URBAN LAWN IRRIGATION AND MANAGEMENT PRACTICES FOR WATER SAVING WITH MINIMUM EFFECT ON LAWN QUALITY

by

R.E. Danielson and C.M. Feldhake

Colorado Water

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"URBAN LAWN IRRIGATION AND MANAGEMENT PRACTICES

FOR WATER SAVING WITH MINIMUM EFFECT ON LAWN QUALITY"

Completion Report

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by

Robert E. Danielson, Principal Investigator

Charles M. Feldhake, Graduate Research Assistant

of

Department of Agronomy

Colorado State University

and

William E. Hart

Department of Agricultural and Chemical Engineering

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COLORADO WATER RESOURCES RESEARCH INSTITUTE
Colorado State University
Fort Collins, Colorado

Norman A. Evans, Director

ABSTRACT

Understanding the response of turfgrass to water and energy is critical in semi-arid regions where energy for evaporation is high and water is often in short supply. During the summers of 1979 and 1980 research was conducted at Colorado State University to help in planning efficient urban lawn irrigation techniques. Forty eight small bucket type weighing lysimeters were used to measure the effect of various management practices on maximum water use and the response of turf quality to limited irrigation levels. Maximum water use was influenced by mowing height, nitrogen fertility, shade level, grass specie, and to a slight degree, soil properties. Nitrogen deficient grass showed a linear decrease in visual quality with decrease in irrigation; adequately fertilized grass, however, had minimal reduction in quality when irrigation was decreased to 70% of that required for maximum evapotranspiration (ET), and a rapid decrease with further irrigation decrease. Shade studies showed that ET increased linearly with incident radiation and all treatments had a constant advective component of ET which averaged 30% of the water used by the full sun treatment. Grass under water stress had a canopy temperature 1.7°C higher for each 10% decrease in ET below maximum on sunny days.

ACKNOWLEDGEMENTS

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Much assistance was provided to this study by Dr. Jackie D. Butler, Extension Turfgrass Specialist in the Department of Horticulture, who provided the plot area for the research, supplied maintenance equipment, and contributed to the success of the project by his advice on numerous occasions. His help is greatly appreciated.

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Dr. William E. Hart resigned from the faculty at Colorado State University early in the project. Assistance was then provided by Dr. Willard Downs, especially in establishing the research area, and by Dr. Thomas Trout. Thanks is due to both of these faculty members from the Department of Agricultural and Chemical Engineering.

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INTRODUCTION

In arid and semi-arid regions the scarcity of water makes it a precious commodity and research is important to increase the efficiency of its use. In Colorado the rapid growth in population is resulting in a redistribution of water from the already often short supply of the agricultural sector to the ever expanding need by the urban sector. Linaweaver et al. (1967) and Williamson (1975) reported that in arid regions 40 to 50 percent of the water treated annually for urban use was applied to lawns. Danielson et al. (1979) determined that outside water use accounted for over 70% of the total urban use in Northglenn, Colorado during the summers of 1977 and 1978. Studies on water requirements of urban lawns by Pochop and Borrelli (1979) and Danielson et al. (1979) showed that water application rates on urban lawns in Wyoming and Colorado varied widely. Even within the narrow range of application rates that suggested efficient irrigation, lawns often differed greatly in visual quality. Information concerning how to manage lawns for a pleasing appearance with minimal water input is not currently available for the general public.

The objective of this research was to establish criteria by which actual evapotranspiration (ET) by urban lawns may be significantly reduced with minimum reduction in turf quality. Bucket lysimeters containing soil and sod were placed in an established turf area. These lysimeters were removed for weighing and irrigation three times a week during the summers of 1979 and 1980. Treatments consisted of irrigation applications at various levels equal to and less than that needed for maximum ET. The effect of mowing height, fertility, and shade was also evaluated.

METHODS AND MATERIALS

SITE PREPARATION

A field at the Holly Plant Environment Research Center on the Colorado State University main campus was chosen as the research site. A 28 by 31 m area of well established Kentucky bluegrass (*Poa pratensis* L.), containing an underground sprinkler system, was fenced with a 1.5 m high welded wire fence to restrict foot traffic. A small shed, modified to serve as a site for weighing lysimeters, was located on the northeast corner of the plot, 12 m from the nearest lysimeters so it would have a minimal effect on the microclimate of the area. The plot area, shown in Figure 1, was divided into two main regions, one containing 32 lysimeters used in the limited irrigation studies, and another containing 16 lysimeters used in the shade studies.

LYSIMETERS

The lysimeters, shown in Figure 2, were constructed from 25 cm lengths of 25 cm diameter PVC irrigation pipe with a plate of PVC cemeted inside one end for a bottom. Two holes with removable plugs were installed in the bottom to facilitate draining when needed and a lip was cemented around the top for use in lifting from the ground. They were filled with a mixture of 80% sand and 20% peat on a volume basis except for two which were filled with a clay soil. Forty-six of the lysimeters, including the two filled with clay, were sodded with Marion Kentucky bluegrass during early May of 1979. The remaining two were planted with Tifway bermudagrass.

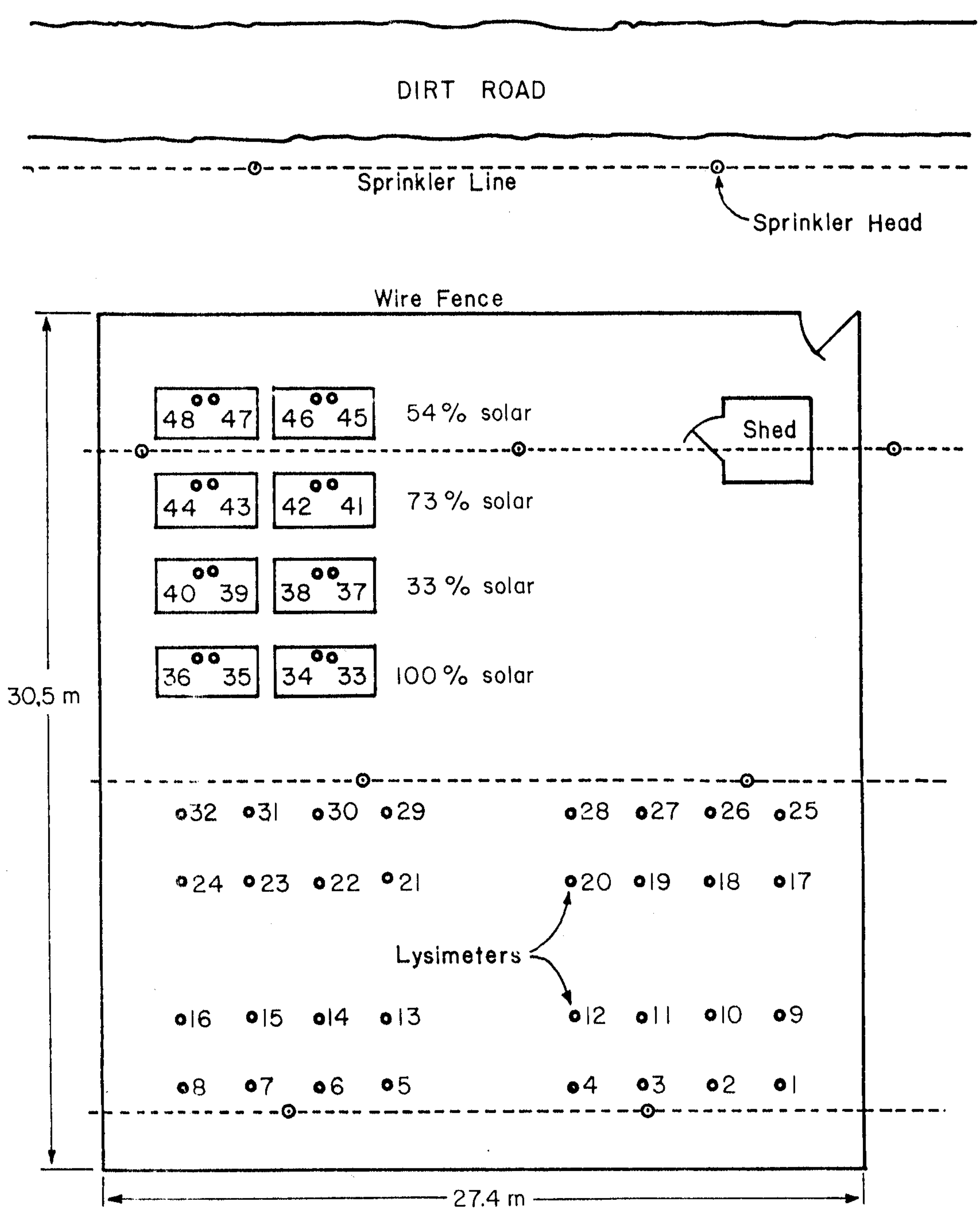

Figure 1. Layout of research area showing location and site number of lysimeters.

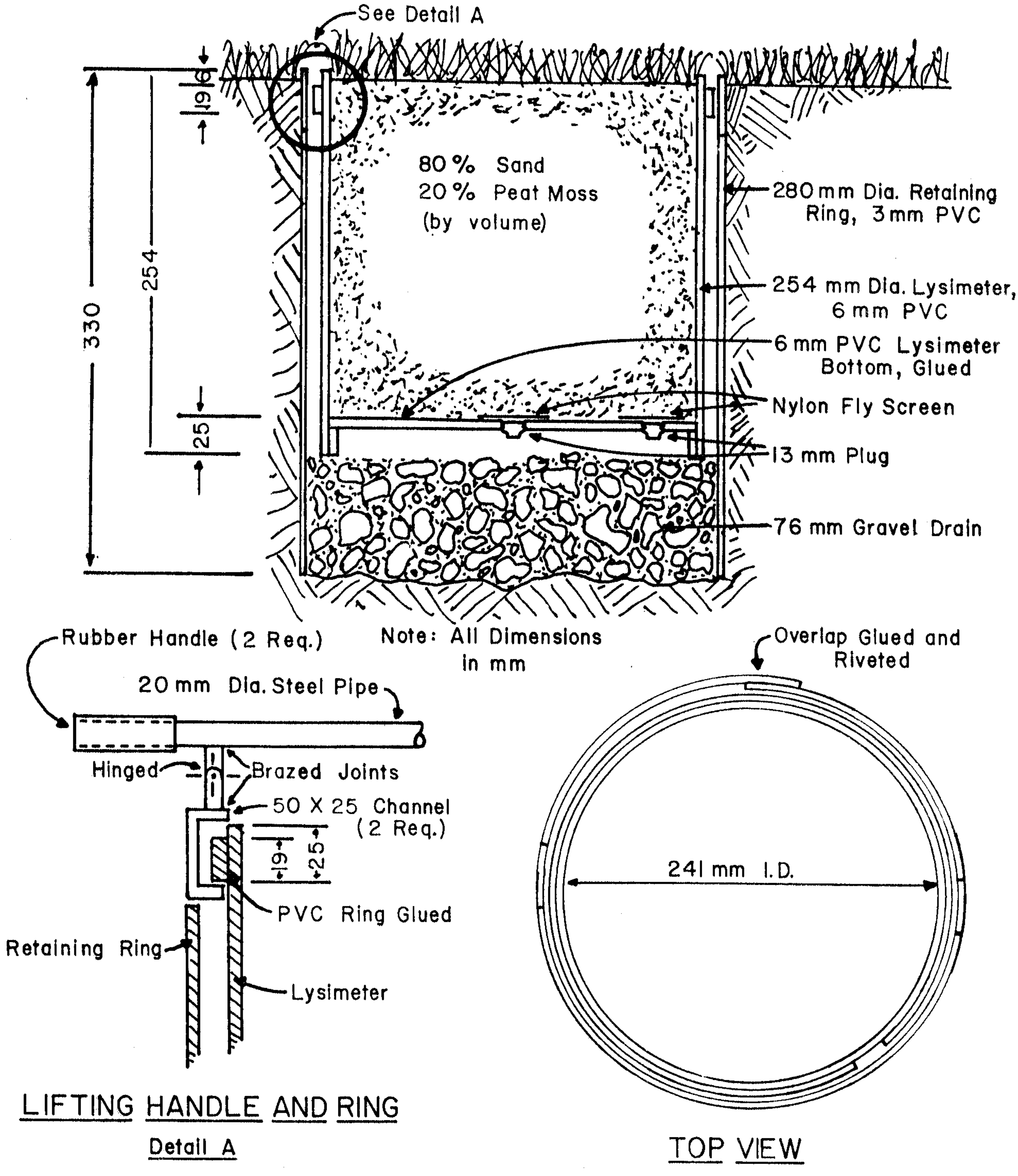

Figure 2. Schematic diagram of installed lysimeter and lifting handle.

During early June holes for the lysimeters were excavated with a tractor powered auger. An outer PVC Shell was placed into each hole to retain its shape and gravel was placed in the bottom. Once the lysimeters were placed into the holes they were hardly detectable. Figures 3 and 4 are photographs of the research area showing the lysimeters installed in the ground and placed on the ground next to the holes. The weight of each lysimeter at the optimal moisture content was determined by applying excessive irrigation, removing the bottom plugs and allowing overnight drainage, then replacing the plugs and weighing. The handle designed for lifting lysimeters from the ground is shown in Figure 5.

SHADE STRUCTURES

The shade structures were designed to provide a fixed fraction of incident solar energy but to have minimal disturbance of air flow across the lysimeters. Eight structures were made each consisting of three 3.1 m support sections of 1.9 cm diameter electrical conduit bent to the shape shown in Figure 6. Each support section was fastened at both ends with set screws threaded through sections of 2.5 cm diameter galvanized water pipe driven into the ground. This anchored them against movement by wind. The black polypropylyene shade cloth had sewn loops at each end so it could be threaded onto the conduit. The cloth was supported about 62 cm above the ground. The structures shaded a 1.85 by 3.65 m rectangular area. Two lysimeters were located below the shades slightly north of center so the shadow would cover them during most of each day during the growing season.

The intended shade treatments were to be 100, 75, 50, and 25 percent of solar radiation. The cloth was purchased to provide those

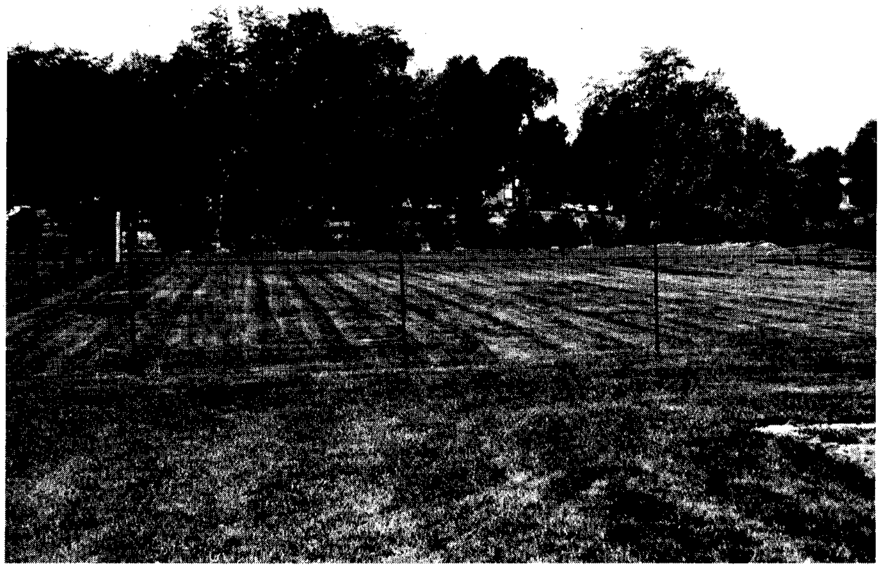

Figure 3. Plot area with lysimeters in place.

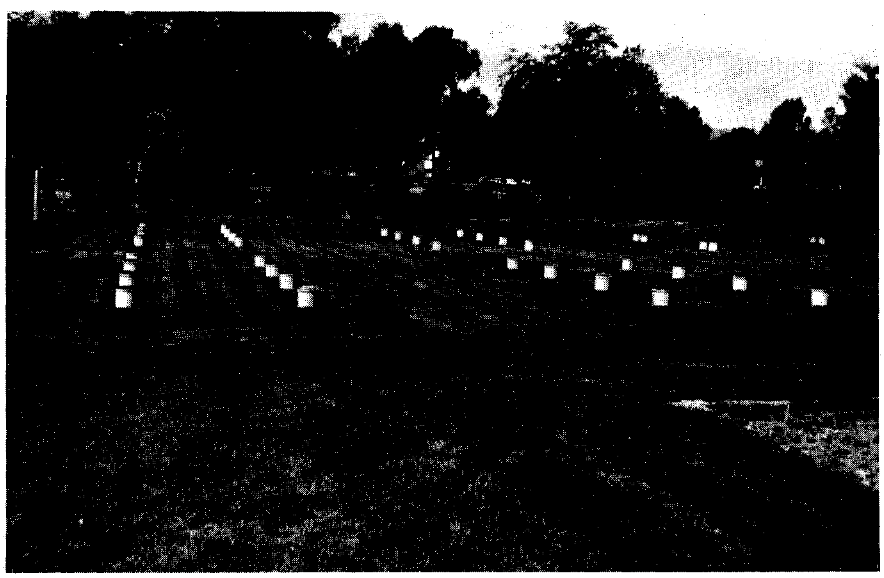

Figure 4. Plot area with lysimeters above ground next to holes.

