maintenance and support services for the industry. In 1982, economic activity was calculated to be over $1 billion per year (4) and in 1979 (5) it was estimated that turfgrass covers 1,380,000 acres in the state.

TURF NEEDS WATER

Turfgrasses need water for growth and development. There is not enough precipitation and it is not adequately spaced throughout the year to sustain turfgrasses or other landscape plants. Therefore, supplemental water supplied as irrigation is needed.

The amount of water used for landscape irrigation can vary from a very small amount of the total in a rural water agency or area to a significant amount of the total in an urban area. Table 1 presents the amount of water used statewide and by the Metropolitan Water District of Southern California (MWD), a water district that supplies a large urban clientele.

In urban Southern California, 10 percent of water used is for agricultural production and 90 percent for the urban categories of residential, commercial, industrial, public and other. It is expected in 1990, a dry year, that 25.7 percent of the 3.6 million acre feet (MAF) for urban use will be used for landscape irrigation. Statewide, however, 78.8 percent of all water is used for agricultural purposes. The statewide urban category accounts for 16.3 percent of total water used in California but there are no estimates of the amount of water used statewide for landscape irrigation. Using the MWD urban irrigation percentage, however, it would be expected that 4 percent of statewide water would be used for landscape irrigation.

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TURFGRASS WATER USE AND IRRIGATION REQUIREMENT

Warm-season grasses and cool-season grasses are used in California based on their climatic adaptability. The warm-season species include common and hybrid bermudagrasses, St. Augustinegrass, seashore paspalum, zoysiagrass and kikuyugrass. These grasses are used in the San Joaquin Valley, Southern California and parts of the greater San Francisco Bay Area. The cool-season grasses used include Kentucky bluegrass, perennial ryegrass, tall fescue, fine-leaved fescues in mixes, and specialty grasses such as creeping bentgrass, roughstalk bluegrass and annual ryegrass.

Cool-season grasses are used exclusively in the northern part of California and in the mountain regions of the state. Cool-season grasses are also used extensively in the major populated areas of the state as the primary species, as an overseeded grass or mixed with warm-season species. The differences between warm- and cool-season grasses are much more fundamental than their geographic distribution (8).

Warm-season grasses use significantly less water than cool-season species. This difference in water use derives from changes in the photosynthetic process that,occurred in grasses evolving under hot, dry conditions. These changes, which include modifications to biochemical reactions and internal leaf anatomy, greatly enhance the photosynthetic efficiency of warm-season species and help reduce water use. Increased photosynthetic efficiency means that plants can maintain high levels of carbohydrate production and continue to grow even when stomates are partially closed. This partial closure of the stomates slows the plant's water use.

Cool-season grasses, with a less efficient photosynthetic process, cannot maintain enough carbohydrate production to maintain growth unless their stomates are nearly wide open. Thus, when water is limited, transpiration rates of cool-season grasses are generally higher than those of warm-season grasses.

Water enters a turfgrass plant through its root hairs, which are located near root tips. Water then moves upward through the plant to the leaves. A very small amount of the water taken up is used for plant growth. Most water leaves the plant through stomatal pores in a process called transpiration. Free water also can be lost from leaf or soil surfaces by evaporation. The WATER USE RATE (WUR) is the total amount of water used by a turfgrass plant or sward through evaporation, transpiration and for growth, per unit time. Because the amount of water used for growth is so small, it is usually referred to as evapotranspiration (ET), which is the evaporation loss plus the transpiration use, per unit time.

Water use is given in units such as inches (in.) or millimeters (mm) per day, per week or per month. Figure 1 illustrates the path of water from a turfgrass leaf blade, in cross section, to the atmosphere. The rate of water use by turfgrass, and all plant material, is influenced by solar radiation, day length, wind, temperature, relative humidity, other environmental factors, the turfgrass species and cultural practices used to maintain the turf.

The most commonly used warm- and cool-season turfgrass species have been categorized for ET rates. Research at Texas A&M by Drs. J. B. Beard and K. S. Kim (2) evaluated the comparative water use rates among 19 turfgrasses grown in the United States. The results for those grasses used in California are presented in Table 2.

TABLE 1. STATEWIDE WATER USE AND WATER USE FOR THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA, BY CATEGORY

	Statewide[1]			Southern California[2]		
Category	Amount	% of Total	% for Urban Irrigation	Amount	% of Total	% for Urban Irrigation
Agriculture	26.941 MAF[3]	78.8%	Not Available	0.4 MAF	10%	--
Urban	5.576	16.3		3.6	90	25.7%
Residential	3.474 MAF	10.2		2.1 MAF	52.5	17.7
Industrial	0.797	2.3		0.3	7.5	1.0
Government	0.385	1.1		--	--	--
Public	--	--		0.2	5	2.8
Other	--	--		0.3	7.5	--
Commercial	0.920	2.7		0.7	17.5	4.2
Wildlife & Recreation	0.818	2.4		--	--	
Energy Production	0.084	0.2		--	--	
Conveyance Loss	0.764	2.2		--	--	
Total	34.183			4.0		25.7

[1] From: California Water: Looking to the Future. Department of Water Resources Bulletin 10-87. January 1988. And: Urban Water Use in California. Department of Water Resources Bulletin 166-3. October 1983.

[2] 1990 Water Use Projections by the Metropolitan Water District of Southern California. May 7, 1990, personal communication, PMCL Report. 1989.

[3] MAF - Million Acre Feet.

Table 2. Evapotranspiration rates of warm- and cool-season turfgrasses commonly used in California.*

Relative Ranking	ET Rate (mm/day)	(in/day)	Turfgrass Cool-Season	Warm-Season
Very low	<6	< .24		Buffalograss
LOW	6-7	.24- .28		Bermudagrass hybrids Bermudagrass Zoysiagrass
Medium	7 - 8.5	.28 - .33	Hard fescue Chewings fescue Red fescue	
High	8.5 - 10	.33 - .39	Perennial ryegrass	
Very high	> 10	> .39	Tall fescue Creeping bentgrass Annual bluegrass Kentucky bluegrass Italian ryegrass	

'From Beard and Kim (1989).

They found that the grasses with a low leaf blade area, including narrow leaves with slow vertical extension rate and grasses that had a high shoot density with a high leaf number, were lower ET grasses.

A study conducted in Irvine, California was designed to investigate the effects of applying optimum and reduced amounts of irrigation water calculated as a percentage of evapotranspiration of applied water on cool- and warm-season turfgrasses. It showed the irrigation requirement differences between these grass groupings (9). The grasses tested included Kentucky bluegrass, perennial ryegrass and tall fescue for the cool- season species and hybrid bermudagrass, zoysiagrass and seashore paspalum for the warm-season grasses. Irrigation regimes resupplied 100, 80 or 60 percent of calculated ET for the grasses. Irrigation regimes resupplied 100,80 or 60 percent of calculated ET for the grasses. Thirty-six percent less water was applied to the warm-season species than to the cool-season species for acceptable turf quality. See Table 3 for results.

The amount of water used by the turfgrasses on an annual basis at the various irrigation regimes is presented in Table 4.

Table 3. Cool- and warm-season turfgrass appearance ratings and water for the duration of the study (August 1981 to December 1983, a 29-month period).

Irrigation Reaime	Turf Appearance 8/81 - 12/83[1]			ET_{grass}[2]
% of ET				
Cool-season	Ken. blue	Per. rye	Tall fesc.	
100	5.5 y	6.2 y	5.8 y	77.3
80	5.3 y	5.9 y	5.7 yz	61.0
60	4.8 z	5.0 z	5.3 z	46.4
Warm-season	Bermuda	Paspalum	Zoysia	
100	6.5 ns[3]	5.8 ns	5.6 x	65.5
80	6.5	5.8	4.8 y	51.4
60	6.4	5.4	4.2 z	39.0

'Rated on a scale of 1 to 9, with 1 indicating worst appearance and 9 best. Values followed by common letters are not significantly different at the 5% level of probability.

[2]ET_{grass} equals the actual applied water divided by the extra water factor (EWF_{90}), which is 1.35.

[3]No significant difference.

Varietal differences in water use rates have been noted within Kentucky bluegrass, perennial ryegrass, tall fescue and creeping bentgrass. These findings support the current research efforts under way to develop turfgrasses that have lower ET rates.