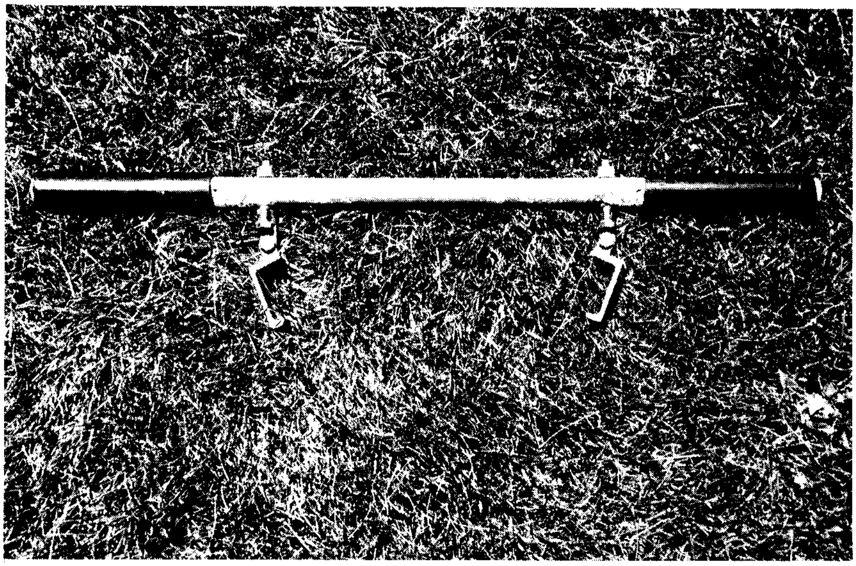

Figure 5. Handle for lifting lysimeters from ground.

Figure 6. Shade structures with lysimeters above ground next to holes. Treatments are, from left to right, 100, 33, 73, and 54% of possible solar radiation.

values and did so reasonably well as an average during the day measured with a Li-Cor photometer as shown in Table 1. After the shades were installed it was realized that the energy level available for evapo-traspiration would include long wave radiation from the black cloth as well as direct light transmission through it. The thermal radiation was calculated (appendix Table A-1) and added to the solar radiation to obtain the actual incident radiation values of 100, 73, 54, 33 percent of solar radiation. This correction is shown in Figure 7. The incident radiation levels are indicative of the energy available for evapotranspiration, not the light level available for photosynthesis. The 16% radiation level in Figure 7 represents a complete shade treatment used only on isolated dates to evaluate possible effects of the adaptation on evapotranspiration under no direct sunlight.

IRRIGATION

Before irrigating, the lysimeters were each weighed using an Ohous Heavy Duty Solution Balance. The loss in weight since the previous irrigation was the amount of water lost through evapotranspiration. After recording the weight, the desired amount of water was added with a graduated cylinder. The lysimeters were irrigated at about the same time every Monday, Wednesday and Friday morning during both years. The water content of the lysimeters allowed for about 5 days of transpiration by the grass before water became limiting enough to decrease ET.

The grass of the surrounding area was irrigated as needed using the underground sprinkler system. This grass required at least one irrigation every week to maintain lushness during summer periods

Table 1. Solar Radiation ($mE/m^2 sec$) on four days during 1980. Values were received by each solar treatment during cloudless periods.

Date	Solar Treatment	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00
6-24	100%	9.2	12.3	15.4	18.6	20.0	20.7	20.1	18.5	15.8	12.2	8.2
	73%	6.0	8.5	11.3	13.3	14.5	15.1	14.8	13.4	11.3	8.2	5.1
	54%	4.8	6.3	8.3	9.6	10.2	10.7	10.4	9.5	8.0	5.9	3.8
	33%	2.6	3.3	4.1	5.1	5.5	5.6	5.6	5.1	4.2	3.2	2.1
7-10	100%		8.1	16.3	18.8	19.8	22.1	20.8				
	73%			11.7	13.7	14.6		17.1				
	54%			8.3	9.7	10.2		11.5				
	33%			3.9	5.2	5.5		6.4				
	0%		0.8	0.7	0.6	0.5		1.2				
7-24	100%		11.8	15.3	18.3	23.3	21.6			14.6		
	73%		7.9	11.4	13.8	17.8				10.0		
	54%		6.4	8.6	10.6	13.2				7.6		
	33%		3.3	4.3	5.3	7.0				3.8		
7-31	100%		11.5	15.2	17.7	19.6	20.2		20.8	16.0	12.5	
	73%		8.2	11.3	13.5	14.7	15.1				8.8	
	54%		6.6	8.3	9.8	10.8	11.1				6.7	
	33%		2.6	4.2	4.8	5.5	5.7			4.5	3.4	
	0%		0.5	0.4	0.4	0.4	0.4			0.7	0.7	

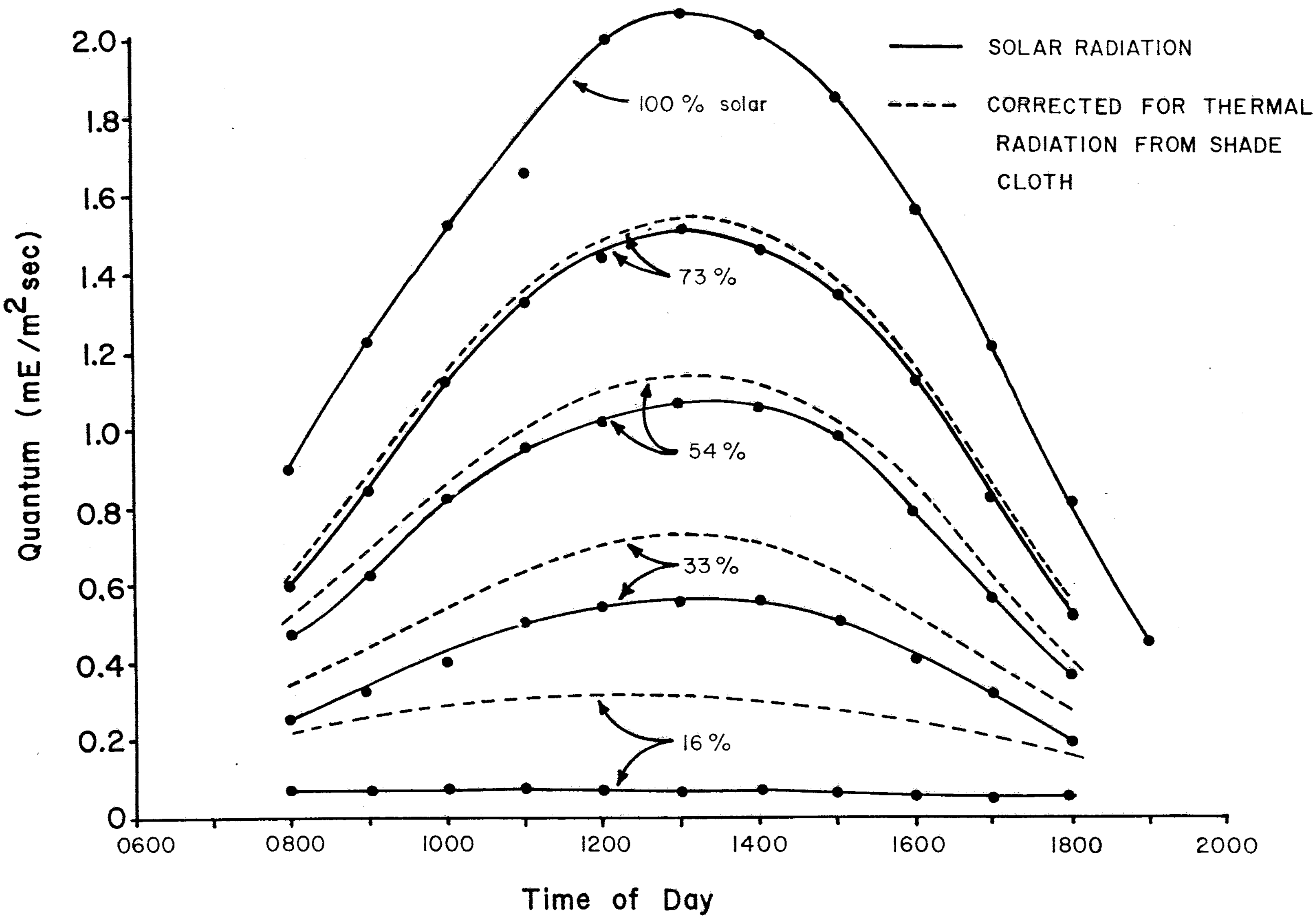

Figure 7. Incident solar radiation measured throughout the day on 6-24-80 and approximate total radiation corrected to include thermal infared from shade cloth.

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lacking rain. Small metal garbage can lids, 33 cm in diameter, were used to cover the lysimeters during sprinkling to prevent entry of an unknown quantity of water. The field was irrigated at night to minimize the effect of covering the lysimeters on ET and to prevent damage to the grass from excessive heating of the covers in the sun.

FERTILIZATION

Fertilizer was added to the lysimeters in solution form along with irrigation water. Granular fertilizer could not be added since the method of irrigation would not completely dissolve the granules and contact with grass blades would result in damage. Potassium and phosphorus were added regularly in small quantities. Nitrogen was added as ammonium sulfate when required.

The surrounding area was fertilized in May and July of both year with granular ammonium sulfate. The metal lids covered the lysimeters when this was done.

MOWING

The entire research area within the fence was mowed twice a week during the summer and as needed during the spring and fall. A small hand pushed power mower was used and mowing height was adjusted when desired. The lysimeters were mowed along with the rest of the field, however special care was taken to ensure that the mower wheels did not roll across the lysimeters themselves which would have resulted in tracks of depressed grass. The grass in the lysimeters was trimmed around the edge weekly by hand to maintain a constant canopy area.

QUALITY EVALUATION

Turfgrass quality was evaluated visually. A scale of 0 to 10 was used where 0 represented totally brown and 10 was for 100% lush, green growth. To help quantify and maintain consistancy in the weekly quality rating, a series of reference cards, 10 cm square, were constructed consisting of narrow bands of green and tan which were about the width of a blade of grass. A total of 11 tan and green cards shown in Figure 8, were constructed varying in 10% increments from 0 to 100% green. The ratings were made by viewing the grass from a near vertical position and comparing it to the cards to find the best match. When viewed from an angle at a distance, the quality rating would be slightly higher since green lives blades stand upright and are generally higher than the dead blades. This effect is most pronounced with the 8 and 9 rating which from a distance were nearly indistinguishable from a rating of 10. Figure 9 is a photograph of four lysimeters and the matching color cards.

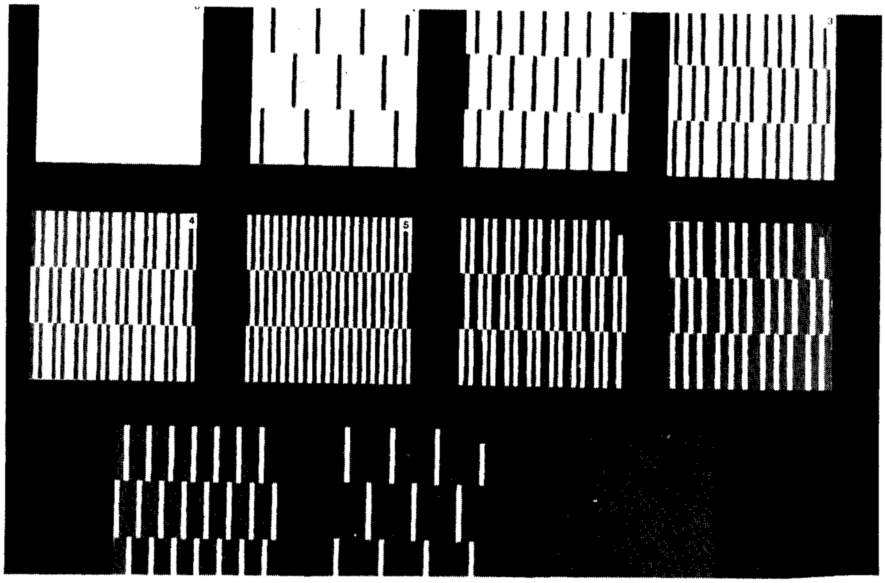

Figure 8. Green and tan color cards for evaluating turf quality, ranging from 0 to 100% green in 10% increments

Figure 9. Lysimeters with color cards matching grass. Values of Q from left to right are 10, 7, 4, and 1.

TREATMENTS

During the growing seasons of 1979 and 1980 the lysimeters were used to evaluate:

1. maximum evapotranspiration by the grass when soil water was never limited.
2. Grass quality when soil water was limited to force evapotranspiration to be specified fractions of maximum.
3. Evapotranspiration rates when the grass was subjected to various levels of solar radiation by shading.
4. Evaluation of possible plant adaptation to shading as reflected by evapotranspiration levels solar radiation was chanted to either full sunlight or complete shade.
5. Influence of mowing height and nitrogen fertilizer levels on evapotranspiration and grass quality.
6. Comparison of idealized send-peat growth media and clay soil.
7. Comparison of bluegrass and bemudagrass.

These studies will be described under the general headings of irrigation studies and solar radiation studies.

IRRIGATION STUDIES - 1979

Treatments during the summer of 1979 included irrigation rates equal to 100, 80, 60, and 40% of maximum ET, low and high mowing heights of 2 and 5 cm, and adaquate and high nitrogen (N) application rates of 4.9 and 9.8 Kg N/1000m^2 per month (1 and 2 lb N/1000 ft^2 per month). Treatments were randomized over the site area as listed in Table 2.

Limited irrigation treatments were begun in the following manner. All lysimeters which were to receive less water than the maximum ET requirement, received no irrigation until water stress resulted in a

Table 2. Treatment at each lysimeter site for the Irrigation Study during 1979

Site	Irrigation Level (%)	Nitrogen	Mowing height (cm)	Other
1	40	H*	2	
2	60	A**	5	
3	100	H	5	
4	80	A	2	
5	80	H	2	
6	100	H	5	
7	60	H	2	
8	80	A	5	
9	100	H	2	
10	60	A	2	
11	100	A	2	Clay soil
12	100	A	2	Clay soil
13	60	H	2	
14	100	A	2	
15	80	H	5	
16	100	H	2	
17	80	H	2	
18	60	H	5	
19	40	A	2	
20	80	H	5	
21	100	A	5	
22	40	H	2	
23	40	A	2	
24	60	A	5	
25	60	H	5	
26	100	A	5	
27	60	A	2	
28	100	A	2	Bermuda grass
29	80	A	2	
30	80	A	5	
31	100	A	2	
32	100	A	2	Bermuda grass

* H is High

** A is Adequate

measured ET lower than the 100% treatment which was irrigated three times each week. The 100% ET lysimeters were always weighed and irrigated first. The average of these was calculated as the maximum ET. The limited irrigation lysimeters were weighed and irrigated with the required amount based on the 100% treatment use. This resulted in some short term error because the limited irrigation treatments received water not on the basis of their need for the starting period, which was unknown, but relative to what the 100% treatment used during the previous period. However, over many measurement periods this procedure resulted in each treatment receiving approximately the desired irrigation. Irrigation was adjusted for rainfall and for the number of days in the measurement period which was 2 days twice each week and 3 days once each week.

Each irrigation treatment was split into two mowing heights each involving four lysimeters. The 40% irrigation treatment was an exception and had no high mowing level because it seemed doubtful that grass would grow to a 5 cm height at this low irrigation level. Each plot area consisted of a 2.5 m square mowed to 2 or 5 cm height shown in Figure 10, with a lysimeter in the center of each. The limited irrigation treatments were irrigated based upon the 100% irrigation treatment for the respective mowing height.

Lysimeters with clay soil and with bermudagrass were irrigated to provide for maximum ET, mowed to a 2 cm height, and received the adaquate N level. A photograph comparing bermudagrass and bluegrass in the lysimeters is shown in Figure 11.

At the end of the summer all lysimeters were fully irrigated to allow vigorous growth during Autumn and ensure winter survival.

Figure 10. Plot area showing difference in mowing height during 1979.