Table 4. The calculated ET_{grass} for 1982 and 1983 at three irrigation regimes.

Irrigation Regime	ET_{grass}	
Cool-season	1982	1983
100% ET	32.0	28.7
80%	25.9	23.6
60%	19.7	18.1
Warm-season		
100% ET	25.2	24.4
80%	20.3	19.1
60%	16.0	14.5

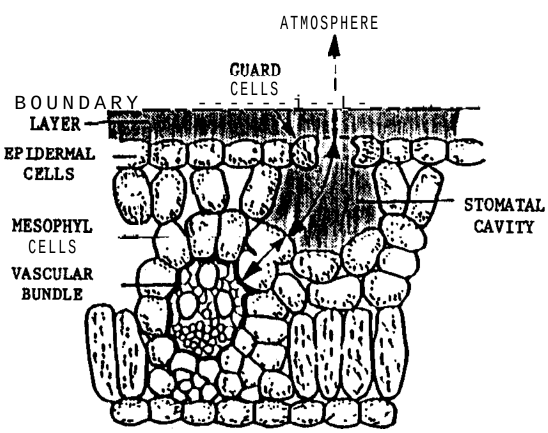

Figure 1. Cross section of a turfgrass leaf blade.

WATER USE VERSUS DROUGHT RESISTANCE

The ET of a turfgrass is not synonymous with its ability to resist drought. Drought resistance encompasses various mechanisms that a turfgrass plant has to withstand in periods of drought. Turfgrasses can resist drought by avoidance or tolerance mechanisms.

> Drought avoidance is defined as:. . the ability of a plant to avoid tissue damaging water deficits even while growing in a drought environment favoring the development of water stress (1).
>
> Drought tolerance is defined as:.. the ability of a plant to endure low tissue water deficits caused by drought (1).

Plant characteristics that contribute to drought avoidance include deep root systems with a high root length and root hair density, rolled leaf blades, thick cuticle or ability to quickly form a thick cuticle following water stress initiation, reduced leaf area, slow leaf extension rates, and leaf orientation and density that give high canopy resistance (2,3). Examples of turfgrass with good drought avoidance mechanisms would be common bermudagrass and seashore paspalum for warm- season species and tall fescue for a cool-season species.

Turfgrasses can tolerate drought by escape or by having hardiness to low tissue water deficits (1). Buffalograss, as an example, tolerates drought with a dormancy mechanism. St. Augustinegrass has high dehydration tolerance (1). Drought resistance comparisons are presented in Table 5 (1).

Beard (1) clearly states that there is considerable variation among cultivars within a species.

From the foregoing, certain turfgrasses may have both low water use rates and high drought resistance mechanisms. Examples would be common and hybrid bermudagrass, seashore paspalum and buffalograss. Other grasses, such as tall fescue, may have high water use rates and medium drought resistance. Some turfgrasses have high water use rates and fair or poor drought resistance such as the ryegrasses and bluegrasses.

Table 5. Drought resistance comparisons of commonly used warm- and cool-season turfgrass used in California.*

Relative Ranking	Turfgrass Species: Cool-Season	Turfgrass Species: Warm-Season
Superior		Bermudagrass (common) Bermudagrass (hybrid)
Excellent		Buffalograss Seashore paspalum Zoysiagrass
Good		St. Augustinegrass
Medium	Tall fescue	
Fair	Perennial ryegrass Kentucky bluegrass Creeping bentgrass Hard fescue Chewings fescue Red fescue	
Poor	Colonial bentgrass Annual bluegrass	
Very poor	Rough bluegrass	

'From Beard (1989)

A study that was conducted at the South Coast Field Station, Irvine, California, evaluated 27 turfgrasses and alternative plant materials to very low irrigation regimes (7). The plant materials, presented in Table 6, were irrigated at 60, 40 and 20 percent of calculated ET. The 20 percent regime applied 6.6 in. per year in 1986.

Table 6. Cover x quality (square root) ratings of 27 plant materials irrigated at 20%, 40%. and 60% of calculated ● v.potr.n.pir.tion for warm-season turfgrass, across May, July, and December 1986 evaluation dates.

Common and Botanical Names	Seeding R.L. lb/1,000 sq ft	Cover x Quality Ratings[1] Percent ET_{wsg} Applied[2] 20%	40%	60%
Santa An. bermuda, Cynodon sp.	4.0 bu	23.8 a	'23.2 .	20.7 .
Common bermuda, Cynodon dactylon	1.0	23.7 .	20.9 ● b	23.1 .
Glaucos saltbush, Atriplex glaucus	.I	22.1 .b	16.5 abcde	15.3 abcd
Seashore Paspalum, Paspalum vaginatum	4.0 bu	21.9 ab	17.7 abcd	22.0 .
Australian ● *ltbu*h. Atriplex semibaccata corta	.7	20.2 abc	20.0 ● bc	15.0 abcd
Buffalograss, Buchloe dactyloides	1.25	18.4 abcd	18.3 abcd	15.7 abcd
Sirosa phalaris, Phalaris stenoptera	6.9	17.8 abcd	12.1 bedef	[illegible] ● bc
Blue grama, Bouteloua	1.0	17.4 abcd	16.3 abcde	16.0 abcd
Sirolan phalaris, Phalaris stenoptera	6.9	14.9 abcd	15.6 abcdef	19.4 ab
Alta tall fescue, Festuca arundinacea	10.0	14.4 abcd	14.8 abcdef	20.2 ab
Fresa strawberry clover, Trifolium fragilerum var. Fresa	.4	12.8 abcde	10.4 cdef	12.9 abcd
Perla koleagrass, Phalaris tuberosa var. hirtiglumus	6.9	12.5 abcde	13.9 abcdef	13.5 abcd
Brookston tall fescue, Festuca ●undinde*e**	10.0	11.6 abcde	11.0 bcdef	14.6 abcd
Fairway wheatgrass, Agropyron desertorum	l.s	10.5 bcde	14.0 abcdef	6.7 abcd
Birdsfoot trefoil, Lotus corniculata	1.0	10.4 bcde	II.3 bcdef	8.8 abcd
El Toro zoysia, Zoysia japonica	4.0 bu	10.3 bcde	13.9 abcdef	14.9 abcd
gsrbar orchardgrass, Dactylis glomerata	3.4	9.9 cde	9.4 defg	7.5 abcd
O'Connor legume, Trifolium fragilerum	.15	9.6 bode	10.7 bcdef	8.3 abcd
Smooth brow, Bromus inermis	1.25	8.5 cde	9.5 defg	10.4 abcd
Crested wheatgrass, Agropyron cristatum	1.5	8.1 cde	11.2 bcdef	0.7 d
Palestine orchardgrass, Dactylis glomerata	3.4	8.0 cde	5.6 fg	9.7 abcd
Hard fescue, Festuca ovina var. duriscula	5.0	7.1 de	6.4 [illegible]	7.1 abed
Yarrow, Archillea millefolium	.06	6.6 de	7.0 efg	3.8 bcd
Tell wheatgrass, Agropyron ● lang*t"m	1.5	5.7 de	7.2 efg	3.1 cd
Indian ricegrass, Oryzopsis hymenoides	1.25	0.0 e	0.0 g	0.0 d
Fults weeping alkaligrass, Puccinellia	1.25	0.0 e	0.0 g	1.8 cd
Lemon alkaligrass, Puccinellia lemmoni	1.25	0.0 e	0.0 g	0.0 d

[1]Turf quality (color. texture. density. and uniformity) rated visually on scale of 1 to 9 (9=highest quality). Percent live desired plant material determined as percent cover. Ratings given represent square root of product of quality x cover.

[2]Values followed by the same letters are not significantly different at 5% level of probability. ET_{wsg}=evapotranspiration for warm-season turfgrass.

Of the 27 turfgrasses and groundcovers tested in this study, bermudagrasses and seashore paspalum were the best performing turfgrasses under very low irrigation regimes. Two species of saltbush, buffalograss, and two varieties of Phalaris also gave comparatively good cover and quality.

This work showed that turfgrasses, and other plant material maintained as turf exist that are capable of surviving and giving cover under extremely low irrigation regimes. These materials apparently resist the stress of low water application by various mechanisms, including dormancy, deep roots, and low rates of water use.