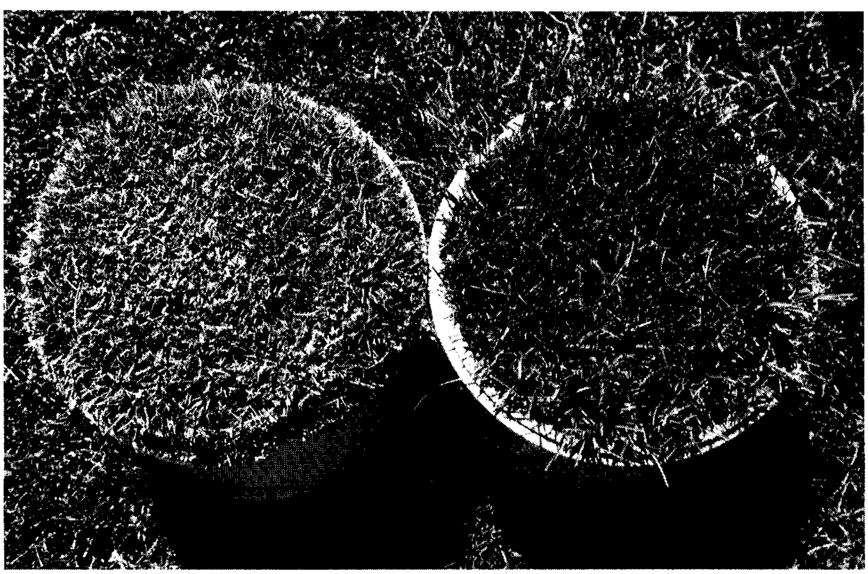

Figure 11. Bermudagrass (left) and bluegrass growing in lysimeters. Note difference in leaf canopy geometry.

IRRIGATION STUDIES - 1980

As a result of the 1979 studies, it was determined that the number of irrigation levels should be increased, the high mowing height treatment should be dropped, and the nitrogen fertilizer levels should be changed. Thus, in 1980 seven irrigation levels were established. These were 100, 90, 80, 70, 60, 50, and 40 percent of maximum evapotranspiration. Nitrogen fertilizer levels were zero (deficient) and 4.9 Kg N/1000 m^2 per month (adequate). The two clay soil and the two Bermuda grass lysimeters were continued at adequate nitrogen and at 100 percent ET as in 1979. All treatments were mowed at the 2 cm height. Treatments for each site location are given in Table 3.

In early May the entire area, including all lysimeters, was mowed. The sod is the lysimeters was de-thatched and fertilized to promote uniform growth for the start of the season. In early June the limited irrigation treatments were established following the same procedure used in 1979.

Each irrigation level was split into the two nitrogen application rates with two lysimeters for each. The N deficient treatments were not fertilized after the May application and resulted in decreased growth and quality. The limited irrigation treatments were given water based upon the ET of the 100% irrigation treatment for the respective nitrogen level.

The bermudagrass lysimeters were kept in a greenhouse between November 1979 and April 1980 since the variety used cannot survive the low temperatures common during the winter in Colorado.

Table 3. Treatment at each Lysimeter Site for the Irrigation Study during 1980

Site	Irrigation Level (%)	Nitrogen	Other
1	90	D	
2	90	A	
3	80	A	
4	60	D	
5	60	A	
6	70	A	
7	100	A	
8	70	D	
9	40	A	
10	90	D	
11	100	A	Clay soil
12	100	A	Clay soil
13	90	A	
14	50	D	
15	70	A	
16	70	D	
17	80	A	
18	40	A	
19	50	D	
20	70	D	
21	60	A	
22	60	D	
23	40	D	
24	50	A	
25	80	D	
26	80	D	
27	100	A	
28	100	A	Bermuda grass
29	40	D	
30	100	D	
31	100	D	
32	100	A	Bermuda grass

* D is Deficient

** A is Adequate

SOLAR RADIATION STUDIES - 1979-1980

Maintenance of grass under the solar radiation treatments was the same for both years. All lysimeters were irrigated to provide water for maximum ET, received 4.9 KG N/1000 m^2 per month and were mowed at the 2 cm height. Shade cloth provided environments receiving 100, 73, 54 and 33% of maximum possible radiation. Lysimeters were irrigated and weighed three times each week. No evapotranspiration values were determined for periods receiving significant rainfall since the shade cloth affected the amount of water each lysimeter received from precipitation. This varied with intensity and direction of the rain.

An effort was made to determine if plant adaptations to low energy environments would moderate ET in relation to available energy. This was accomplished by removing all shade cloths from two lysimeters of each treatment for a single day or by covering them with a tight weave material that shaded all direct sunlight. If plant adaptations were significant, the grass adapted to different shade environments would have different ET rates when all were exposed to the same environment for a day.

On days when environments were switched, all 16 lysimeters in the solar treatments were weighed immediately before sunrise and after sunset to determine ET for the day. Solar radiation, canopy temperature and leaf water potential was measured at intervals during cloudless periods of the day. Solar radiation was measured with a Li-Cor photometer, canopy temperature with a Barnes 14-220 infrared thermometer, and leaf water potential with a model J-14 leaf press.

Heat tolerance of the grass from each solar treatment was measured as an indication of adaptation to the energy of each environment. Two methods were used. Both involved taking approximately 100 blades of grass from each solar treatment and placing them in a vial with 50 ml of distilled water. The vials were heated in a water bath and heat damage was determined by measuring electrical conductivity (EC) of the water which increased as electrolytes leaked through cell membranes.

The first method involved heating the sample to increasingly higher temperatures in 2 to 3°C increments. At each temperature the samples were equilibrated for ten minutes then cooled to 20°C, and the EC measured, before being heated to the next higher temperature. The EC at each temperature was divided by the EC following exposure to 80°C to obtain the relative damage at each temperature. The second method involved exposure for 30 minutes at 51°C followed by total killing at 80°C. EC measurements were made after cooling to 20°C following each temperature exposure and the ratio was obtained as above to express relative damage.

RESULTS AND DISCUSSION

The results are presented under the general classification of irrigation studies and radiation studies. While the treatments for each year differed somewhat, year is not important to the discussion and it is not broken down accordingly. Reference is made to other studies to help clarify the interpretation whenever possible. All tables within the results and discussion section are summaries or averages of data. A complete listing of data is found in the appendices.

IRRIGATION STUDIES

Maximum evapotranspiration

Evapotranspiration by a crop, over a specified time period, will be maximum when the soil is adequately fertilized, the plants are disease and insect free, and the soil water content is not allowed to become limiting. Under such conditions, evapotranspiration is determined only by the energy available to vaporize the water. This energy may involve solar radiation or advective energy resulting from warm, dry air movement across and through the foliage.

The lysimeters involving the 100 percent irrigation treatments were maintained at non-limiting soil moisture by weighing three times each week and adding water each time to bring the soil back to field capacity. Thus, the evapotranspiration for this treatment was maximum for the particular conditions involved. The maximum ET values for each weighing period is summarized in Tables 4 and 5 for 1979 and 1980 respectively. Figure 12 shows the variability of these

Table 4. Maximum Evapotranspiration for 1979. Values are in millimeters per day for each weighing period and in millimeters cumulative from June 20. Grass quality ratings, at specified times during the season, are indicated. Fort Collins, Colorado.

Dates	ET (mm/day)	Cum (mm)	Q	Date	ET (mm)	Cum (mm)	Q
6-20,21	6.47	12.94	10	29,30	4.53	360.58	
22,23,24	4.94	27.76		31,1,2	5.59	377.35	
25,26	5.30	38.36		9-3,4,	6.87	391.09	10
27,28	4.23	46.82		5,6	5.41	401.91	
29-5	5.84	87.56		7,8,9	4.75	416.16	
7-6,7,8	6.43	106.85	10	10,11	2.12	420.40	
9,10	8.27	123.39		12,13	1.23	422.86	
11,12	7.67	138.73		14,15,16	4.44	436.18	
13,14,15	7.74	162.01		17,18	5.02	446.22	
16,17	3.89	169.79		19,20	3.88	453.98	
18,19	4.62	179.03		21,22,23	4.19	466.55	
20,21,22	5.05	194.18		24,25	3.78	474.11	
23,24	4.93	204.04		26,27	3.97	482.05	
25,26	5.57	215.18		28,29,30	4.70	496.15	
27,28,29	5.36	231.26		10-1,2	5.31	506.77	10
30,31	2.82	239.72		3,4	3.75	514.57	
8-1,2	6.62	252.96	10	5,6,7	5.10	529.57	
3,4,5	7.61	275.79		10,11	4.20	537.97	
6,7	7.23	290.25		15,16	4.00	545.97	
8-12	3.37	307.10		17,18	1.80	549.57	
13-16	1.00	311.10		19	1.85	551.42	
17-21	3.15	326.85		20-23	1.60	557.82	
22,23	3.94	335.73		24,25	2.60	563.02	7
24,25,26	3.07	343.94		11-16,17	1.23	565.48	
27,28	3.79	351.52		18	1.36	566.74 = 22"	

Table 5. Maximum Evapotranspiration for 1980. Values are in millimeters per day for each weighing period and in millimeters cumulative from March 12. Grass quality ratings at specified times during the season are indicated. Fort Collins, Colorado.

Dates	ET (mm/day)	Cum (mm)	Q
3-12,13	1.83	3.66	3
18,19,20	2.15	10.11	
21,22,23	1.51	14.64	
4-14,15	4.95	24.54	6
16,17	4.46	33.46	
18,19,20	5.18	49.00	
5-3,4	2.12	53.24	7.5
5,6	1.87	56.98	
7,8,9	0.85	59.53	
10,11,12	2.11	65.86	
19,20	4.29	74.44	
21,22	5.59	85.62	
23-26	5.69	108.38	
27,28,29	6.10	126.68	
30,31,1	7.41	148.91	
6-2,3	8.36	165.63	9
4,5	10.81	187.25	
5,7,8	8.05	211.40	
9,10	6.51	224.42	
11,12	8.94	242.30	
13,14,15	7.71	265.43	
16,17	7.64	280.71	
18,19	4.45	289.61	
20,21,22	6.14	308.03	
23,24	8.37	324.77	
25,26	8.44	341.65	
27,28,29	8.96	368.53	
30,1	5.51	379.55	
7-2,3	3.50	386.55	10
4,5,6	8.76	412.83	
7,8	7.52	427.87	
9,10	6.39	440.65	
11,12,13	5.23	456.34	
14,15	8.16	472.66	
16,17	7.79	488.24	
18,19,20	4.18	500.78	
21,22	5.41	511.60	
23,24	4.89	521.38	
25,26,27	5.59	538.15	
28,29	7.89	553.93	
30,31	6.83	567.59	
8-1,2,3	6.74	587.81	10
4,5	5.36	598.53	
6,7	8.51	615.55	
8,9,10	3.83	627.04	
11,12	8.04	643.12	
13,14	4.34	651.80	
15,16,17	4.34	660.48	
18,19	7.22	674.92	
20,21	6.67	688.26	
22,23,24	5.35	704.31	
25,26	5.15	714.61	
27,28	5.58	725.77	
29,30,31	3.54	732.85	
9-1,2	5.82	744.49	9.5
3,4,	6.17	756.83	
5,6,7	5.68	773.87	
8,9	1.89	777.65	
10,11	4.82	787.29	
12,13,14	3.12	796.65	
15,16	3.77	804.19	
17,18	5.20	814.59	
19,20,21	4.71	828.72	
22,23	3.59	835.90	
24,25	3.30	842.50	
26,27,28	3.89	854.17	
29,30	4.56	863.29	
10-1,2	3.28	869.85	
3,4,5	4.04	881.97	
6,7	4.03	890.03	
8,9,10	3.60	900.83	
11,12	3.11	907.05	
13-20	0.82	913.61	
21-2	2.13	939.17	
11-3-11	1.87	956.00	6.0

vs start 6-20 for 1979 (22" cum)

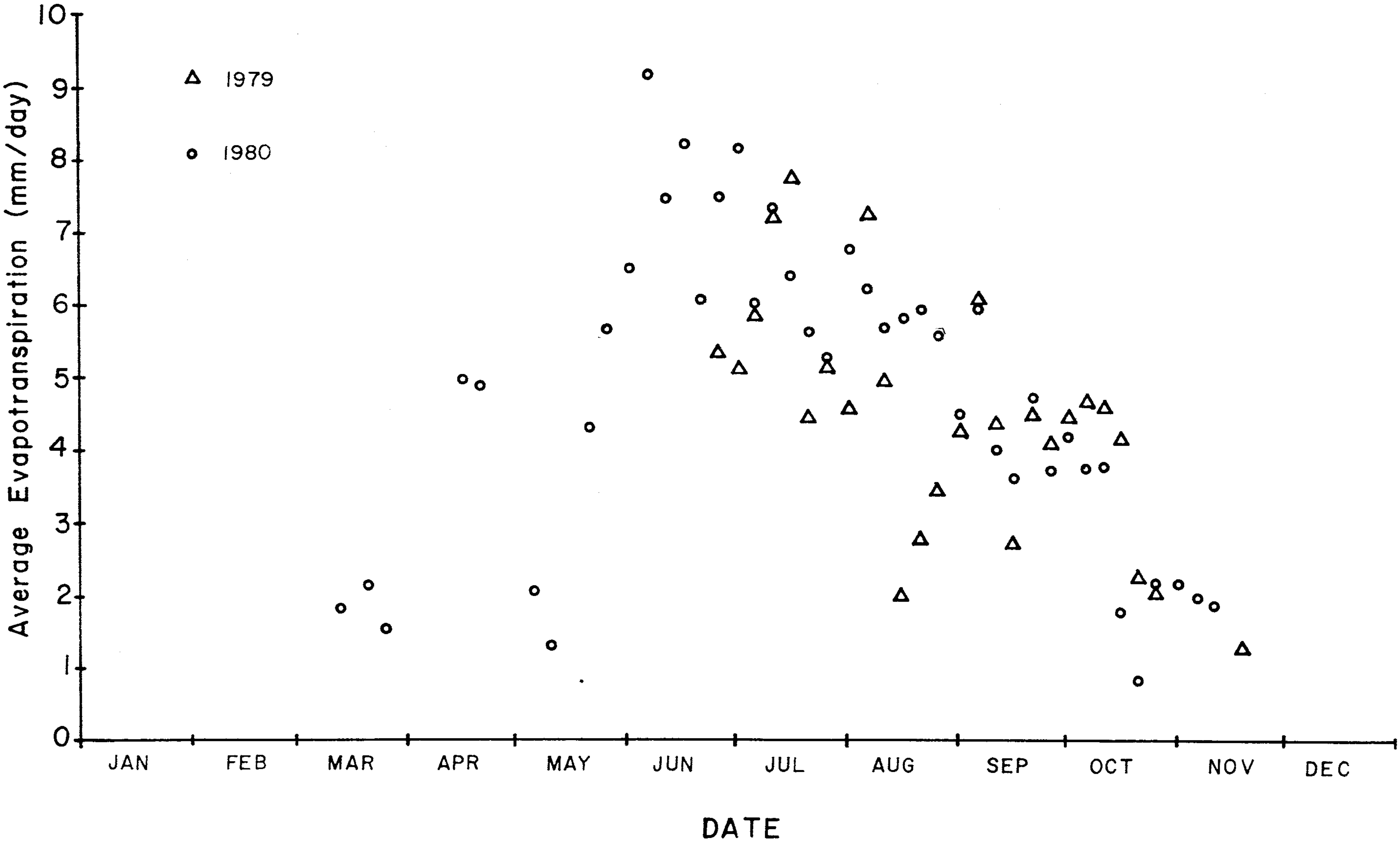

Figure 12. Evapotranspiration for 1979 and 1980. Each point represents a five day average.

data over the season. This variability reflects the changes in day length, clouds, and wind. Evapotranspiration data for all irrigation treatments are provided in Appendix B and weather data are recorded in Appendix C.

The effect of mowing height, soil fertility, soil type and grass species on evapotranspiration for the 100 percent irrigation treatments is shown in Table 6. The grass mowed at 5 centimeters used approximately 15 percent more water than that mowed at 2 centimeters. This is not surprising because, while they both received the same solar energy, the taller grass had a larger leaf surface area exposed to the advective energy of warm, dry wind. There was some concern about a possible oasis effect with only a 2.5 m square fetch of tall grass around the lysimeters. Measurements with a Barnes 14-220 infrared thermometer showed that under mild wind conditions the border effect did not extend very far into the plot. Figure 13 shows that the canopy temperature within the tall grass plots was constant except within 0.5 m from the edge. The tall grass canopy temperature was cooler which was expected if ET was higher.

Other investigators have also measured the effect of mowing height on water use. Shearman and Beard (1971) observed a 53% increase in the water use of Pencross Creeping Bentgrass turf in a special wind tunnel growth chamber when the mowing height was increased from 0.7 to 2.5 cm. This observation was made under rather extreme conditions and would not be as large within normal lawn environments. Mitchell and Kerr (1966) found that tall grass used more water than short grass and that grass used more water than clover at about the same mowing height. This implies that not only is the geometry of the

Table 6. Maximum evapotranspiration and relative ET for 100% irrigation treatments. The 2 cm high bluegrass grown in sand and receiving adequate N was used as the reference treatment.