NEW GRASSES

Research is under way to develop new grasses that require less water. The most extensive effort has been funded by the United States Golf Association and the Golf Course Superintendents Association of America over the past several years. The following are examples of projects underway that would foster an irrigation trend of reduced water needs by turfgrasses.

— Bermudagrasses are being developed by Dr. Charles Taliaferro and a research team at Oklahoma State University that will be seed-propagated, cold-tolerant, fine-textured, and useful in the northern half of the bermudagrass belt. Dr. Taliaferro hopes to be able to field-test parent Iii in the near future for seed production and turfgrass quality characteristics.

— A second bermudagrass program, directed by Dr. Arden Baltensperger of New Mexico State University, resulted in the release of 'NuMex Sahara' bermudagrass In the spring of 1987. NuMex Sahara bermudagrass is an improvement over common bermudagrass because it has shorter leaves, shorter internode, greater density, and somewhat better color.

— Dr. Milton Engelke, of the Dallas Station of Texas A&M University, is improving zoysiagrasses. Two new zoysiagrasses from his breeding efforts, currently labeled DALZ 8501 and DALZ 8502, are vegetatively propagated grasses that have an improved ability to recover rapidly from divoting, scarring and general injury. This is a major breakthrough since slow recovery from injury has been a major drawback with zoysiagrass.

— A second zoysiagrass improvement program is under way at the University of California, Riverside. El Toro Zoysiagrass has recently been released by U.C. Experimental lines that give rapid establishment, good turf characteristics, and improved winter color are being evaluated.

There is great interest in developing improved native grasses because of their ability to survive and give good cover under stress and low moisture conditions in areas where they are adapted. Such grasses may be used in play areas, such as fairways, and possibly tees, but they would be particularly useful in nonplay or out-of-play locations with minimum maintenance.

— Dr. Terrance Riordan of the University of Nebraska, heads a buffalograss improvement program that has developed turf types adapted to the Plains states. Wider ranges of adaptation for buffalograss are also being investigated.

— Dr. Lin Wu of the University of California, Davis, is working on new buffalograsses. Work at Davis has studied turf quality improvements, seed production characteristics, color retention during winter months, and vegetative cover opportunities.

— Dr. Robin Cuany of Colorado State University is breeding native western grasses for turf use. Dr. Cuany has amassed a large amount of native grass germplasm and is quite far along on the production and release of an improved alkaligrass.

Other breeding programs are being supported on bentgrasses, annual bluegrasses, Kentucky bluegrasses and fine fescues. Numerous other research programs by breeders at universities and seed firms are developing varieties that require less water than existing cultivars.

IRRIGATION AND OTHER CULTURAL PRACTICES FOR TURFGRASS

Irrigation

Of course, watching for those areas in a turfed site that show water stress first, and the regular use of soil probes and/or soil moisture measuring devices will help to perfect irrigation schedules and give the desired results with the most efficient use of water resources. The basis of irrigation scheduling can be calculated with the water budget method of water application. This method best matches the grass ET with the reapplication of water to replace the water used by the turfgrass sward.

The water budget method of irrigation accounts for the water available to the plant based on its rooting depth and soil moisture capacity. It also accounts for ET of turfgrass so the amount of irrigation and frequency of irrigation can be determined.

Water Availability All soils contain two water fractions when viewed in terms of plant absorption. The first, unavailable water, is tightly held by mineral and organic particles and is unavailable for plant use. The second, available water, is that amount the plant can absorb for transpiration and metabolism.

The amount of available and unavailable water differs with different soil textures. The following table gives a general relationship between soil moisture characteristics and soil texture.

Table 7. Inches of available and unavailable water per foot of soil.

	inches per Foot	
Soil Texture	Available	Unavailable
Sand	0.4-1.0	0.2-0.8
Sand and Loam	0.9-1.3	0.9-1.4
Loam	1.3-2.0	1.4-2.0
Silt Loam	2.0-2.1	2.0-2.4
Clay Loam	1.8-2.1	2.4-2.7
Clay	1.8-1.9	2.7-2.9

These data are approximate but nevertheless give an insight into the amount of water that is available per unit depth for plant use. Generally, for turfgrass irrigation practices, a 50 percent depletion of soil water is suggested, as will be further explained. This information, in conjunction with a knowledge of root depth, gives an indication of the amount of water that is available to the turfgrass in the soil profile.

Root System. When considering turfgrass in profile, it must be emphasized that turf species naturally differ in their rooting ability. In addition to species difference, root depths are also influenced by seasonal fluctuations, management practices such as mowing and fertilization, and by on-site soil compaction. The best method to determine root depth in a particular location is by physical inspection; however, a general guide to root depths would be as follows:

Table 8. Approximate root depths of cool- and warm-season turfgrass under normal use conditions.

Cool-Season Grasses	Root Depth
Kentucky bluegrass	6.0"-1.5'
Perennial ryegrass	6.0"-1.5'
Tail fescue	1.5'-3.0'
Creeping bentgrass	4.0"-1.5'
Annual bluegrassq	1.O"-4.0"

Warm-Season Grasses	Root Depth
Bermudagrass	1.5'-6.0
St. Augustinegrass	1.5'-5.0
Seashore paspalum	1.5'-5.0'
Zoysiagrass	1.5'-2.5

As can be seen, rooting depths vary from a few inches to many feet. Since it should be the objective of irrigation to supply water to the root system, root depths and soil texture play an important role in both the amount of water to apply and the irrigation frequency.

As an example, Table 9 has been constructed to show the amount of water available to turfgrasses growing in three soils and with three root system depths. In all instances, a 50 percent water depletion factor has been incorporated to insure nonlimiting water status.

Table 9. Water available to turfgrass, in inches, under three soil textures and with three root system depths, adjusted for a 50 percent depletion allowance.

	Water Status	Rooting Depth		
Soil Texture	Available water (in.)	6 in.	1 ft.	3 ft.
Sand	1.0 x 50% depl. = 0.50	0.25	0.50	1.50
Loam	1.5 x 50% depl. = 0.75	0.38	0.75	2.25
Clayloam	2.0 x 50% depl. = 1.00	0.50	1.00	3.00

Evapotranspiration, CIMIS and Turfgrass Water Budget. The California Irrigation Management System (CIMIS) provides irrigation managers, scientists and water agencies with an accurate and site specific means of estimating plant water demand based on climatic parameters that drive evapotranspiration in plants. Reference evapotranspiration (ET_o) approximates the water use of an irrigated grass pasture. Water use (ET) by turfgrasses is estimated with a correlation factor or crop coefficient K_c x ET, = grass water use. This crop coefficient will change during the season based on the plant cover, growth rate, root growth, and stage of plant development and turf management practices: see Table 10 for the monthly crop coefficients for warm- and cool-season turfgrasses. If an annual average K_c is desired, use 0.8 for cool-season turfgrasses and 0.6 for warm-season turfgrasses. (Note: Turf coefficients, K_p, for a Class A Weather Bureau Pan are also given in Table 10.)

Now, with over 70 CIMIS stations throughout California, managers can get up to the day water use information for virtually any agricultural or urban area. By taking the average water use rates over a period of years, a historical picture of the turf water demand in an area can be constructed. This allows the manager to plan irrigation needs based on the past history or on actual climatic, conditions at the site by accessing current ET, values by computer modern.

Table 10. Turfgrass crop coefficients (Kp and Kc) of warm- and cool-season grasses.

	KP[1]		Kc[2]	
Month	Warm	Cool	warm	cool
J	.44	.49	.55	.61
F.	.43	51	54	.64
M	.61	.60	.76	.75
A	.58	.83	.72	1.04
M	.63	.76	.79	.95
J	.54	.70	.68	.88
J	.57	.75	.71	.94
A	.57	.69	.71	.86
S	'.50	.59	.62	.74
0	.43	.60	54	.75
N	.46"	.55	58	.69
D	.44	.48	.55	.60

[1]Monthly crop coefficient fKp) is used with a class A Weather Bureau evaporation pan with the equation ET_{grass} = ET,, x Kp.

[2]The crop coefficient Kc is used with reference evapotranspiration (ET_o) from a CIMIS weather station with the equation ET_{grass} * ET, x Kc.