Treatment	6/18 - 7/15		7/16 - 7/31		8/1 - 8/31		9/1 - 9/30	
1979	mm/day	Rel	mm/day	Rel	mm/day	Rel	mm/day	Rel
Low Mow (reference)			4.86	1.00	4.81	1.00	4.37	1.00
High Mow			5.50	1.13	5.63	1.17	4.83	1.11
Clay Soil			4.46	0.92	4.44	0.92	4.33	0.99
Bermuda grass			3.80	0.78	3.80	0.79	3.17	0.73
1980								
Adequate N	6.85	1.00	5.93	1.00	6.41	1.00	4.35	1.00
Deficient N	6.03	0.88	5.32	0.90	5.21	0.81		
Clay Soil	6.58	0.96	5.53	0.93	5.09	0.79		
Bermudagrass	5.24	0.76	4.86	0.82	4.11	0.64	2.98	0.69

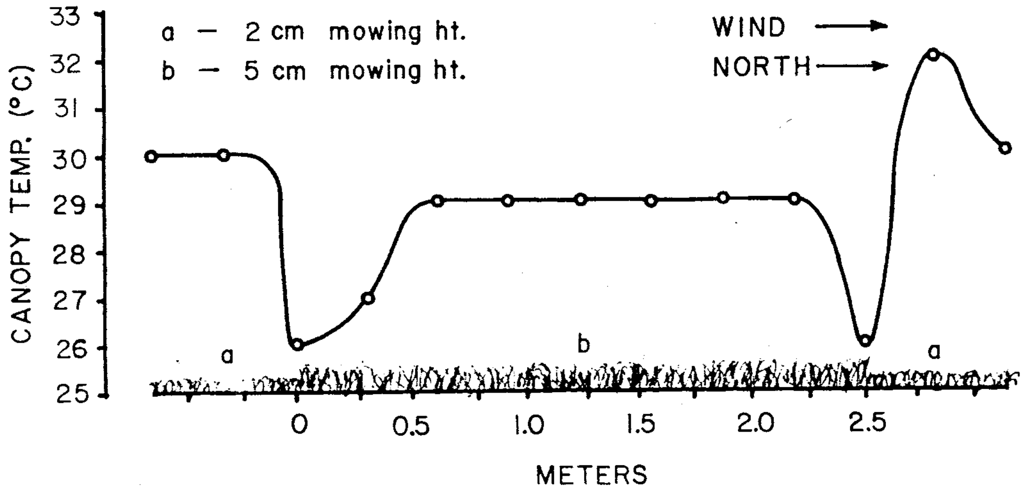

Figure 13. Variation in canopy temperature, at change in mowing height boundary, over fully irrigated grass on a warm, sunny, mid-summer afternoon with a steady breeze of about 2 to 4 Km/hr out of the south.

canopy important but the geometry of the plant within the canopy may also measurably affect plant water use.

Bermudagrass mowed at 2 cm used approximately 20% less water than bluegrass mowed at the same height. This is shown in the summary Table 6. Complete data are recorded in Appendix D. This is in agreement with the findings of Marsh et al. (1980) and Kneebone and Pepper (1979), that cool season grasses used more water than warm season types. Since warm season grasses are much more efficient at removing carbon dioxide from the air for fixation by photosynthesis, there is some indication that they may not open their stomata as wide and therefore not lose as much water. Another possibly more important factor is the plant geometry within the canopy. The bermudagrass at 2 cm formed a dense mat with short semi-horizontal leaf blades at the surface (Figure 11) while the bluegrass at 2 cm had tall erect blades which permitted greater wind flow through the canopy. More research is needed to evaluate water requirements of warm season species more adapted to Colorado conditions.

The effect of nitrogen levels on water use was not determined during 1979 due to problems in implementing the treatments. In 1980 the adequate N level treatments used about 10% more water than deficient treatments. This was probably due to the rapid growth resulting in taller grass by the time of the next mowing. Thus, an increased canopy height is likely responsible for the increased water use rather than a change in the functioning of the plant. Krogman's (1967) data agree with these results. He found that fertilized pastures used more water than unfertilized ones but they also produced much more biomass in relation to water use.

Grass in lysimeters containing clay soil used less water than that grown in sand-peat mix although the effect was small and varied somewhat (Table 6 and Appendix D). Feldhake (1979) found in a growth chamber study that grass used slightly less water when grown in clay soil than when grown in a sandy loam. Root washings from soil cores clearly showed there was much more root growth in the sandy loam than in the clay. It is not known if this was the specific reason for reduced water use. Probably the reason for both lower ET and limited root development was restricted soil aeration in the clay. Letey et al (1961) showed that plants grown in soil low in oxygen often wilted during midday, when transpiration rates were high, due to reduction of the root membrane permeability.

Oxygen levels are often low in clay soils especially if soil moisture is maintained at a high level. It is also possible that the grass growing in the clay soil used less water due to a slight decrease in leaf growth which reduced exposure to wind. However, the quality and amount of top growth was not visibly affected. Even though grass may use slightly less water when grown on clay soil, it is not advantageous to limit ET in this way. The limited root system results in decreased drought tolerance and creates the need for frequent irrigation since the grass taps a very small soil water reservoir.

Limited evapotranspiration

Evapotranspiration data for limited irrigation treatments during both years is listed in Appendix B. It should be noted that since lysimeters receiving limited irrigation were located in a well irrigated field there may have been an inverse-oasis effect. However, maintaining a fetch area around each limited irrigation treatment in the same manner as the lysimeter itself was not feasible. While this limitation should be kept in mind, it is doubtful that it resulted in serious interpretive error. Evapotranspiration was not affected; however, it was limited by the applied water; but, quality of the grass could have been slightly enhanced by the inverse-oasis effect. A graph of the relation between turf quality and relative ET was made for each irrigation-mowing height treatment for 1979 and for each irrigation-N level for 1980 and are shown in Appendix E. Relative ET is the ET of the treatment divided by the maximum ET measured by the corresponding 100% irrigation treatment.

During 1979 there were frequent rain showers which prevented the attainment of extended equilibrium periods between ET and irrigation levels. The rise and fall of ET, and with a slight lag the rise and fall of quality, is shown for the plots in 1979 in Appendix E. The summer of 1980 was drier and the period from July 25 to August 14 closely approximated the desired situation where ET equaled irrigation. Figure 14 is a plot of the relation between turf quality and relative ET for this period. The grass with a slight N deficiency decreased in quality in a nearly linear manner with the decrease in available water. At the adequate N level the grass had more vigor and showed a slow decrease in quality until irrigation provided less than about 70% of the maximum ET possible. The change in the slope of the line is probably the point where damage to the grass as a result of high canopy temperature and dessication overrides a mere reduction in

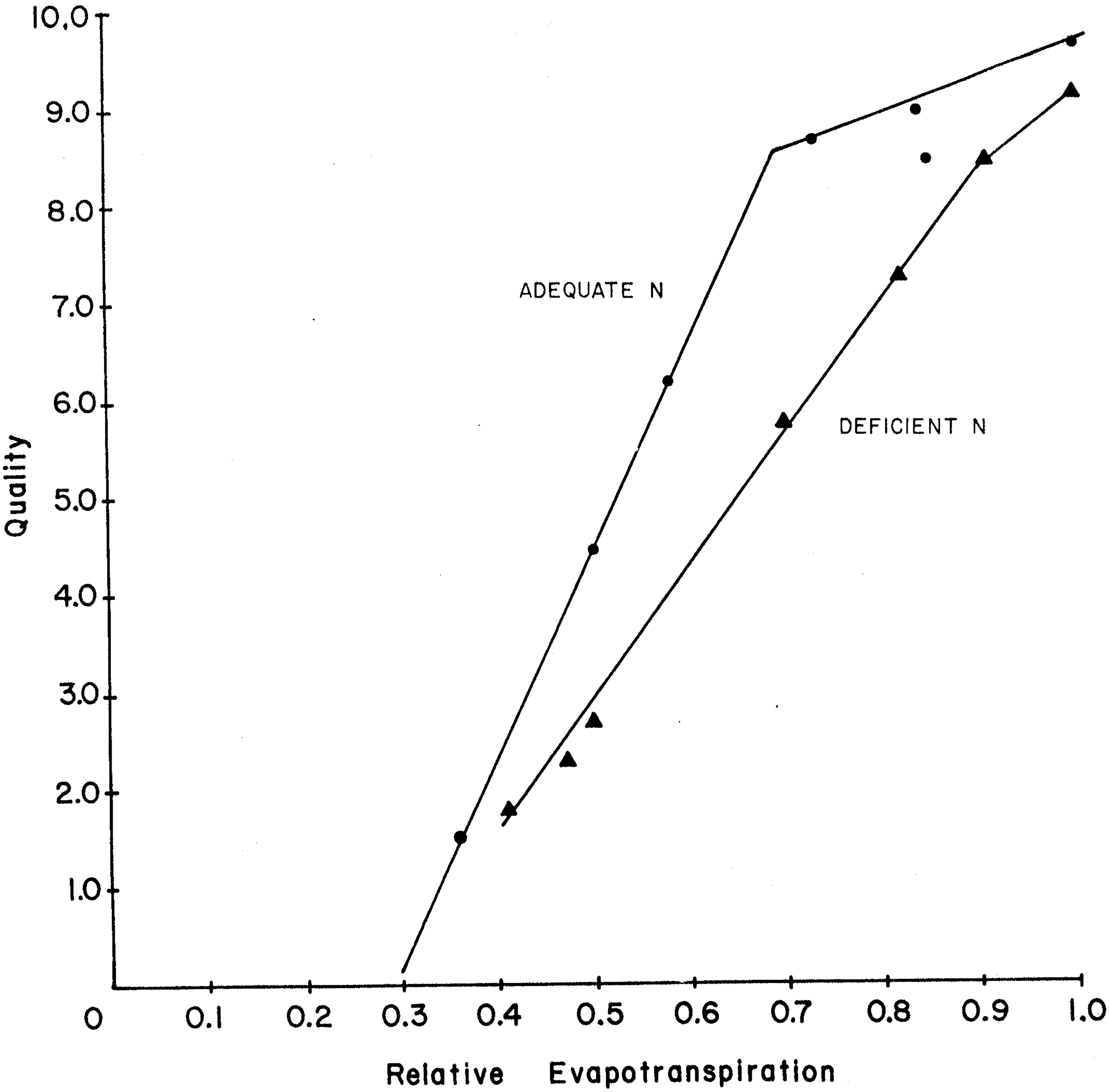

Figure 14. Relation of grass quality to relative ET for two nitrogen levels during 1980. Each point is the average of data from two lysimeters from 7-25 to 8-14 1980.

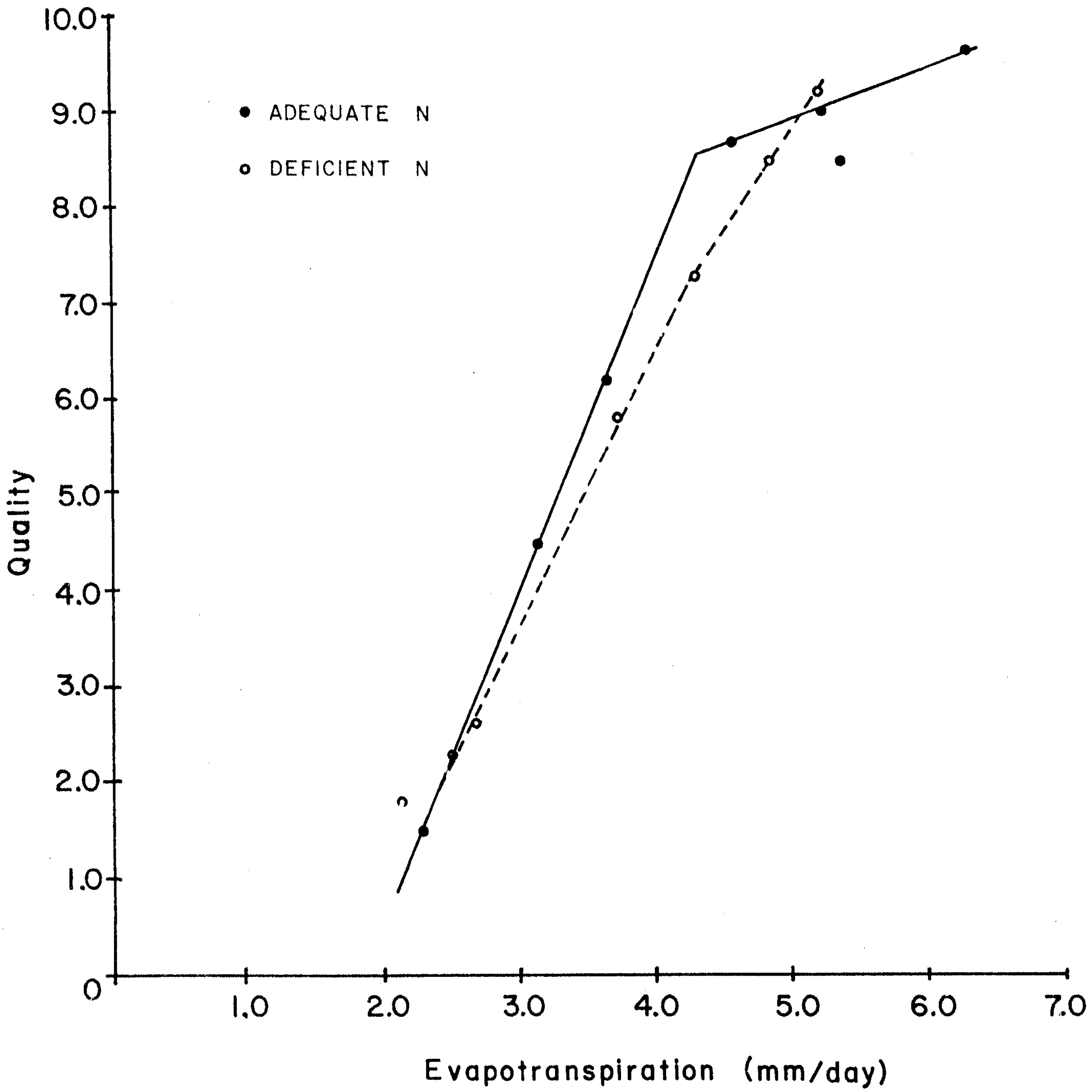

Figure 15. Relation of grass quality to ET for two nitrogen levels during 1980. Each point is the average of data from two lysimeters over the period of 7-25 to 8-14 1980.

growth as the dominate reason for decreased quality.

Figure 15 shows the relation between grass quality and actual ET during the same period represented in Figure 14. Since the deficient N treatment had a lower maximum ET, the lines are closer together than on the relative ET plot. The grass where N was adequate had higher quality at most application rates. This is in agreement with the observation of Mantell (1966) who stated that "infrequent irrigation of fertilized plots produced a lawn of only slightly reduced quality compared to that obtained when frequent irrigations were given in the absence of nitrogen, and the former treatment was accompanied by a considerable saving in water and labor." Too much N can, however, cause a reduction in root growth and drought tolerance. Paul and Madison (1972) found that at moderate water stress bluegrass decreased growth more at high N levels than at adequate levels. Sprague and Graber (1938) reported that during drought, high N levels decreased turf density and increased disease susceptibility.

During the dry years of the mid 1950's Beach (1958) found that water application greater than 4 mm/day did not give a corresponding increase in turf quality. While actual ET was not measured, this break point when corrected for rainfall is in agreement with the results of this study. Beach also found that root biomass and root depth increased as irrigation frequency and amount decreased.

An interaction of mowing height with limited irrigation was not well documented in this study but it is suggested in Figure E-6 of Appendix E. At the 60% irrigation level quality did not decrease as much for the 5 cm height as for the 2 cm. While taller grass used more water when fully irrigated, it maintained higher quality when water was limiting.

This may be a result of less heat damage since the sun's energy is dissipated over a greater leaf surface area. A constant amount of solar radiation was dissipated over a 5 cm depth rather than a 2 cm depth. Taller lawn grass also has the advantage of a deeper root zone which results in the need for less frequent irrigation. In the event of severe drought where the grass turns totally brown, a larger root mass contains more stored carbohydrates to aid in survival and provide for rapid regrowth when water is again available. Madison and Hagan, (1962) demonstrated that the taller grass had a larger and deeper root system.

It should be noted that while limited ET correlates well with decreased quality over a long time period, the actual ET on a given day may not be directly related to quality. Feldhake (1979) showed that bluegrass with a quality rating of 3 was capable of ET rates around 75% of maximum if the soil was fully irrigated, and that bluegrass at quality 10 could be reduced to about 60% of maximum for a day by allowing soil drying and if irrigated the next day showed no visible damage.

Midday canopy temperature was measured for lysimeters where the grass was experiencing different degrees of water stress as indicated by daily ET. Values obtained on three warm, sunny days in 1980 are plotted in Figure 16 where relative values are compared to relative ET rates. A linear relationship exists over the range of 100 to 45% ET and then temperature of the foliage increases rapidly with further decrease in transpiration. Under the atmospheric conditions of the experiment, the canopy temperature increased 3^{o} F for every 10 percent decrease in ET below maximum. It could therefore be expected that reducing lawn irrigation below that required for

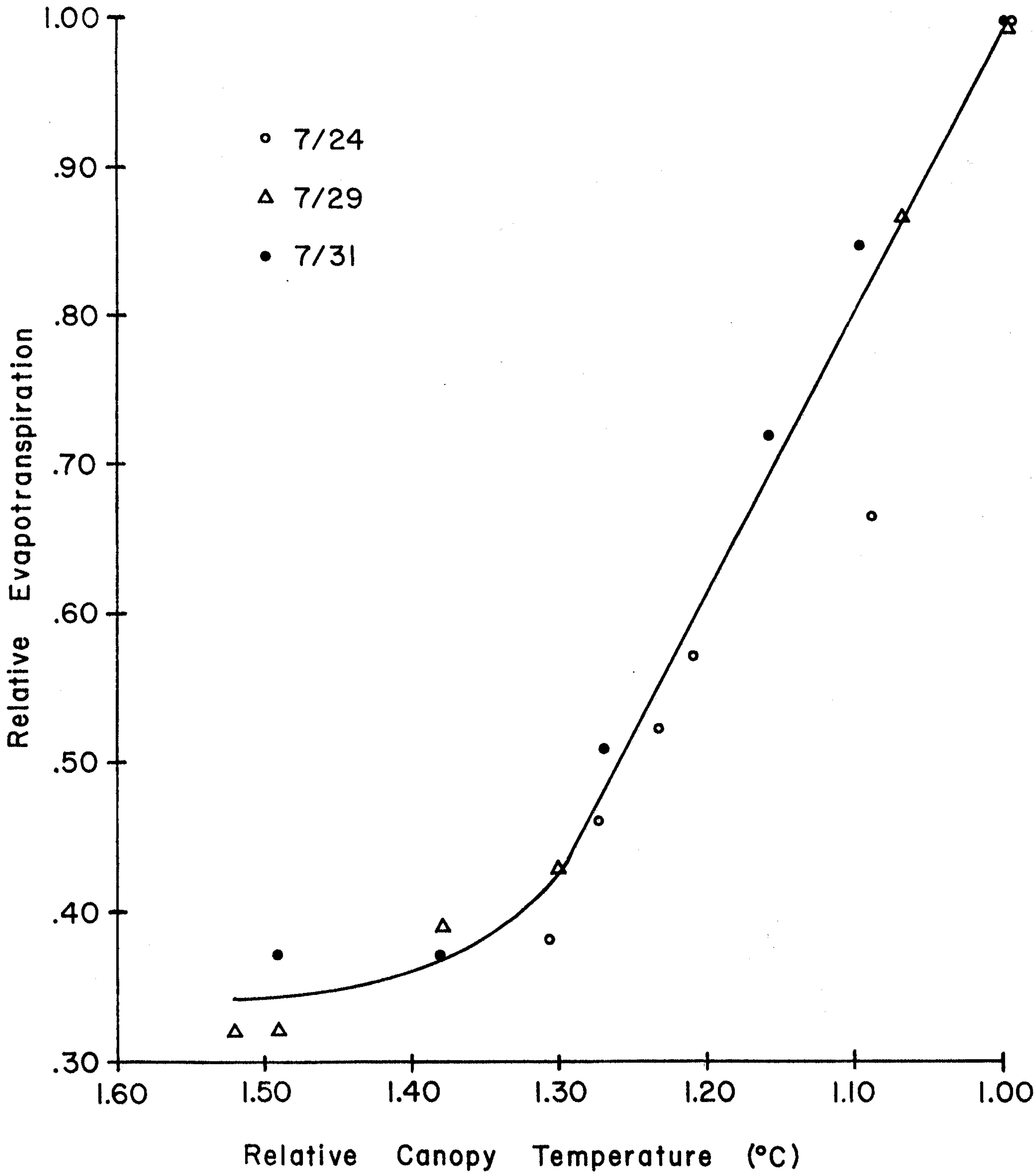

Figure 16 Relation between relative ET and relative canopy temperature. Each point is from a lysimeter where the grass was of a different water stress level. Canopy temperatures at maximum ET was approximately 28°C. ET was measured for the day and temperature was averaged over several time periods during the middle of the day.

maximum ET, while not necessarily reducing lawn quality very much, might result in higher temperatures causing increased discomfort during outside activities and higher energy costs for air conditioning. Similar effects would result if lawn area was converted to gravel or wood chips.

RADIATION STUDIES

Shade effects on evapotranspiration

The complete evapotranspiration data for 1979 and 1980 are listed in Appendix F. A graph of typical relationships of ET rate to radiant energy is provided in Figure 17. The ET values are maximum for each shade condition since soil water was maintained at non-limiting levels. The linearity is apparent. The extrapolated value of ET at zero solar radiation (approximately 2 mm per day) is the component resulting from advective energy. This value would of course vary with the amount of wind received. Under the conditions for which the data of Figure 17 were obtained, a decrease in radiant energy of 50% resulted in an average decrease in ET of about 30%.

It must be noted that the reduction in ET by shade cannot be related to water savings from the shade produced by trees in urban areas. The reduced water use by the shaded lawn may be more than offset by the ET of the tree. Trees have a higher advective component since they protrude into the air and are more in a position to be affected by wind and by reflection from streets, sidewalks, rooftops and other non-transpiring surfaces. The net result is that trees and shrubs in mature landscapes may use more water than the grass.

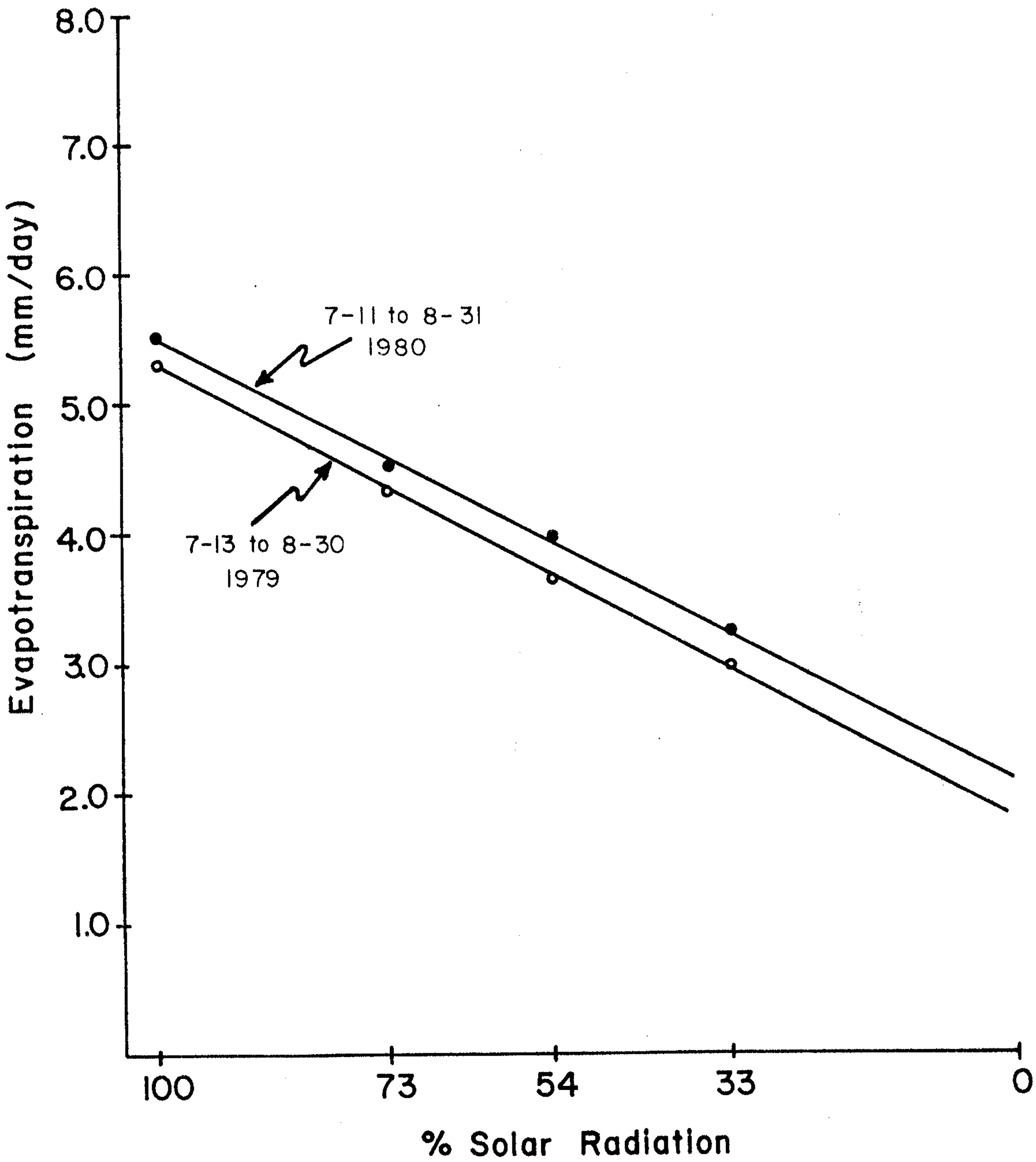

Figure 17. Relation of ET to solar radiation over the periods indicated during 1979 and 1980. Each point is the average of four observations.

Plant adaptation to shade

The lysimeters exposed to the various radiation levels were maintained continuously under the shade cloths until the bluegrass was evaluated for possible adaptation or conditioning effects on evapotranspiration. Evaluations were made on four days as indicated in Table 7. On June 24, two lysimeters from each of the three shade levels were uncovered in order to subject them to full solar radiation for one entire daylight period. The other two lysimeters from each shade level remained at that level for comparison purposes. The same evaluation was made again on July 24. It can be seen in Table 7 that the ET rate of the shade treatment plants on these two days was essentially identical to that of the four lysimeters which had been at the 100% solar level all the time. Thus, there was no apparent conditioning effect on the grass due to previous exposure to any of the shade levels. On July 10 and 31 two lysimeters from each of the four radiation levels were covered to provide full shade and limit ET to that resulting from advective energy. Again the results shown in Figure 7 indicate no difference due to previous levels of exposure to shade. The ET for the day was between 42 and 46 percent of maximum for all sixteen lysimeters.

Canopy temperatures of the lysimeter grass were measured at hourly intervals during portions of the days that plant adaptation was tested. These temperature data, together with ambient air temperature values, are listed in Appendix G. Again, previous environmental conditions did not influence the results. This would be expected since the plants had not become adapted as far as evapotranspiration rates were concerned. Interesting comparisons of blade temperature as related to time of day, degree of shade, and air temperature are

Table 7. Turf Evapotranspiration. Values are for turf adapted to four solar levels. Two lysimeters remained at the indicated level and two from each treatment were subject to either 0 or 100 % solar levels on the date indicated.

Solar Treatment	Site	6/24 mm/day	6/24 Rel.	7/10 mm/day	7/10 Rel.	7/24 mm/day	7/24 Rel.	7/31 mm/day	7/31 Rel.
100%	33	7.3		5.1		4.1		6.8	
	34	7.7		5.0	1.00	3.9		6.8	1.00
	35	7.8		2.1**		4.2		3.1**	
	36	8.0	1.00	2.2**	0.43	4.3	1.00	3.2**	0.46
73%	41	8.5*		4.2		4.4*		6.3	
	42	7.9*	1.06	4.3	0.84	4.1*	1.03	5.8	0.89
	43	6.3		2.1**		3.3		2.9**	
	44	6.4	0.82	2.2**	0.43	3.7	0.85	3.1**	0.44
54%	45	7.9*		3.4		4.2*		5.3	
	46	7.7*	1.01	3.5	0.68	4.2*	1.02	5.0	0.76
	47	5.0		2.0**		3.1		3.1**	
	48	4.9	0.64	2.2**	0.42	2.8	0.72	3.0**	0.45
33%	37	7.9*		2.8		4.3*		4.2	
	38	7.7*	1.01	2.7	0.54	4.2*	1.03	3.9	0.60
	39	4.2		2.2**		2.7		3.2**	
	40	3.9	0.53	2.2**	0.44	2.5	0.63	3.0**	0.46

* Measurement from lysimeters receiving 100% solar on indicated date

** Measurement from lysimeters receiving 0% solar on indicated date.

available from Appendix Tables G-1 and G-2.

Leaf water potential was measured to aid in interpretation in case there was a difference in water use related to adaptation. There was a decrease in leaf water potential for all treatments as the transpiration rate increased from early morning to midday. This is a normal response to environmentally induced increase in water flow through plants. The lowest solar level treatment showed the smallest diurnal fluctuation. This reflects the low evapotranspiration rates and the fact that all lysimeters were maintained at high soil water levels.

The heat tolerance test data are listed in Appendix H and show no decisive trends. The data from the variable temperature test (Table H-1) is plotted as Figure 18 and shows all solar levels had grass that resulted in 50% damage when the constant temperature bath was raised to 53°C for 10 minutes. When samples from all treatments were exposed to 51°C for 30 minutes (Table H-2) there was a very slight increase in heat tolerance with solar radiation level but the trend had an R^2 of only 0.35.

A lack of significant difference in heat tolerance between treatments was unexpected. Wallner (1981) found that grass grown in a growth chamber at an ambient air temperature of 38°C had significantly greater heat tolerance than grass grown at 22°C canopy temperature data in Appendix Table G-1 and G-2 show that during midday, grass under full sun was commonly 8-10°C warmer than grass receiving only 33% of possible radiation. Heat tolerance measurements did not indicate plant adaptation to the energy within each shaded environment.

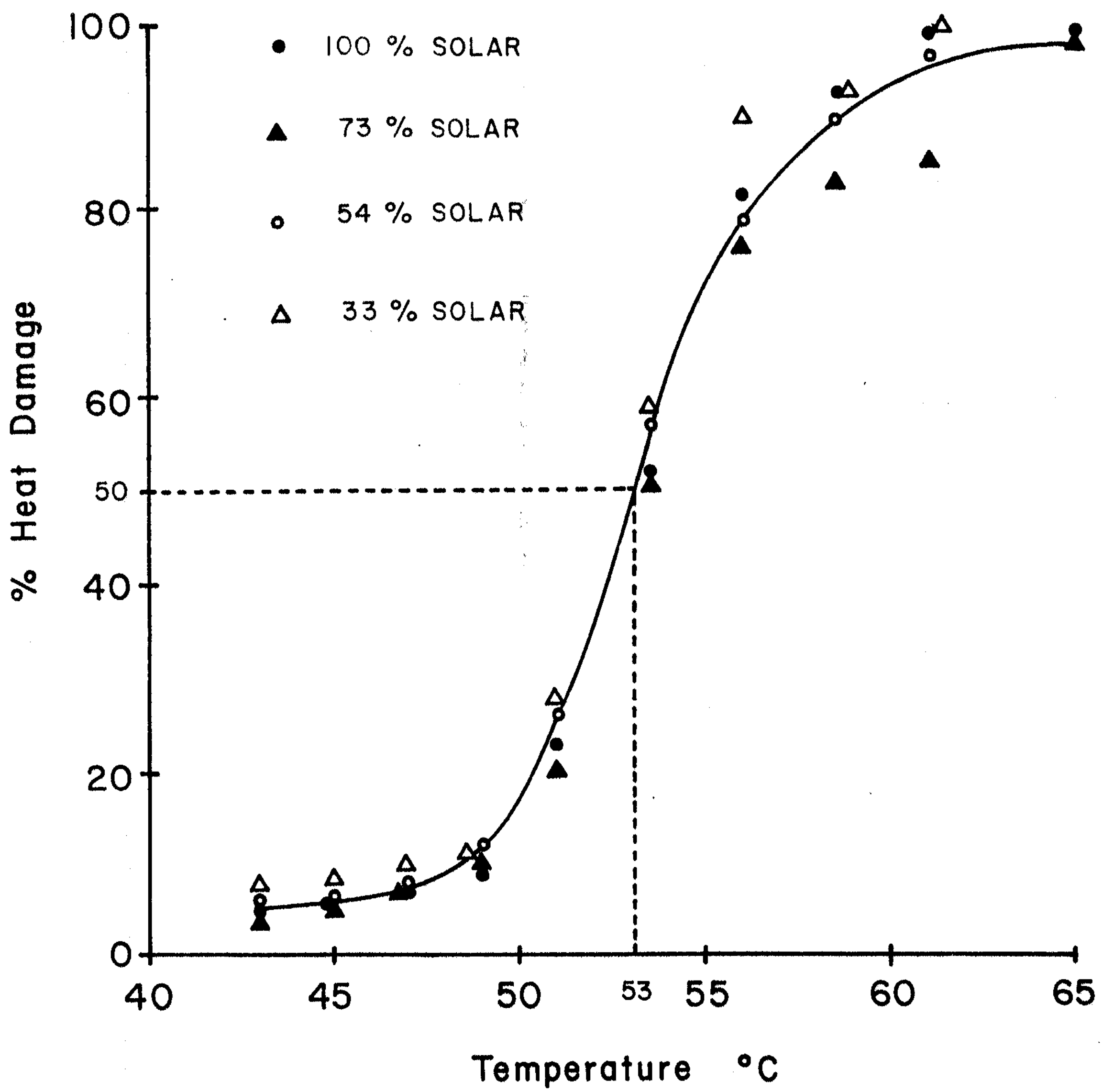

Figure 18. Percent heat damage, measured by the electrolyte leakage method, of blades of grass exposed to increasing water bath temperatures. Each point is the average of two samples composed of about 100 blades of grass. The killing temperature is defined as the point of 50% heat damage which is about 53°C for all samples regardless of the amount of solar radiation in the growth environment.