To gain access to the CIMIS information for daily ET,, at over 70 sites in California, write:

Office of Water Conservation
State Dept. of Water Resources
Sacramento, CA 942360001
or call; (916) 445-8327

By having the available water, per soil depth, the effective root system depth and the evapotranspiration data, one can then use the water budget method of irrigation management. As an example, a cool-season grass with a one foot root system depth, growing on a loam soil, would have the following soil water reservoir:

Water available/ft (in inches) x root depth (in feet)
= soil water reservoir
e.g., 0.75" available/ft x 1 foot
= 0.75" water available.
If the daily water use is 0.15" per day, then

$$\frac{\text{soil water reservoir}}{\text{ET}} = \text{days of sufficient supply}$$

$$\text{e.g., } \frac{0.75\text{"/ft}}{0.15\text{"/day}} = \text{5-day water supply.}$$

It is normally desirable to water turf as infrequently as possible so for the above example, the site would be irrigated after five days of similar ET, or until 0.75 inches of soil water has been accumulatively used.

The time of sprinkler operation to resupply the water used by ET must account for the sprinkler application rate, the uniformity of distribution, the soil infiltration rate and the facility usage. The goal of irrigation, however, must be to resupply the turfgrass with the water that is used per unit time, applied as infrequently as possible, and without runoff.

Moisture Sensors

Moisture sensors are instruments used to detect the soil moisture present and available to plants. The information collected is correlated against the needs of a plant and the irrigation scheduled accordingly. In turfgrass management, there are two primary methods for sensing moisture-soil suction and electrical resistance.

Soil suction is measured with tensiometers consisting of a plastic tube with a porous cup attached to one end and a vacuum gauge at the other. As soil dries, a vacuum is created and indicated on the gauge. Research has determined that a predictable amount of soil moisture is available to the plant corresponding to the vacuum reading. Tensiometers are quite accurate instruments, giving a clear picture of the soil moisture available to the turf plants.

Water is a good conductor of electricity. As soil dries, electrical resistance increases at a predictable rate and available moisture can be calculated. The resistance type moisture sensors actually consist of porous composition blocks with electrodes embedded in the center. Resistance block moisture sensors are practical and easy to use.

The turf manager can use moisture sensors as individual instruments and take periodic readings as a guide to adjust the irrigation schedule. Of more value is the role the moisture sensors can play in the automatic operation of an irrigation system. Moisture sensors can be connected by wire or telemetry to an irrigation controller and call for water when the turf needs it, not just by the clock and calendar.

The most critical factor in the use of moisture sensors is the location and depth of the instruments within the turf site. For most turf swards, putting the sensor in a dry spot at a depth of four to six inches is effective. Improper installation of moisture sensors is responsible for far more failures than the reliability of the equipment.

In the CIMIS water budget method of irrigation scheduling, the sprinklers are set to apply water to replace that lost to ET. Historical ET, or real time ET, may be used to schedule the irrigation system run frequency and rate. Historical refers to using an ET, value measured at some earlier time, such as the same month the year before. Real time refers to the ET, value at this point in time; in other words, now.

CIMIS is based upon the general local area weather data, and moisture sensors are site specific. Combining CIMIS and moisture sensors provides the state of the art of science to maximize turfgrass irrigation efficiency.

Mowing

In addition to irrigation practices, mowing affects turfgrass growth, including root system development, and water use. Higher cutting heights result in deeper root systems and higher water use rates. The higher water use rate with higher mowed turf would be dependent upon the more open canopy, with reduced shoot density. Conversely, close mowed turf has higher shoot density, and a tight canopy. These are characteristics which have been shown to reduce ET, as previously mentioned.

The frequency of mowing also affects ET. Infrequently mowed turfgrass with long grass leaves between mowings results in higher water use than more frequently mowed grass during the same time period. Infrequently mowed turf is also aesthetically and functionally inferior to a turfgrass sward maintained consistently at an appropriate height.

The balance that is desired is to use mowing practices that enhance root system depth and density yet efficiently use water resources. Turf mowed at optimum heights for the individual species and at a frequency that allows no more than 1/3 to 1/2 the leaf blade removal achieves that balance as much as possible given the overall uses of turfgrass.

Fertilization

Most nutrients required for turfgrass growth are normally available in sufficient amounts in soil, air and water, but some are needed in greater amounts than are naturally supplied. All turfgrasses require nitrogen fertilizer, and others may need phosphorus, potassium and sometimes iron. Fertilization influences turfgrass growth. The greater the growth rate, the greater will be the water use rates so turfgrass fertilization practices, especially nitrogen fertilization, directly influences water use.

Both root and shoot growth increase as nitrogen nutrition is raised from a deficiency level. The resulting deeper roots and more vigorous topgrowth are beneficial for the turfgrass sward. Additional nitrogen fertilization at high rates and/or at frequent intervals is less beneficial and, in fact, can be detrimental to the turfgrass because of root growth stoppage and excessive, lush topgrowth. Managers must monitor and adjust nitrogen fertilization programs to produce the least amount of topgrowth and the greatest rooting possible within the use parameters of the turfed facility. Otherwise, rapid growing grasses will have an unnecessarily high water use rate.

Soil Cultivation and Thatch Removal

Soil compaction reduces root and shoot growth of turfgrasses and water infiltration rates. Turfgrass quality decreases in compacted soils and water use decreases with the slower growing, poorer quality turfgrass cover. Soil cultivation, such as aerification, will result in an increase in shoot and root growth, water infiltration rate, water use rate and water use efficiency.

A deep thatch layer, if hydrophobic, reduces or eliminates water infiltration with the turfgrass profile. Water use efficiency increases when thatch is maintained at acceptable depths and not allowed to dry out.

MAXIMUM IRRIGATION EFFICIENCY

Irrigation trends for the future are influenced by concepts which stress water conservation and lower maintenance costs yet allow the landscaped sites to achieve the stated goals for the particular site. Site design for the landscape, as well as irrigation system design, are important in maximizing irrigation efficiency. Designs are common that reduce total irrigated acreage and that include low water-using plant materials. Many golf courses are now being designed to use effluent water as their primary water source, and some will be designed to harvest and conserve natural precipitation (6).

There is also an obvious design trend to zone water application based on real time water needs. This will allow the placement of water where it is needed, when it is needed. Overwatering will be reduced or eliminated.

Equipment

The newest sprinklers available combine lower precipitation rates to more nearly equal soil infiltration rates, thereby reducing or eliminating water runoff. Presently available are low volume 0.25 - 0.4 in./hr sprinklers, and under test are sprinklers with even lower application rates. These new turfgrass heads also have lower pressure requirements yet maintain a very high uniformity.

For maximum efficiency, matched sprinkler heads should be used. Matched sprinklers refer to "matching" the precipitation rates of the partial heads to the full heads. A quarter head would emit onequarter of the amount that the matched full head would put out. Not all sprinklers within a manufacturer's series are matched. The newest matched lower pressure heads also have increased interruption of the full bore water stream. By increasing the jet interruption, water distribution from each head is more even and uniformity of application among sprinklers can be as high as 90 percent in no wind conditions. Uniformities of 90 percent and over are the goal of all manufacturers.

Cost savings in sprinkler systems will occur because the lower application rates and the lower volume of water flow allows designers to use smaller plastic lateral sizes and smaller submainlines. Many irrigation controllers contain microprocessors operating to within one minute accuracy, multiyear embodied batteries, and multiple repeat programs. Full year evapotranspiration or historical' water use programs can be built into self-contained controllers. The new age controller will automatically downstage or reduce watering times as weather historically cools and direct read-out soil moisture devices indicate lower turfgrass needs.

Maintenance

All irrigation trends point to the need for better informed water managers. There has been a tremendous increase in educational opportunities from groups such as the Golf Course Superintendents Association of America, the Irrigation Association, and local educational programs sponsored by universities, the irrigation industry and other professional organizations. There will be continued and increased need for in-service training of landscape maintenance personnel. These educational opportunities are stressing the interactive importance of grass variation and water use, and the influence of mowing, fertilization, coring, and the use of growth regulators, antitranspirants, and wetting agents on irrigation practices. Of course, irrigation scheduling is a major focus of cultural attention.