CONCLUSIONS

During the summers of 1979 and 1980 research was conducted to help better understand water use and plant response by turfgrass. Forty-eight small "bucket type" weighing lysimeters were installed in a field of well maintained Kentucky bluegrass. The lysimeters were weighed and irrigated three times each week. The research was divided into two areas with treatments involving irrigation studies and solar radiation studies.

Part of the irrigation studies were designed to measure the effect of various lawn maintenance practices on water use when grass was irrigated with the maximum amount it could use. The other aspect of the irrigation studies involved irrigating lysimeters with increments of water less than the maximum usable amount and observing the effect on visual quality. Under the conditions of this study the following observations were made.

1) Grass maintained at a 5 cm mowing height used about 15% more water than grass at 2 cm when irrigation was provided for maximum use. However, the taller grass remained at high quality longer than the short grass when irrigation was limited.

2) Grass receiving adequate nitrogen fertilizer used 10% more water than N deficient grass. This was likely a result of the difference in rate of leaf elongation after mowing. Adequately fertilized grass had a minimal reduction in visual quality when irrigation was decreased to 70% of maximum ET but quality decreased rapidly with further decrease in irrigation. Grass with a nitrogen deficiency showed a linear decrease in quality beginning at irrigation equal to 90% of maximum ET.

3) Bermudagrass used about 20% less water than bluegrass during the summer months. This may be due to differences in stomatal control of warm season compared to cool season grasses; but, is probably mainly due to differences in advective energy received due to canopy geometry. Warm season grasses like bermudagrass are only green during the frost free period of each summer while bluegrass greens up much earlier in the spring and continues to grow a couple of months after the first frost in the fall. During 1979 the bermudagrass had a quality rating of 1.5 by October 7 when the bluegrass was still rated at the maximum of 10.

4) Grass grown in clay soil used slightly less water than grass grown in the sand-peat mix. This was probably due to slower growth after mowing so that the time average height of the clay grown grass was lower. In general, clay is unsatisfactory for growing turfgrass because root growth is restricted and frequent irrigation is necessary to maintain high quality. Thus drought tolerance is reduced. The infiltration rate of clay is low, especially if compacted, and urban irrigators may lose a large percent of their water to runoff. A non-compacted sandy loam soil is best for developing and maintaining a healthy, vigorous lawn.

5) Decreasing irrigation below maximum usable levels increases surface temperature. For every 10% decrease in evapotranspiration the surface temperature increased as much as 3°F.

In the solar radiation studies lysimeters were placed under shade cloth to compare radiation levels of 100, 73, 54, 33% of maximum possible solar radiation. All treatments were irrigated to provide for maximum ET within each environment. The following results were obtained.

6) Water use increased linearly with increase in incident radiation

7) Advective energy from air movement was constant for all treatments and provided an ET component of about 2 mm/day for both summers. This was approximately 30 percent of maximum ET.

8) There was no indication that grass would adapt to the shade environments in any way that would affect water use in relation to energy available for evaporation.

9) Trees and shrubs are in a position to use more water than when grass only covers the same area. A water conserving landscape should have a minimum of woody plants and those should be species adapted to dry areas. Woody plants need some irrigation to survive drought even though some grasses may not.

In drawing conclusions from the results of this study it is helpful to put into perspective why we irrigate in urban areas. The region along the Front Range of Colorado contains cities where most of the state's population lives. Ecologically this area developed as a short grass prairie. There are few naturally occuring bushes and trees except along streams because precipitation is insufficient to ensure their survival.

A town built on the natural short grass prairie with vegetative areas given no supplemental irrigation would soon be lacking even grasses as a result of foot traffic incurred by outdoor activities. Therefore grasses have been planted that grow more vigorously than natives and are irrigated to maintain a good ground cover. With the increased irrigation, trees and shrubs are able to survive and add to the appearance of residential areas. Lush vegetation provides a low dust environment and pleasing appearance. The evaporation of water from leaf surfaces contributes considerable cooling and makes the urban environment more pleasant during the summer.

There is a need to conserve water as the cities in Colorado grow. A substantial savings can be had by educating the public how to irrigate efficiently. Danielson et al. (1979) found that many people over-irrigate. While this excess water is not consumed, but enters the groundwater and is used downstream, it is a waste of our municipal resources required to clean and treat it.

When the need to conserve requires that less water be applied than the vegetation can efficiently use, this study indicates that proper management can minimize the loss of quality in turfgrass. Even if drought is so severe that there is no water available for lawn irrigation, bluegrass properly cared for will have no problem greening up from a brown, dormant state once water is again available. Regular periods of mild water stress helps promote soil aeration and growth of a vigorous root system, increases drought tolerance, and conserves water without greatly reducing quality.

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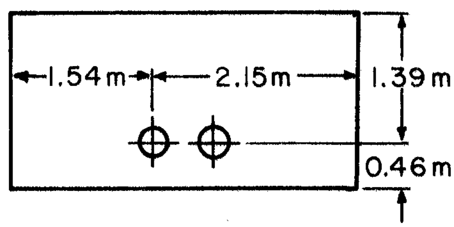
APPENDIX A CALCULATION OF TOTAL INCIDENT RADIATION ON SOLAR TREATMENTS TO INCLUDE THERMAL INFARED FROM SHADE CLOTH

Appendix - Calculation of Thermal Radiation for Shade Cloth

If the shade cloth extended as an infinite plane at a constant height, Z, above the ground, the thermal radiation incident at any point on the ground would be equal to the radiation emitted from any point on the shade cloth, assuming it has a constant temperature. Since the shade cloth does not extend as an infinite plane, the radiation received is proportional to the ratio of the above ground solid angle the shade cloth intercepts, which is the steradians intercepted divided by 2π

The dimensions of the shade cloths and the lysimeters, and their general orientation, are shown in the following diagram.



The range for each space coordinate in meters is

$$Z = 0.62 \qquad \begin{array}{l} -1.54 < x < 2.15 \\ -0.46 < y < 1.39 \end{array}$$

The solid angle Θ, in steradians is

$$\Theta = \left| \iint \frac{xdydz + ydzdx + zdxdy}{(x^2 + y^2 + Z^2)^{3/2}} \right|$$

but, dz = 0, so this reduces to

$$\Theta = \left| \iint \frac{Zdxdy}{(x^2 + y^2 + Z^2)^{3/2}} \right|$$

The integral with respect to x is (from math table)

$$\Theta = \left| \int \frac{x}{(y^2 + Z^2)(x^2 + y^2 + Z^2)^{1/2}} \right|_{x = 1.54}^{x = 2.15} dy \right|$$

useing Simpson's rule to evaluate integral with respect to y

$$\int f(y)\,dy = \frac{\Delta y}{3}\left[f(y_0) + 4f(y_1) + 2f(y_2)\ldots + 4f(y_{n-1}) + f(y_n)\right]$$

Choose $y_0 = -0.46,\ y_n = 1.39,\ \Delta y = 0.01$

where $y_1 = y_0 + \Delta y,\ y_2 = y_1 + \Delta y$ ect ...

Plugging in values we find $\Theta = 3.29$

Solid Angle ratio = $\dfrac{3.29}{2\Pi} = 0.52$

Solving for radiation from shade cloth

$R = (\Theta)(\alpha)(\varepsilon)T^4$

R = radiation

$\Theta = 0.52$

ε = emissivity, assume equals 1.00

$\alpha = 5.672 \times 10^{-8}\ Jm^{-2}\ K^{-4}\ sec^{-1}$

T = temperature of shade cloth (^{o}K)

Temperature was measured with a Barnes 14-220 infrared thermometer and is the intergrated average of the temperature of the shade cloth and open sky between the weave.

Table A-1 Determination of Actual Percent Radiation for Solar Treatments

Intended Treatment percent	0	25	50	75	100
Measured solar percent	2	27	51	71	100
Maximum solar radiation ($Jm^{-2}sec^{-1}$)	32	375	709	987	1390
Temperature through Shade Cloth (°K)	323	293	279	269	258
Thermal Radiation ($Jm^{-2}sec^{-1}$)	321	217	176	154	131
Radiation from shade cloth ($Jm^{-2}sec^{-1}$)	190	86	45	23	0
Total Solar Plus Thermal Radiation ($Jm^{-2}sec^{-1}$)	222	461	754	1010	1390
Actual Incident percent	16	33	54	73	100

APPENDIX B EVAPOTRANSIPRATION AND TURF QUALITY VALUES FOR 1979 AND 1980 IRRIGATION STUDIES

Table B-1. Turf evapotranspiration - 1979. Values represent average daily ET in millimeters over the period indicated

Treatment: 100% Irrigation - Low Mow

Date	Adequate N		High N				
	14	31	9	16	Ave.	Cum.	Q
7- 9,10	8.14	8.19	9.07	7.69	8.27	123.39	
11,12	7.87	7.48	8.01	7.31	7.67	138.73	
13,14,15	7.65	7.65	8.36	7.28	7.74	162.01	
16,17	3.92	3.70	4.16	3.77	3.89	169.79	
18,19	4.51	4.44	4.91	4.63	4.62	179.03	
20,21,22	4.96	5.12	5.04	5.06	5.05	194.18	
23,24	4.91	4.66	5.18	4.95	4.93	204.04	
25,26	5.47	5.31	5.61	5.89	5.57	215.18	
27,28,29	5.35	5.21	5.48	5.38	5.36	231.26	10
30,31	2.83	2.73	3.19	2.52	2.82	239.72	
8- 1, 2	6.78	6.49	6.78	6.44	6.62	252.96	
3, 4, 5	6.29	8.07	8.12	7.95	7.61	275.79	10
6, 7	6.96	7.25	7.50	7.20	7.23	290.25	
8-12	3.34	3.31	3.61	3.22	3.37	307.10	10
13,16						311.10	
17-21						326.85	10
22,23	3.91	4.01		3.89	3.84	334.73	
24,25,26	3.14	2.91	3.02	3.19	3.07	343.94	
27,28	3.84	3.67	3.73	3.90	3.79	351.52	10
29,30	4.68	4.52	4.37	4.53	4.53	360.58	
9-31, 1, 2	5.62	5.42	5.58	5.75	5.59	377.35	
3, 4	6.87	6.82	6.81	6.99	6.87	391.09	10
5, 6	5.31	5.38	5.39	5.54	5.41	401.91	
7, 8, 9	4.78	4.71	4.72	4.80	4.75	416.16	10
10,11	2.13	2.28	1.99	2.06	2.12	420.40	
12,13	1.41	1.13	1.09	1.27	1.23	422.86	
14,15,16	4.29	4.38	4.32	4.75	4.44	436.18	
17,18	5.31	3.56	5.43	5.79	5.02	446.22	10
19,20	3.86	3.78	3.94	3.94	3.88	453.98	
21,22,23	4.16	3.91	4.25	4.31	4.19	466.55	10
24,25	3.68	3.65	3.85	3.92	3.78	474.11	
26,27	4.18	3.69	3.93	4.08	3.97	482.05	10
28,29,30	5.20	4.35	4.60	4.64	4.70	496.15	
10- 1, 2	5.60	5.09	5.40	5.14	5.31	506.77	
3, 4	3.89	3.19	3.97	3.95	3.75	514.27	
5, 6, 7	4.99	5.00	5.25	5.15	5.10	529.57	10

Table B-2. Turf evapotranspiration - 1979. Values represent average daily ET in millimeters over the period indicated

Treatment: 80% Irrigation - Low Mow

Date	Adequate N		High N				
	29	4	5	17	Ave.	Cum.	Q
7- 9,10	7.63	7.84	7.86	7.73	7.77	119.79	
11,12	7.31	7.20	7.26	7.22	7.25	134.29	
13,14,15	6.93	7.14	7.53	7.21	7.20	155.89	
16,17	3.28	3.26	3.59	3.40	3.38	162.65	
18,19	4.27	4.30	4.45	4.56	4.40	171.45	
20,21,22	4.48	4.77	4.90	4.70	4.71	185.58	10
23,24	4.52	4.70	4.89	4.49	4.65	194.88	
25,26	4.95	5.04	5.33	5.06	5.10	205.08	
27,28,29	4.57	4.63	4.82	4.67	4.67	219.09	9
30,31	2.43	2.83		2.59	2.62	224.33	
8- 1, 2	5.50	5.58	3.84	5.67	5.15	234.63	
3, 4, 5	5.86	6.16	5.47	6.23	5.93	252.42	8.8
6, 7	5.34	5.26	5.33	5.34	5.32	263.06	
8-12	2.76	2.80	2.85	2.84	2.81	277.11	9.3
13-16	0.90	0.90	0.80	0.91	0.88	280.63	
17,21	2.78	2.66	2.93	2.77	2.79	294.58	10
22,23	3.92	3.91	4.16	4.25	4.06	302.70	
24,25,26	2.87	2.81	3.20	2.97	2.96	311.58	
27,28	3.71	3.47	4.09	3.88	3.79	319.16	10
29,30	4.18	4.20	4.67	4.14	4.30	327.76	
9-31, 1, 2	5.02	4.96	5.52	5.17	5.17	343.27	
3, 4	4.85	4.98	3.96	4.83	4.66	352.59	9
5, 6	4.03	4.15	3.64	4.10	3.98	360.55	
7, 8, 9	3.96	4.12	3.76	3.97	3.95	372.40	8.3
10,11	1.88	1.61	1.95	2.01	1.86	376.12	
12,13	0.74	0.89	0.47	0.89	0.75	377.62	
14,15,16	3.79	3.81	4.07	4.24	3.98	389.56	
17,18	4.44	4.28	4.89	4.59	4.55	398.66	9.5
19.20	2.92	3.01	3.04	3.14	3.03	404.72	
21,22,23		3.47	3.44	3.56	3.49	415.19	
24,25	2.95	2.97	2.92	2.83	2.92	421.03	
26,27	3.00	2.97	3.01	2.87	2.96	426.95	
28,29,30	3.39	3.54	3.48	3.37	3.45	437.30	9.5
10- 1. 2	3.59	3.82	3.70	3.70	3.70	444.70	
3, 4	2.90	2.97	3.10	2.90	2.97	450.64	
5, 6, 7	3.58	3.64	3.69	3.56	3.62	461.50	9.5

Table B-3. Turf evapotranspiration - 1979. Values represent average daily ET in millimeters over the period indicated