Other Considerations

Other points to consider to increase watering efficiency would include some short- and long-term considerations including:

- ✓ Irrigating late at night or early in the morning. At these times water loss by evaporation is minimal and distribution is usually good because of good water pressure and limited wind.
- ✓ Avoid runoff by matching water application rates to soil infiltration percolation rates. Cycle water application when necessary to ensure infiltration.
- ✓ Practice good weed control methods. If not controlled, the weeds, not the desired turf species, will use the water.
- ✓ Shaded areas will use much less water than turf in open sun, so water the shaded areas less. Soil moisture measuring devices can be used to determine water needs of shaded areas.
- ✓ Line water storage lakes to reduce water loss.
- ✓ If your facility is considering the installation of a new, more effective and efficient irrigation system, then this may be the time to act.
- ✓ Level mounds and redesign other hard to irrigate topographic features.
- ✓ Investigate the possible availability of effluent water.
- ✓ Remove poor performing plants from the landscape.
- ✓ If establishing plant material, group plants with similar water requirement so all can be irrigated for optimum performance.
- ✓ Use mulches l-2 inches thick to reduce evaporation water loss in plant beds.

TURF'USE AND RESOURCE INPUT

There are a wide variety of uses for turfgrasses and within each several levels of performance expectations exist. Accordingly, different maintenance intensity requirements and resource input are needed to meet the expectations which ultimately satisfy the demands of the users.

Turfgrass uses can be loosely categorized into four groups: aesthetic, land protection, fine turf, and high-traffic turf. Although all turf is considered to have aesthetic value, some uses are strictly for appearance, such as commercial lawns, boulevard median strips, gardens, and many home lawns.

Turf established for land protection generally provides soil erosion control from wind or water. Fine turf is found in formal gardens, on putting greens, and on bowling greens. High-traffic turf on sports fields, in parks, and on golf course tees/fairways is subjected to a heavy volume of play.

Within each of the turfgrass use categories are various expectations for appearance and performance. The use of the turf and the respective expectations determine the ultimate practical potential for input or conservation of water, energy, financial, and human resources.

Turf that does not receive traffic and only has to provide a minimum of cover either for appearance or for land protection can certainly be maintained with little resource input. Where established for land protection, the expectations are that the turf will help prevent erosion. Water application must be sufficient to maintain the grasses at a level where they are capable of performing the required task, which can merely be grass survival. Water can be applied at a rate adequate to simply keep the grass alive corresponding to a small percentage of the ET, value.

Fine turf has been singled out as a large consumer of important resources, especially water. The performance of any turf is decreased by excessive use of any resource, be it water, fertilizer, or manpower. In the management of fine turf there is a premium on performance, an obvious incentive to avoid excesses. While the total area of fine turf and the quantity of resources such as water and energy required for fine turf statewide are not great, it is true that the input per square foot is high. It is misleading to criticize turf as wasteful citing the maintenance of fine turf as the example. Specialty turfs require the maximum management experience and knowledge and optimum resources.

High-traffic turf has been traditionally maintained at levels varying from wry Iow maintenance input to very high. Frequently, facilities receiving low Input are subject to significant abuse from play volume and intensity. Turfs that are expected to provide a safe, durable surface with good playability require that optimum levels of all resources be provided.

High-traffic turf is submitted to severe stresses from traffic abuses and should not be subjected to water or nutrient deficiencies. The manager of high-traffic turf applies the optimum amount of water for turf growth and does not consider minimum ET for irrigation. The choice of the turfgrass is to be made according to the durability, traffic tolerance and suitability for play, with water use rate an important but clearly secondary consideration.

To avoid waste and promote conservation, it is crucial that resource distribution systems and equipment be as efficient as possible. Poor irrigation systems are common on high traffic turf facilities in parks and on school grounds. Conservation in the traditional sense is not so important on high traffic turf as minimiring waste through maximizing turf management efficiency.

SUMMARY

In summary, turfgrass is an important component of the California lifestyle. As a part of man's planned landscape, it provides a medium for play, it positively modifies our environment, it provides an aesthetic and functional use around homes and buildings, it is the backbone of many tourist interests, and it has a significant economic impact on our economy. Turfgrass needs water and in a drought, which is defined as a prolonged period of abnormal moisture deficiency, water must be carefully used. This definition implies that normal moisture conditions will return to an area in time. Such a situation means that temporary changes may be sufficient to ride out the water shortage.

Conversely, some areas face the possibility of permanent drought conditions because of jurisdictional, political action or economic considerations. Turf managers of large turfed facilities in such areas may consider fairly major design and equipment changes in order to continue their operation.

Literature Cited

1. Beard, J. B. 1989. Turfgrass water stress: drought resistance components, physiological mechanisms, and species-genotype diversity in Proceedings of the Sixth Int'l Turf Res. Conf., Tokyo, Japan. Ed.: Hiroshi Takatoh. p. 23-28.
2. Beard, J. B. and K. S. Kim. 1989. Low water-use turfgrasses. Green Section Record. 27(l): 12-13.
3. Carrow, R. W. 1988. A look at water conservation. Green Section Record. 26(4): 77-9.
4. Cockerham, S. T. and V. A. Gibeault. 1985. The size, scope and importance of the turfgrass industry in Turfgrass Water Conservation, Univ. of Calif. Pub. 21405. Ed.: V. A. Gibeault and S. T. Cockerham. p. 7-12.
5. Gibeault, V. A. 1979. Importance of turfgrass in California. Calif. Turfgrass Culture. 29(4): 25-26.
6. Gibeault, V. A. and J. L. Meyer. 1989. Tracking trends in irrigation. Golf Course Mgmt. 57(5): 6-12.
7. Gibeault, V. A., J. L. Meyer, R. Autio and R. Strohman. 1989. Turfgrass alternatives with low water needs. Calif. Agric. 43(6): 20-22.
8. Leonard, M., S. Cockerham and V. Gibeault. 1987. Water use by turfgrass plants. Landscape Mgmt. 26(7): 30-32.
9. Meyer, J. L. and V. A. Gibeault. 1986. Turfgrass performance under reduced irrigation. Calif Agric. 40(7,8): 19-20.

A Simulator for Cleated-Shoe Sports Traffic on Turfgrass Research Plots

S. T Cockerham and D. J. Brinkman[1]

Figure 1. The Brinkman Traffic Simulator.

Turf injury from cleated-shoe traffic on a sports field occurs as a result of 1) wear from friction and scuffing, 2) compaction from the concentrated weight distribution on the cleat, and 3) lateral shear injury to the turf from the thrust drive of the cleats.

To conduct research for sports fields, it is desirable to uniformly simulate sports traffic across a set of plots. Criteria for a device to simulate sports traffic are: 1) to impose wear; 2) to cause focused compaction as with cleats; and 3) to create a thrust producing lateral shear injury. Additional criteria that make the simulator practical are: 1) to be of simple construction to minimize maintenance; 2) to be able to cover a large number of plots in a minimum amount of-time; and 3) to be easy to operate.

The Brinkman Traffic Simulator (BTS) (Figure 1) was developed at the University of California, Riverside. The BTS consists of a frame with two cleated rollers connected by chain and sprockets (Figure 2) pulled by a small tractor unit.

The frame is made of steel box tubing (Figure 3) with a hydraulic ram to raise and lower the transport wheels. In order to allow the hitch to be rigid for transport and still be free to float during

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use, a sleeve on the tongue slides with the action of the ram (Figure 4). Each roller is 11 1/2 inches diameter by 48 inches wide (Figure 5). The front sprocket is 5 1/2 inches diameter with 21 teeth and the back is 6 1/2 inches diameter with 26 teeth.

To represent cleats 3/8 inch inside diameter, hex nuts are welded to the rollers and bolts threaded into the nuts. The bolts have 5/8 inch outside diameter hex heads and are 3/4 inch long. The bolts are easily replaced when wear is excessive. The diameter and length are approximately that of the cleats on the shoe of professional football linemen.

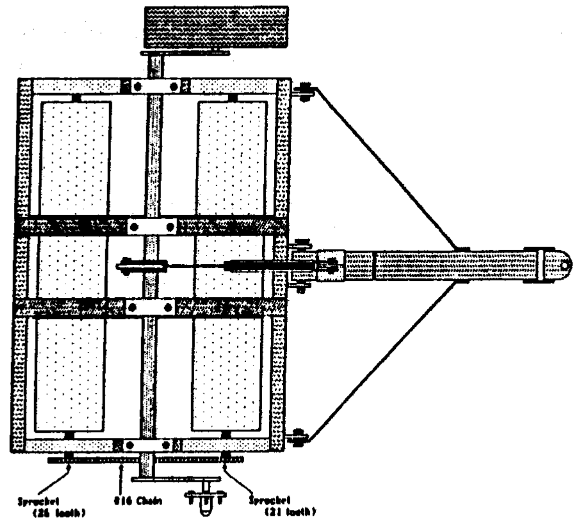

Figure 2. The Brinkman Traffic Simulator, top view.

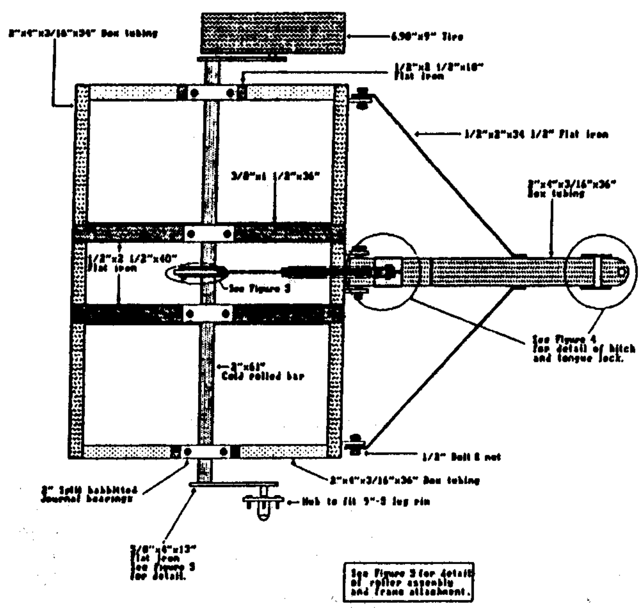

Figure 3. The Brinkman Traffic Simulator, frame detail.

The cleat pattern on each roller is a spiral to allow smooth roller movement. The lateral placement is such that in one complete rotation there are no gaps between the cleats. Earlier designs with a gap proved to be a problem with the turf injury appearing in rows.

The number of cleats are based upon the Zone of Traffic Concentration (ZOTC). ZOTC is the area between the hash marks and from the back foot of the offensive lineman to the back foot of the defensive lineman each in three-point stance. At an average of 14 cleats per square foot per roller, the simulator makes 56 cleat dents per square foot, the equivalent of one football game ZOTC, in two passes.

The BTS weighs 900 pounds. There is an average of 12 cleats on the ground during operation for an average of 75 pounds per cleat or 250 lb/sq in. A 300-pound lineman, with seven cleats per shoe, averages a standing 42 pounds per cleat or 140 lb/sq in. Running or leg-drive thrust produces a working weight per cleat

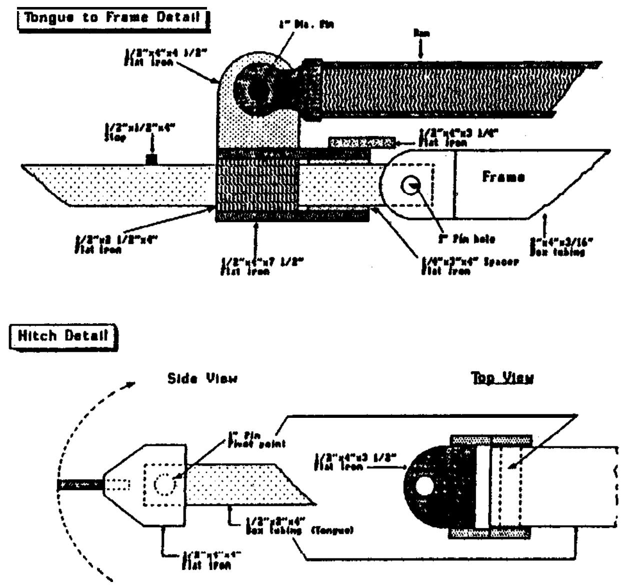

Figure 4. The Brinkman Traffic Simulator, tongue and hatch detail.

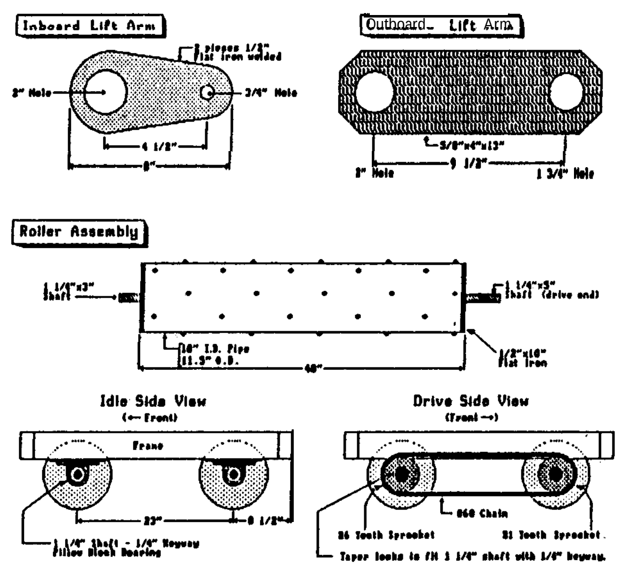

Figure 5. The Brinkman Traffic Simulator, roller detail.

well in excess of the standing weight as well as adding the lateral shear to the turf tensibility.

The BTS produces wear, compaction and turf lateral shear. The drive thrust yielding lateral shear is produced by the difference in sprocket sizes turning the rollers at unequal speeds.

The BTS is a simple, rugged apparatus that will uniformly apply simulated football-type traffic on turfgrass sports field plots.

Cleated-Shoe Traffic Concentration on a Football Field

Stephen T. Cockerham[1]

American football is a sport most injurious to a turfgrass playing field. One of the major challenges facing a sports turf manager is keeping grass on the center of a football field. Even though the play may utilize the entire field during a game, the nature of the sport is that 78 percent of the traffic is concentrated on 7 percent of the field.

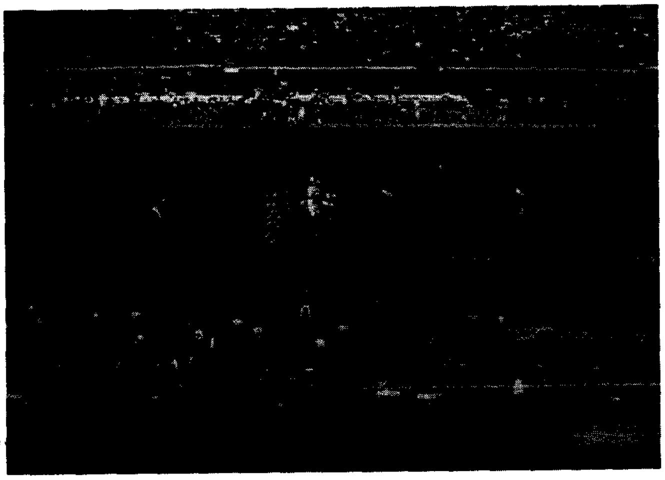

Figure 1. The zone of traffic concentration (ZOTC) is where most traffic will occur on any play.

Action in football is not continuous as it is in some other sports. There is a start and stop for each scrimmage or play. Each play begins with the ball placed on or between the hash marks and ends a few seconds later. Player activity can be readily studied to determine the amount of traffic the heavy use areas receive.

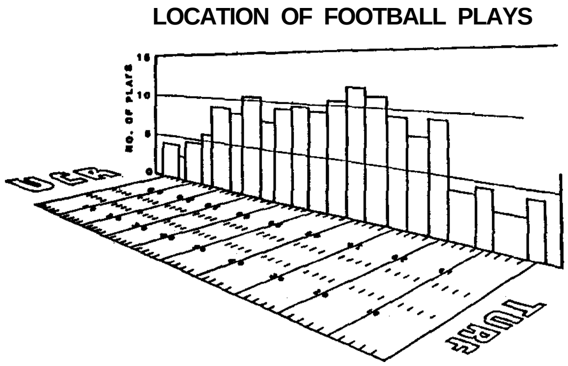

Figure 2. The average number of plays, by field location, for 14 football games.