Treatment: 60% Irrigation Low mow

Date	Adequate N		High N		Ave.	Cum.	Q
	10	27	7	13			
7- 9,10	7.83	8.06	7.09	8.21	7.80	117.44	
11,12	7.08	7.48	6.59	7.82	7.24	131.92	
13,14,15	7.32	7.06	6.90	7.63	7.23	153.61	
16,17	3.46		3.23	3.51	3.40	160.41	
18,19	4.22	3.78	3.93	4.31	4.06	168.53	
20,21,22	4.58	3.91	4.29	4.32	4.28	181.37	9.8
23,24	4.56	3.94	4.28	4.22	4.25	189.87	
25,26	4.64	3.34	3.80	3.56	3.84	197.55	
27,28,29	4.38	3.18	3.77	3.21	3.64	208.47	7.5
30,31	2.83	1.53	1.90	1.89	2.04	212.55	
8- 1, 2	4.66	3.98	3.86	3.88	4.10	220.75	
3, 4, 5	4.69	4.27	4.20	4.18	4.34	233.77	5.8
6, 7	3.90	3.98	3.85	3.94	3.92	241.61	
8-12	2.68	2.38	2.31	2.42	2.45	253.86	7.3
13-16	1.03	0.97	1.01	1.14	1.04	258.02	
17-21	2.65	3.07	2.92	3.22	2.97	272.87	10
22,23	3.91	4.27	3.94	4.21	4.08	281.03	
24,25,26	3.02	3.16	2.90	3.20	3.07	290.24	
27,28	3.58	3.92	3.67	4.17	3.84	297.92	10
29,30	4.20	4.14	4.18	4.38	4.23	306.38	
9-31, 1, 2	5.00	4.71	4.96	4.72	4.85	320.93	
3, 4	3.86	3.31	4.28	2.65	3.53	327.99	8
5, 6	3.36	2.95	3.63	2.64	3.15	334.29	
7, 8, 9	3.37	3.10	3.20	2.99	3.17	343.80	6.5
10,11	1.91	1.64	1.74	1.50	1.70	347.42	
12,13	1.08		0.99	0.94	1.00	399.20	
14,15,16	4.04	2.72	3.95	3.68	3.65	360.15	
17,18	4.22	3.89	4.38	4.00	4.12	368.39	7.8
19,20	2.20	2.56	2.20	2.35	2.33	373.05	
21,22,23	2.70	3.06	2.65	3.04	2.86	381.63	8.8
24,25	2.09	2.35	2.14	2.50	2.27	386.17	
26,27	2.18	2.34	2.11	2.45	2.27	390.71	
28,29,30	2.57	2.66	2.66	2.72	2.65	398.66	7.5
10- 1, 2	2.62	2.63	2.74	2.64	2.66	403.98	
3, 4	2.41	2.36	2.34	2.39	2.38	408.74	
5, 6, 7	2.95	2.64	2.68	2.75	2.76	417.02	7.8

Table B-4. Turf evapotranspiration - 1979. Values represent average daily ET in millimeters over the period indicated

Treatment: 40 % Irrigation - Low Mow

Date	Adequate N		High N				
	19	23	22	1	Ave.	Cum.	Q
7- 9,10	8.36	7.50	8.37	8.17	8.10	120.03	
11,12	7.96	7.67	7.33	7.53	7.62	135.27	
13,14,15	7.44	6.73	6.57	7.02	6.94	156.09	
16,17	3.28	3.22	2.91	2.78	3.05	162.19	
18,19	3.62	4.20	3.47	3.19	3.62	169.53	
20,21,22		3.84	2.83	2.95	3.21	179.16	5.8
23,24	2.62	3.64	2.85	2.76	2.97	185.10	
25,26	1.98	2.66	2.22	2.10	2.24	189.58	
27,28,29	1.99	2.29	1.60	2.08	1.99	195.55	2.5
30,31	0.95	1.04		0.88	0.96	197.47	
8- 1, 2	3.13	3.31	2.82	3.00	3.07	203.61	
3, 4, 5	3.21	3.05	3.30	3.18	3.19	213.18	2
6, 7	2.95	2.50	3.15	2.70	2.83	218.84	
8-12	1.80	1.55	1.83	1.88	1.77	227.69	4
13-16	1.12	0.89	1.09	0.70	0.95	231.49	
17-21	3.20	2.86	2.97	2.48	2.88	245.89	8.3
22,23	4.64	4.08	4.06	3.78	4.14	254.17	
24,25,26	3.22	2.92	3.11	2.97	3.06	263.35	
27,28	4.25	3.80	3.80	3.66	3.88	271.11	9.3
29,30	4.13	4.09	4.28	4.09	4.15	279.41	
9-31, 1, 2	4.40	4.71	4.88	4.96	4.74	293.63	
3, 4	2.27	3.77	3.79	4.26	3.52	300.67	7.3
5, 6	1.71	3.10	2.85	3.39	2.76	306.19	
7, 8, 9	1.82	2.74	2.66	2.65	2.47	313.60	5
10,11	0.93	1.07	1.24	1.10	1.09	315.78	
12,13	0.69		0.74	0.84	0.76	317.30	
14,15,16	3.06		3.65	3.50	3.40	327.50	
17,18	3.45	3.69	3.75	3.73	3.66	334.82	6.5
19,20	2.35	2.00		2.05	2.13	339.08	
21,22,23	2.79	2.31	2.22	2.31	2.41	346.31	7
24,25	2.16	1.67	1.76	1.67	1.82	349.95	
26,27	1.96	1.70	1.66	1.62	1.74	353.43	
28,29,30	1.99	1.75	1.72	1.83	1.82	358.89	5.8
10- 1, 2	1.85	1.71	1.73	1.80	1.77	362.43	
3, 4	1.68	1.66	1.56	1.59	1.62	365.67	
5, 6, 7	1.81	1.82	1.68	1.82	1.78	371.01	4.8

Table B-5. Turf evapotranspiration - 1979. Values represent average daily ET in millimeters over the period indicated

Treatment: 100% Irrigation - High Mow

Date	Adequate N		High N				
	21	26	6	3	Ave.	Cum.	Q
7- 9,10	8.16	10.84	8.77	9.73	9.38	126.77	
11,12	8.27	9.64	7.13	9.48	8.64	144.05	
13,14,15	8.65	9.81	8.54	9.80	9.20	171.65	
16,17	4.35	4.98	4.50	5.11	4.74	181.13	
18,19	5.19	5.96	5.10	6.27	5.64	192.41	
20,21,22	5.63	6.19	5.70	6.37	5.98	210.35	10
23,24	5.41	5.80	5.86	6.03	5.78	221.91	
25,26	5.98	6.17	6.26	6.90	6.33	234.57	
27,28,29	5.75	6.00	5.98	6.46	6.05	252.72	10
30,31	3.25	3.49	4.02	3.37	3.54	259.80	
8- 1, 2	7.17	8.08	7.58	8.43	7.82	275.44	
3, 4, 5	8.14	9.47	9.01	9.91	9.14	302.86	10
6, 7	7.53	8.61	8.14	8.81	8.28	319.42	
8-12	3.42	3.61	3.63	4.16	3.71	337.97	10
13-16						341.97	
17-21						357.72	10
22,23	4.21	4.90	4.35	4.76	4.56	366.84	
24,25,26	3.50	3.60	3.43	3.83	3.59	377.61	
27,28	4.82	4.44	3.93	4.57	4.44	386.49	10
29,30	6.17	5.47	5.20	5.58	5.61	397.71	
9-31, 1, 2	5.81	6.63	5.51	6.86	6.21	416.34	
3, 4	7.16	7.93	7.63	7.97	7.68	431.70	10
5, 6	5.90	6.36	6.15	6.23	6.16	444.02	
7, 8, 9	4.86	5.29	4.96	5.32	5.11	459.35	10
10,11	2.09	2.22	2.07	2.29	2.17	463.69	
12,13	1.20	1.00	1.18	1.24	1.16	466.01	
14,15,16	4.33	4.86	4.66	5.28	4.79	480.38	
17,18	5.32	5.83	5.91	6.15	5.81	492.00	10
19,20	3.96	4.71	4.97	4.64	4.58	501.16	
21,22,23	4.31	4.84	4.62	4.96	4.69	515.23	9
24,25	3.98	4.42	4.30	4.65	4.34	523.91	
26,27	4.00	4.27	4.13	4.65	4.26	532.43	9
28,29,30	4.60	5.23	5.00	5.23	5.02	547.49	
10- 1, 2	5.47	6.43	6.17	6.22	6.07	559.63	
3, 4	4.09	4.58	4.54	4.55	4.44	568.51	
5, 6, 7	5.11	5.59	5.75	5.71	5.54	585.13	9.8

Table B-6. Turf evapotranspiration - 1979. Values represent average daily ET in millimeters over the period indicated

Treatment: 80% Irrigation - High mow

Date	Adequate N 30	Adequate N 8	High N 15	High N 20	Ave.	Cum.	Q
7- 9,10	10.67	9.44	9.40	9.55	9.77	129.88	
11,12	6.76	9.06	6.99	7.39	7.55	144.98	
13,14,15	6.74	8.49	6.81	7.08	7.28	166.82	
16,17	3.58	3.99	3.83	3.78	3.80	174.42	
18,19	4.86	5.37	5.13	5.09	5.11	184.64	
20,21,22	4.83	5.71	5.00	5.34	5.22	200.30	9.8
23,24	4.94	5.46	5.20	5.27	5.22	210.74	
25,26	5.49	5.90	5.47	5.78	5.66	222.06	
27,28,29	4.94	5.32	5.00	5.29	5.14	237.48	9.5
30,31	2.77	3.51	3.10	3.16	3.14	242.76	
8- 1, 2	6.14	6.07	5.51	5.80	5.88	255.52	
3, 4, 5	6.50	6.55	6.44	6.58	6.52	275.08	9.3
6, 7	6.05	6.17	6.16	6.06	6.11	287.30	
8-12	2.83	3.20	3.17	3.06	3.07	293.44	9.3
13-16	0.94	1.00	1.08	0.98	1.00	297.44	
17-21	2.84	3.05	3.33	3.36	3.15	313.19	10
22,23	4.49	4.51	4.92	5.10	4.76	322.71	
24,25,26	3.38	3.28	3.48	3.54	3.42	332.97	
27,28	4.24	4.03	4.44	4.42	4.28	341.53	10
29,30	4.82	4.77	5.35	5.21	5.04	351.61	
9-31, 1, 2	6.02	5.65	5.39	5.34	5.60	368.41	
3, 4	6.66	5.81		5.15	5.85	380.11	9.5
5, 6	5.26	4.82	4.18	4.40	4.67	389.45	
7, 8, 9	4.53	4.38	4.06	4.40	4.34	402.47	8.5
10,11	1.77	1.55	1.55	1.72	1.56	405.59	
12,13	0.64	0.59	0.62	0.54	0.60	406.79	
14,15,16	4.39	4.20	4.66	4.48	4.43	420.08	
17.18	5.37	5.17	5.13	5.34	5.25	430.58	9.8
19,20	3.46	3.50	3.79	3.20	3.49	437.56	
21,22,23	3.92	3.91	4.05	3.95	3.96	449.44	9
24,25	3.33	3.31	3.17	3.25	3.28	456.00	
26,27	3.40	3.58	3.21	3.27	3.37	462.74	
28,29,30	3.63	3.90	3.56	3.46	3.64	473.66	8.8
10- 1, 2	4.13	4.45	3.92	3.70	4.05	481.76	
3, 4	3.35	3.45	3.17	3.16	3.28	488.32	
5, 6, 7	4.18	4.27	4.02	3.91	4.10	500.62	8.8

Table B-7. Turf evapotranspiration - 1979. Values represent average daily ET in millimeters over the period indicated

Treatment: 60% Irrigation High Mow

Date	Adequate N		High N				
	24	2	18	25	Ave.	Cum.	Q
7- 9,10	9.91	9.19	11.32	7.87	9.78	133.84	
11,12	8.66	7.79	7.53	7.66	7.92	149.68	
13,14,15	6.71	7.00	6.35	6.88	6.74	169.90	
16,17	3.30	3.55	3.38	3.80	3.51	176.92	
18,19	4.07	3.99	4.09	4.46	4.16	185.24	
20,21,22	4.24	3.88	4.15	4.29	4.14	197.66	9.3
23,24	4.31	4.23	3.75	4.47	4.19	206.04	
25,26	3.44	3.60	3.51	3.56	3.53	213.10	
27,28,29	3.43	3.86	3.54	3.58	3.61	223.93	8.3
30,31	3.52	2.23	2.32	2.24	2.58	229.09	
8- 1, 2	3.34	4.45	3.89	4.18	3.97	237.03	
3, 4, 5	4.39	4.93	4.72	4.64	4.67	251.04	8
6, 7	4.26	4.72	4.75	4.95	4.67	260.38	
8-12	2.33	2.49	2.84	2.66	2.58	273.28	8.8
13-16	1.09	0.96	1.16	0.96	1.02	277.36	
17-21	3.32	2.74	3.53	3.16	3.19	293.31	10
22,23	4.70	4.73		4.89	4.77	302.85	
24,24,26	3.39	3.47	3.87	3.55	3.57	313.56	
27,28	4.27	4.17	4.84	4.45	4.44	322.44	10
29,30	5.10	4.83	5.04	5.03	5.01	332.46	
9-31, 1, 2	5.44	5.26	3.54	4.92	4.79	346.83	
3, 4	4.39	5.17		4.24	4.60	356.03	8.5
5, 6	3.84	4.09		3.59	3.84	363.71	
7, 8, 9	3.67	3.60	3.89	3.72	3.73	374.90	7.5
10,11	1.62	1.28	1.66	1.74	1.58	378.06	
12,13	0.44	0.39	0.73	0.64	0.56	379.18	
14,15,16	4.27	4.08	4.47	4.66	4.38	392.32	
17,18	4.82	4.60	4.67	4.36	4.62	401.56	8.5
19,20	2.31	2.82	2.17	1.89	2.30	406.16	
21,22,23	2.85	3.30	2.87	2.62	2.92	414.92	8.3
24,25	2.26	2.25	2.43	2.24	2.30	419.52	
26,27	2.46	2.26	2.46	2.40	2.40	424.32	
28,29,30	2.77	2.75	2.72	2.70	2.74	432.54	7.8
10- 1, 2	3.04	3.04	2.84	2.98	2.98	438.50	
3, 4	2.63	2.50	2.70	2.60	2.61	443.72	
5, 6, 7	3.12	3.08	3.04	3.21	3.11	453.05	7.5

Table B-8. Turf evapotranspiration - 1980. Values represent average daily ET in millimeters over the period indicated

Treatment: 100 % Irrigation

Date	Deficient N					Adequate N				
	30	31	Ave	Cum	Q	27	7	Ave	Cum	Q
6- 18,19	4.10	3.68	3.89	7.78	9	4.71	4.19	4.45	8.90	9
20,21,22	5.80	5.40	5.60	24.58		6.60	5.68	6.14	27.32	
23,24	7.64	7.40	7.52	39.62		8.81	7.92	8.37	44.06	
25,26	7.62	7.18	7.40	54.42		8.71	8.17	8.44	60.94	
27,28,29	7.77	7.57	7.67	77.43		9.38	8.53	8.96	87.82	
7- 30, 1	4.55	4.31	4.43	86.29	9	5.77	5.25	5.51	98.62	10.0
2, 3	3.21	3.05	3.13	92.55		5.58	3.41	3.50	105.62	
4, 5, 6	7.71	7.63	7.67	115.56		9.03	8.49	8.76	132.10	
7, 8	6.67	6.56	6.62	128.80	10	7.65	7.38	7.52	147.14	9.5
9,10	4.86	6.06	5.46	139.72		6.72	6.06	6.39	159.92	
11,12,13	4.83	5.10	4.97	154.63		5.33	5.13	5.23	175.61	
14,15	7.09	7.19	7.14	168.91	9	8.23	8.09	8.16	191.93	10
16.17	7.17	7.03	7.10	183.11		7.99	7.58	7.79	207.51	
18,19,20	3.85	4.01	3.93	194.90		4.02	4.34	4.18	220.05	
21,22	4.53	4.72	4.63	204.16	10	6.01	4.81	5.41	230.87	9
23,24	4.33	4.66	4.50	213.16		4.78	4.99	4.89	240.66	
25,26,27	4.69	5.13	4.91	227.89		5.48	5.69	5.59	257.42	
28,29	6.47	7.22	6.85	241.59	10	7.66	8.12	7.89	273.20	9
30,31	*	6.22	6.22	254.03		6.64	7.02	6.83	286.86	
8- 1, 2, 3	5.03	6.07	5.55	270.68		6.64	6.83	6.74	307.08	
4, 5	4.59	5.17	4.88	280.44	8.5	5.19	5.53	5.36	317.80	10
6, 7	6.28	7.61	6.59	293.62		8.14	8.88	8.51	334.82	
8, 9,10	2.58	3.12	2.85	302.17		3.68	3.98	3.83	346.31	
11,12	5.21	6.27	5.74	313.66	8.5	7.46	8.62	8.04	362.39	9.5
13,14	3.43	3.65	3.54	320.74		4.34		4.34	371.07	
15,16,17	3.43	3.65	3.54	331.36		4.34		4.34	384.09	
18,19	5.09	5.46	5.28	341.92		7.45	6.89	7.22	398.53	
20,21	5.01	5.52	5.27	352.46	9.5	6.68	6.65	6.67	411.87	10
22,23,24	4.76	5.11	4.94	367.28	9	5.15	5.55	5.35	427.92	9.5
25,26	3.99	4.01	4.00	375.28	9	5.24	5.06	5.15	438.22	9.5
27.28	4.09	3.70	3.90	383.08	9	5.60	5.55	5.58	449.38	9.5
29,30	4.57	3.09	3.83	394.57	9	3.72	3.36	3.54	460.00	9.5