The area between the hash marks and from the back foot of the offensive lineman to the back foot of the defensive lineman each in three-point stance defines the Zone of Traffic Concentration (ZOTC), which is the area where most of the traffic will occur on any given play (Figure 1).

The average depth of the ZOTC is 3.25 yards or 9.75 feet (Table 2). The width in professional' football (NFL) rules, the distance between the hash marks, is 18.5 feet. A ZOTC is therefore calculated to be 180.4 square feet (9.75 ft x 18.5 ft). College football (NCAA) hash marks are 53 feet 4 inches apart. The college rules spread the traffic over a wider ZOTC causing less damage to the field on a given play. The college plays always start with the ball on a hash mark, thus the number of players in the ZOTC is the same as in the professional game.

Data were collected from the study of 14 professional and major college football games. The location of 'each play on the football field was recorded to the nearest 5-yard line. Plays per

Table 1. Location of football plays. Nearest S-yard line.

Yard Line	Average No. Plays/Game[1]
0	4.0
5	2.7
10	4.4
15	5.6
20	9.0
25	8.4
30	10.1
35	7.9
40	9.1
45	9.8
50	9.1
45	10.2
40	11.7
35	11.0
30	9.3
25	8.3
20	9.3
15	4.5
10	4.9
5	3.6
0	4.6
Total	157.5

[1]Average of 14 games.

Table 2. Activity in zone of traffic concentration.

Average Width of ZOTC (ft.)	9.75
Average Area of ZOTC (sq. ft.)	180.40
Average Number of Players	11.20
Average Number of Steps Per-Player	10.90
Cleats Per Shoe	7.00
Average Plays/Games (high ZOTC)	11.70
Average Cleat-Dents/Sq. Ft./Play (high ZOTC)	4.47
Average Cleat-Dents/Sq. Ft./Game (high ZOTC)	55.46

*Superintendent of Agricultural Operations, UC Riverside

game averaged 157.5 (Table l), with an average of 11.7 plays in the highest ZOTC occurring at one 40-yard line.

The play locations are better visualized in graph forms (Figure 2). If there is a lot of scoring, goal-line area traffic increases due to points-after-touchdown plays. The overall traffic pattern concentration data compare with the wear patterns that are visually observed on football fields throughout the season.

On each play, an average of 11.2 players took 10.9 steps in the ZOTC. Football linemen shoes for natural turf have seven cleats per shoe. In the high ZOTC at 11.7 plays per game, there were 4.47 cleat-dents per square foot per play for 55.46 cleat-dents per square foot per game ([11.2 x 10.9 x 7]/180.4 = 4.73; 4.73 x 11.7 = 55.34).

The assumptions made in drawing the conclusions reported are: 1) each play occurs on a 5-yard line, 2) each play uses the full 18.5 feet between the hash marks, and 3) the players use all seven cleats taking each step on the heel and toe.

To quantify the location of maximum traffic concentration, a football field receives the most traffic at the forty-yard line, where 56 cleat dents per square foot are made per game. The sports turf manager, as well as the turf researcher, should focus the intensity of cultural practices on field management for that area.

Tolerance of Cool Season Turfgrasses to Sports Traffic

S.T. Cockerham, V.A. Gibeault, J. Van Dam, and M. K. Leonard'

Sports fields are high traffic turf areas that are subject to several demands-use and playability as well as safety and aesthetics. Sports fields include: parks; youth baseball, football, and soccer fields; high school and college fields and stadiums. Many are used seven days per week and 16 hours per day including night play under lights. The turfgrasses are expected to withstand the stress of this intense play use plus the pressure of ordinary foot traffic.

Several cool season turfgrasses were subjected to simulated cleated-shoe traffic to evaluate their tolerance of traffic. The Brinkman Traffic Simulator (BTS) was used to approximate football game-type traffic.

Perennial Ryegrass Cultivars

Fifty-three perennial ryegrass (Lolium perenne L.) cultivars were planted in the National Perennial Ryegrass Evaluation Trial in October 1984, at the Agricultural Experiment Station, University of California, Riverside. From mid-May to mid-July 1988, the grasses were rated for four weeks of one-half equivalent game per week and four weeks of one equivalent game per week simulated cleated-shoe traffic produced by the BTS.

Most of the perennial ryegrasses tolerated BTS traffic much better than expected (Table 1). 'Pippin' and 'Linn' were poorest, weakening significantly under traffic. The best performance was 'Citation II,' although it was not significantly different from the remaining varieties.

Thatch thickness of each cultivar was measured prior to applying the traffic and compared with the traffic tolerance ratings. The correlation was significant (r = -0.251, p = 0.00l), indicating a trend that increased thatch accumulation may enhance perennial ryegrass traffic tolerance.

Table 1. Mean turfgrass ratings for perennial ryegrass at UCR.

Cultivar	Traffic Tolerance-LSD (0.4)[1]
citation II	1.7
Palmer	2.0
M-382	2.0
Gator	2.0
Blazer	2.0
Prelude	2.0
SWRC-1	2.0
Manhattan II	2.0
Mom LP 702	2.0
NK 80389	2.0
Ranger	2.0
Yorktown II	2.0
Acclaim	2.0
Barry	2.0
Premier	2.0
Derby	2.0
HE-168	2.0
Mom LP 792	2.0
HE 178	2.0
Fiesta	2.0
Diplomat	2.0
omega	2.0
Crown	2.0
Cowboy (2EE)	2.0
Manhattan	2.0
Delray	2.0
Mom LP 210	2.0
Pennfine	2.0
Regal	2.0
NK 79309	2.0
WE 19	2.0
Tara (BT-I)	2.3
Pennant	2.3
Dasher	2.3
All*Star (IA 728)	2.3
Elka	2.3
citation	2.3
Cockade	2.3
Cupido	2.3
NK 79307	2.3
HR-1	2.7
Birdie II	2.7
Ovation (Mom LP 736)	2.7
Cigil	2.7
Pippin	3.0
Li""	3.3

'Traffic tolerance 1-0%; 3-25% 5-50% 9-100% injury. To determine statistical differences among entries, subtract one entry's mea" from another entry's mea". sta-tistical differences occur when this value is larger than the corresponding LSD (least significant difference) value.

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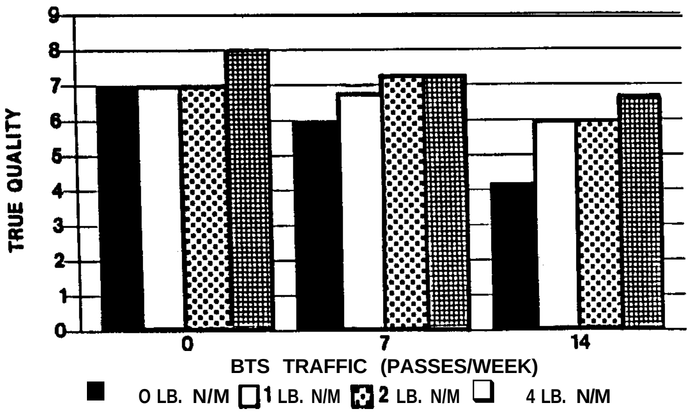
Tall Fescue Traffic Tolerance

Established 'Mojave' tall fescue (*Festuca arundinaceae* Schreb.) was submitted to 0, one-half, and one equivalent game per week of simulated cleated-shoe traffic with the BTS in March through December 1987. Subplots consisted of one nitrogen fertilizer application at 0, 1, 2 and 4 lb nitrogen (N)/lOOO sq ft.

The tall fescue plots were rated weekly for turf quality. At the termination of the trial, the hardness of the turf plus soil compaction were measured with a penetrometer as a simple technique to estimate the reduction in impact absorption capability.



'Figure 1. Tall fescue traffic study: nitrogen application.

The highest turf quality rating for all 'Mojave' tall fescue treatments was in the highest N treatment (Figure 1). As the traffic level increased, the overall turf quality decreased. The tall fescue under the heaviest traffic and no fertilizer treatment was significantly below acceptable quality. One nitrogen fertilizer application significantly improved the turf quality of tall fescue under traffic. At the heaviest traffic level, one equivalent game per week, and the highest N treatment, the tall fescue was still of acceptable quality.

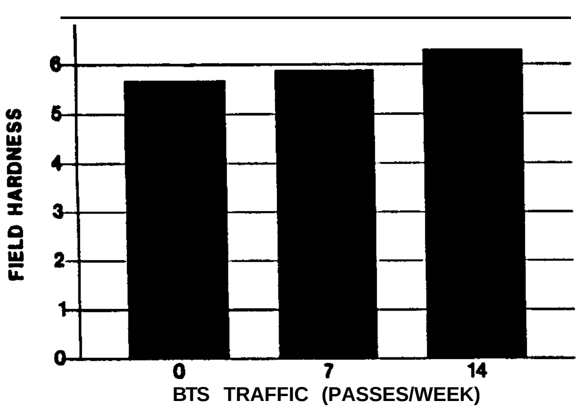


Figure 2. Tall fescue traffic study: penetrometer survey.

The penetrometer comparison of the hardness of the field in each of the traffic treatments showed that with traffic increase, field hardness increased significantly (Figure 2). The increase in hardness indicates a decrease in the impact absorption capability of the turf. There were no significant differences in penetrometer readings between the fertilizer subtreatments suggesting that one application of nitrogen fertilizer did not affect impact absorption.

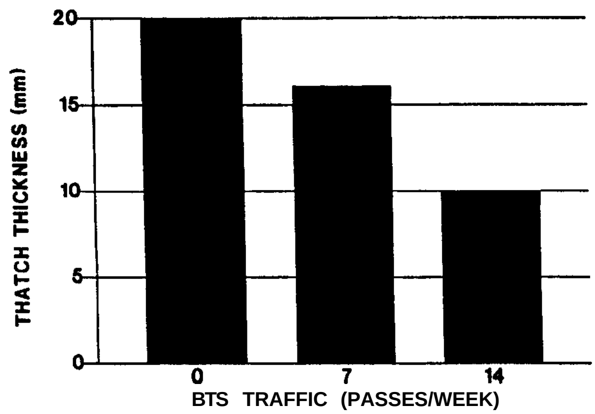


Figure 3. Tall fescue traffic study: thatch thickness.

The thatch thickness of the tall fescue was measured in each of the traffic treatments (Figure 3). As the level of traffic increased, there was a significant reduction in the thickness of the thatch. This also indicates the reduced absorption capability of the turf.

Overseeding Traffic Study

Common bermudagrass (*Cynodon dactylon* L.) was overseeded with several cool-season grasses in October 1986 (Figure 4). Roughstalk bluegrass (*Poe trivalis* L.) was seeded at 3 lb/1000 sq ft (1.5 kg/are) and all of the rest were seeded at 10 lb/1000 sq

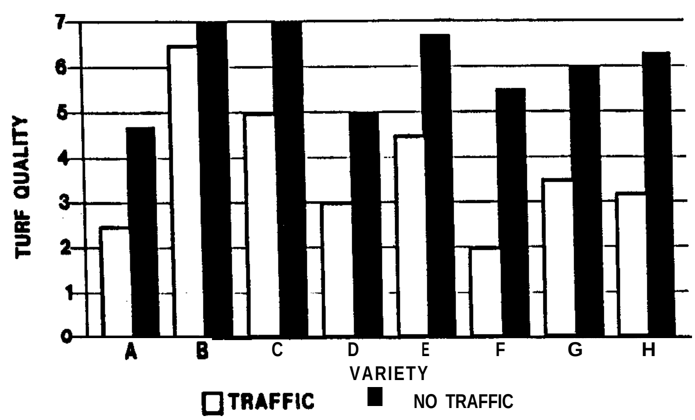


Figure 4. Overseeding traffic study: turf quality.

A - Control
B - Caliente perennial ryegrass
C - Elka perennial ryegrass
D - Annual ryegrass
E - Rebel II tall fescue
F - Roughstalk bluegrass
G - Shadow Chewing's fescue
H - Flyer creeping red fescue

ft (4.8 kg/are). Two-thirds equivalent game of BTS traffic one day per week was applied for a year beginning February 1987. The plots were rated weekly for turf quality.

The highest quality overseeded bermudagrass turf without traffic was observed for the two perennial ryegrasses followed closely by the three fescues. Roughstalk bluegrass and annual ryegrass (Lolium multiflorum Lam.) were acceptable but significantly lower in quality.

Roughstalk bluegrass did not tolerate traffic. Annual ryegrass and the two fine fescues-'Shadow' Chewing's fescue (Festuca rubra var. commutata Gaud.) and 'Flyer' red fescue *(Festuca* ***rubra*** L.)-performed better. The 'Rebel II' tall fescue under traffic was significantly better than all the perennial ryegrasses.

The two perennial ryegrasses as overseeded grasses performed remarkably well under traffic through a wide range of temperatures. 'Caliente' perennial ryegrass was significantly better under traffic than 'Elka.' With no traffic, there was no difference between them. There was very little observable difference between the 'Caliente' with traffic and without.

In the Spring of 1988, the plot area was treated with pronamide herbicide to eradicate the remaining cool-season grasses. Figure 5 shows the percentages of common bermudagrass cover in the plots after'the cool-season grasses had been eliminated. The grasses that were weak under traffic as overseeded turf were better for the spring transition from cool-season grass to bermudagrass. The tall fescue did not allow a good transition to bermudagrass but was better as a result of the traffic eliminating some of the fescue. The perennial ryegrass allowed a poor transition without traffic and significantly reduced the bermudagrass stand with traffic.

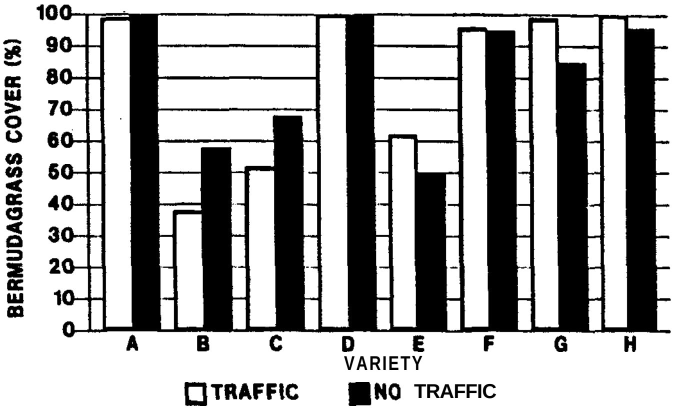


Figure 5. Overseeding traffic study: bermudagrass transition.

A - Control
B - Caliente perennial ryegrass
C - Elka perennial ryegrass
D - Annual ryegrass
E - Rebel II tall fescue
F - Roughstalk bluegrass
G - Shadow Chewing's fescue
H - Flyer creeping red fescue

WARNING ON THE USE OF CHEMICALS

Pesiictdes are poisonous. Always read and carefully follow all precautions and safety recommendations given on the container label. Store all chemicals in their original labeled containers in a lacked cabinet or shed, away from food or feeds, and out of the reach of children, unauthorized persons, pets, and livestock.

Recommendations are based on the best information currently available, and treatments based on them should not leave residues exceeding the tolerance established for any particular chemical. Confine chemicals to the area being treated. THE GROWER IS LEGALLY RESPONSIBLE for residues on his crops as well as for problems caused by drift from his property to other properties or crops.

Consult you County Agricultural Commissioner for correct methods of disposing of leftover spray material and empty containers. Never burn pesticide containers.

PHYTOTOXICITY: Certain chemicals may cause plant injury if used at the wrong stage of plant development or when temperatures are too high. Injury may also result from excessive amounts or the wrong formulation or from mixing incompatible materials. Inert ingredients. such as wetters, spreaders, emulsifiers, diluents, and solvents, can cause plant injury. Since formulations are often changed by manufacturers, it is possible that plant injury may occur, even though no injury was noted in previous seasons.

NOTE: Progress reports give experimental data that should not be considered es recommendations for use. Until the products and the uses given appear on a registered pesticide label or other legal, supplementary direction for use, it is illegal to use the chemicals as described.

CALIFORNIA TURFGRASS CULTURE EDITORIAL COMMITTEE

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