Table B-9. Turf evapotranspiration - 1980. Values represent average daily ET in millimeters over the period indicated

Treatment: 90% Irrigation

Date	Deficient N					Adequate N				
	1	10	Ave	Cum	Q	2	13	Ave	Cum	Q
6- 18,19	4.37	4.34	4.35	8.70	9	4.43	4.43	4.43	8.86	9
20,21,22	3.45	5.63	4.54	22.32		5.17	6.11	5.63	25.90	
23,24	7.48	7.45	7.47	37.26		7.73	7.76	7.75	41.40	
25.26	7.46	7.48	7.47	52.20		7.22	7.86	7.54	56.48	
27,28,29	7.74	7.65	7.70	75.30				7.98*	80.42	9
7- 30, 1	4.32	4.39	4.36	84.09	9	1.25	4.01	4.01	88.44	
2, 3	2.71	2.96	2.84	89.70		1.62	3.07	3.07	94.58	
4, 5, 6	7.71	7.76	7.74	112.92		4.12	7.28	7.74	117.80	10
7, 8	6.57	6.58	6.58	126.08	9	2.97	6.19	6.19	130.18	
9,10	5.71	5.97	5.84	137.76		3.75	5.57	5.57	141.32	
11,12,13	4.85	4.77	4.81	152.19		3.89	4.79	4.79	155.69	
14,15	6.78	7.14	6.96	166.11	9	6.06	6.71	6.71	169.11	9
16,17	6.49	6.95	6.72	179.55		6.38	6.83	6.61	182.33	
18,19,20	3.85	4.40	4.13	191.94		3.79	4.35	4.07	194.54	
21,22	4.41	3.26	3.84	199.62		4.35	4.59	4.47	203.48	9
23,24	4.54	4.55	4.55	208.72		4.52	4.68	4.60	212.68	
25,26,27	3.94	4.93	4.44	222.04		4.69	5.22	4.96	222.60	
28,29	6.10	6.07	6.09	234.22	9	6.53	6.73	6.63	235.86	9
30,31	5.23	5.26	5.25	244.72		5.76	5.88	5.82	247.50	
8- 1, 2, 3	5.47	5.31	5.39	266.28		5.92	5.78	5.85	265.05	
4. 5	4.40	4.09	4.25	274.78	8.5	4.73	4.69	4.71	274.47	8.5
6. 7	6.21	6.15	6.18	287.14		6.86	7.05	6.96	288.39	
8, 9,10	1.46	2.79	2.13	293.53		3.32	3.10	3.21	298.02	
11,12	6.06	5.53	5.80	305.13	8	6.28	5.99	6.14	310.30	8
13,14	4.11	3.85	3.98	313.09		4.51	4.26	4.39	319.07	
15,16,17	4.11	3.85	3.98	325.03		4.51	4.26	4.39	332.24	
18,19	4.11	3.85	3.98	332.99		4.51	4.26	4.39	341.02	
20,21	6.19	8.67	3.10	339.19	9	6.51	6.41	6.46	353.94	9.5
22,23,24	5.09	4.71	4.90	393.89	8.5	5.24	5.25	5.24	369.66	9.5
25,26	4.65	4.29	4.47	362.83	8.5	4.75	4.63	4.69	379.04	9
27,28	5.13	4.52	4.83	372.49	9	5.17	5.05	5.11	389.26	9
29,30	2.15	3.04	2.60	377.69	9	2.54	3.33	2.94	395.14	9

Table B-10. Turf evapotranspiration - 1980. Values represent average daily ET in millimeters over the period indicated

Treatment: 80% Irrigation

Date	Deficient N					Adequate N				
	25	26	Ave	Cum	Q	3	17	Ave	Cum	Q
6- 18,19	4.83	4.47	4.65	9.30	9	4.95	4.44	4.70	9.40	9
20,21,22	6.17	6.19	6.18	27.84		6.13	6.32	6.23	28.09	
23,24	7.64	7.81	7.73	43.30		8.14	8.51	8.33	44.75	
25,26	7.95	7.93	7.94	59.18		7.79	8.52	8.16	61.07	
27,28,29	5.42	5.88	5.65	76.13			4.79	4.79	75.44	
7- 30, 1	2.43	3.68	3.06	82.31	9	1.58	4.41	4.41	84.26	9
2, 3	2.12	2.91	2.52	87.35		1.15	3.01	3.01	90.28	
4, 5, 6	5.62	7.03	6.32	106.31		3.94	8.10	8.10	114.58	
7, 8	4.88	5.93	5.41	117.13	9	3.69	6.86	6.86	128.30	9
9,10	4.64	5.05	4.85	126.83		3.62	5.63	5.63	139.56	
11,12,13	4.25	4.64	4.45	140.18		3.77	4.81	4.81	153.99	
14,15	6.50	5.36	5.93	152.04	7	6.21	6.62	6.42	166.82	9
16,17	6.51	5.36	5.94	163.92		6.40	6.52	6.46	179.74	
18,19,20	3.48	3.29	3.39	174.09		3.96	3.71	3.84	191.25	
21,22	4.45	3.84	4.15	182.39	8	4.53	3.35	3.94	199.13	9
23,24	4.48	3.99	4.24	190.87		4.74	4.82	4.78	208.69	
25,26,27	4.96	4.20	4.58	204.61		5.31	5.00	5.16	224.17	
28,29	3.76	4.97	4.37	213.35	8.5	6.13	4.97	6.05	236.27	9
30,31	5.06	4.46	4.76	222.87		5.45		5.45	247.17	
8- 1, 2, 3	4.83	4.50	4.67	236.88		5.70	5.35	5.53	263.74	
4, 5	3.98	3.53	3.76	244.40	7	4.57	4.54	4.56	272.85	9
6, 7	5.22	5.28	5.25	254.90		6.28	7.80	7.04	286.93	
8, 9,10	2.63	2.56	2.60	262.70		3.11	3.21	3.16	296.41	
11,12	5.08	4.74	4.91	272.52	6.5	6.07	6.62	6.35	309.10	9
13,14	3.66	3.54	3.60	279.72		4.35	4.26	4.31	317.71	
15,16,17	3.66	3.54	3.60	290.52		4.35	4.26	4.31	330.64	
18,19	3.66	3.54	3.60	297.72		4.35	4.26	4.31	339.26	
20,21	5.52	5.09	5.21	308.14	8.5	6.02	6.31	6.17	351.60	9
22,23,24	4.36	4.42	4.39	321.31	8.5	5.52	5.29	5.41	367.83	8.5
25,26	4.20	4.02	4.11	329.53	9	4.89	4.63	4.76	377.35	8.5
27,28	4.19	4.28	4.24	338.01	9	5.44	5.09	5.27	387.89	8.5
29,30	3.09	3.16	3.13	344.27	9	3.18	3.35	3.27	394.43	8.5

Table B-11. Turf evapotranspiration - 1980. Values represent average daily ET in millimeters over the period indicated

Treatment: 70% Irrigation

Date	Deficient N					Adequate N				
	8	20	Ave	Cum	Q	6	15	Ave	Cum	Q
6- 18,19	4.07	4.12	4.10	8.19	9	4.48	5.13	5.13	10.26	9
20,21,22	5.59	5.58	5.59	16.76		*	6.65	6.65	30.21	
23,24	7.30	7.34	7.32	31.40		*	8.48	8.48	47.17	
25,26	7.34	7.69	7.52	46.43		7.92	8.03	8.03	63.23	
27,28,29	6.19	6.25	6.22	65.09		8.45	8.45	8.45	88.58	
7- 30, 1	3.58	3.35	3.47	72.02	8.5	4.64	3.34	3.34	95.26	9
2, 3	2.72	2.96	2.84	77.70		3.28	2.54	2.54	100.34	
4,5, 6	6.69	6.61	6.65	97.65		7.59	6.77	6.77	120.65	
7, 8	5.58	5.23	5.41	108.46	8	6.46	5.68	5.68	132.01	9
9,10	4.59	4.44	4.52	117.49		*	5.21	5.21	142.43	
11,12,13	4.01	3.87	3.94	129.31		4.64	4.78	4.78	156.77	
14,15	4.86	4.97	4.92	139.14	7	*	7.04	7.04	170.81	8
16,17	4.27	4.65	4.46	148.06		7.04	6.72	6.72	184.25	
18,19,20	3.01	3.07	3.04	157.18		3.59	4.33	4.33	197.24	
21,22	3.52	3.56	3.54	164.26	8	4.64	4.65	4.65	206.54	9
23,24	3.74	3.52	3.63	171.52		4.50	4.64	4.64	215.82	
25,26,27	3.77	3.61	3.69	182.59		4.85	4.42	4.42	229.08	
28,29	4.15	3.97	4.06	190.71	6	4.58	5.34	4.96	239.00	9
30,31	3.74	3.66	3.70	198.11		5.13	4.64	4.89	248.77	
8- 1, 2, 3	4.04	3.77	3.91	209.82		4.81	5.14	4.98	263.70	
4, 5	3.24	3.06	3.15	219.27	5.5	4.29	4.13	4.21	272.12	9
6, 7	4.57	2.83	3.70	226.67		5.55	5.65	5.60	283.32	
8, 9,10	2.29	2.03	2.16	233.15		2.72	3.03	2.88	291.94	
11,12	3.91	3.84	3.88	240.90	6	5.59	5.16	5.38	302.69	8
13,14	3.24	3.08	3.16	247.22		3.95	4.08	4.02	310.72	
15,16,17	3.24	3.08	3.16	256.70		3.95	4.08	4.02	322.78	
18,19	3.24	3.08	3.16	263.02		3.95	4.08	4.02	330.82	
20,21	4.66	4.20	4.43	271.88	8	5.48	5.09	5.29	341.40	9
22,23,24	3.91	3.40	3.66	282.86	7.5	4.77	4.36	4.57	355.11	9
25,26	3.54	3.42	3.48	289.82	8	4.39	4.19	4.29	363.69	9
27,28	4.06	3.85	3.96	297.74	8.5	5.04	4.83	4.94	373.57	9
29,30	2.42	2.69	2.56	302.86	8.5	3.15	3.19	3.17	379.91	9

Table B-12. Turf evapotranspiration - 1980. Values represent average daily ET in millimeters over the period indicated

Treatment: 60% Irrigation

Date	Deficient N					Adequate N				
	4	22	Ave	Cum	Q	5	21	Ave	Cum	Q
6- 18,19	3.93	4.16	4.16	8.32	9	4.24	4.51	4.38	8.75	9
20,21,22	5.31	5.63	5.63	25.21		5.81	6.20	6.01	26.77	
23,24	6.89	7.29	7.29	39.79		7.63	7.88	7.76	42.28	
25,26	7.06	7.47	7.47	54.77		7.76	7.39	7.58	57.43	
27,28,29	5.77	6.24	6.24	73.49		7.00	7.00	7.00	78.43	
7- 30, 1	3.29	3.34	3.34	80.17	8	3.56	3.59	3.58	85.58	9
2, 3	2.77	2.42	2.42	85.01		3.37	2.84	3.11	91.79	
4, 5, 6	6.26	6.40	6.40	104.21		6.58	6.61	6.60	111.57	
7, 8	5.06	5.15	5.15	114.51	8	5.35	5.59	5.47	122.51	9
9,10	3.98	4.11	4.11	122.73		4.51	4.56	4.54	131.58	
11,12,13	3.64	3.50	3.50	133.23		2.72	4.01	3.37	141.68	
14,15		4.05	4.05	141.33	5	4.65	4.47	4.56	150.80	7.5
16,17	4.76	3.54	3.54	148.41		4.23	4.38	4.31	159.41	
18,19,20	3.10	2.54	2.54	156.03		3.04	2.99	3.02	168.45	
21,22		2.92	2.92	161.87	5	3.55	3.47	3.51	175.47	7.5
23,24	3.80	2.88	2.88	167.63		3.57	3.50	3.54	182.54	
25,26,27	4.56	2.86	2.86	176.21		2.65	3.68	3.67	193.54	
28,29	6.14	3.37	3.37	182.95	3	3.90	4.07	3.99	201.51	6
30,31		2.92	2.92	188.79		3.63	3.75	3.69	208.89	
8- 1, 2, 3	4.89	1.33	1.33	192.78		4.00	3.84	3.92	220.65	
4, 5	4.44	2.31	2.31	197.40	2	3.32	3.24	3.28	227.21	6.5
6, 7	6.47	3.24	3.24	203.88		4.49	4.41	4.45	236.11	
8, 9,10	2.68	1.53	1.53	208.47		2.37	2.23	2.30	243.01	
11,12	5.09	2.45	2.45	213.37	2	4.65	4.18	4.42	251.84	6
13,14	3.52	2.38	2.95	219.27		3.63	3.45	3.54	258.92	
15,16,17	3.52	2.38	2.95	228.12		3.63	3.45	3.54	269.54	
18,19	3.52	2.38	2.95	234.02		3.63	3.45	3.54	276.62	
20,21	4.93	3.49	3.49	241.00	4	5.37	4.78	5.08	286.78	8
22,23,24	4.34	3.04	3.04	250.12	5	5.17	4.32	4.75	301.03	8.5
25,26	3.84	3.32	3.32	256.76	6	4.65	4.17	4.41	309.85	9
27,28	4.33	3.55	3.55	263.86	6	5.82	4.94	5.38	320.61	9
29,30	2.47	2.80	2.80	269.46	7	3.46	3.23	3.35	327.31	9

Table B-13. Turf evapotranspiration - 1980. Values represent average daily ET in millimeters over the period indicated

Treatment: 50% Irrigation

Date	Deficient N					Adequate N				
	14	19	Ave	Cum	Q	16	24	Ave	Cum	Q
6- 18,19	3.98	4.42	4.20	8.40	9	4.07	4.60	4.34	8.67	9
20,21,22	5.29	5.84	5.57	25.10		5.64	6.10	5.87	26.28	
23,24	7.07	7.87	7.47	40.04		7.85	8.08	7.97	42.21	
25,26	6.49	8.12	7.31	54.65		7.09	7.72	7.41	57.02	
27,28,29	4.40	6.75	5.58	71.37				5.58	73.76	
7- 30, 1	2.50	3.39	2.95	77.26	7	3.09	3.92	3.51	80.77	8.5
2, 3	2.43	2.62	2.53	82.31		2.51	2.99	2.75	86.27	
4,5, 6	5.56	6.28	5.92	100.07		6.36	7.21	6.79	106.63	
7, 8	4.56	4.51	4.54	109.14	6.5	5.11	5.40	5.26	117.14	8.5
9,10	3.75	3.34	3.55	116.23		4.04	3.98	4.01	125.16	
11,12,13	3.42	2.85	3.14	125.64		3.63	3.31	3.47	135.57	
14,15	3.61	2.97	3.29	132.22	4	3.82	3.41	3.62	142.80	5
16,17	3.45	2.74	3.10	138.41		3.50	3.10	3.30	149.40	
18,19.20	2.66	2.33	2.50	145.89		2.79	2.33	2.56	157.08	
21,22	2.84	2.83	2.84	151.56	5	3.08	3.20	3.14	163.36	5
23,24	2.88	2.67	2.78	157.11		3.11	3.33	3.22	169.80	
25,26,27	2.78	2.72	2.75	165.36		3.00	3.14	3.07	179.01	
28,29	2.77	2.79	2.78	170.92	2.5	3.22	3.18	3.20	185.41	4.5
30,31	2.76	2.72	2.74	176.40		3.29	3.14	3.22	191.84	
8- 1, 2, 3	3.00	3.01	3.01	182.92		3.38	3.46	3.42	202.10	
4, 5	2.46	2.45	2.46	187.34	3	2.87	2.79	2.83	207.76	5
6, 7	3.19	3.16	3.18	193.70		3.75	3.66	3.71	215.17	
8, 9,10	1.78	1.74	1.76	198.98		1.98	1.99	1.99	221.14	
11,12	3.14	3.93	3.54	206.05	2.5	3.61	3.82	3.72	228.57	4
13,14	2.89	2.65	2.77	211.59		3.43	3.63	3.53	235.63	
15,16,17	2.89	2.65	2.77	219.90		3.43	3.63	3.53	246.22	
18,19	2.89	2.65	2.77	225.49		3.43	3.53	3.53	253.28	
20,21	4.80	4.22	4.51	234.46	6	5.09	5.41	5.25	263.78	6.5
22,23,24	3.95	3.80	3.88	246.10	6.5	4.28	4.90	4.59	277.55	7
25,26	3.96	3.90	3.93	253.96	7	4.16	4.78	4.47	286.49	7.5
27,28	4.24	4.58	4.41	262.78	7.5	4.83	6.19	5.51	297.51	8
29,30	2.95	3.06	3.01	268.80	8	3.26	4.11	3.69	354.89	8

Table B-14. Turf evapotranspiration - 1980. Values represent average daily ET in millimeters over the period indicated

Treatment: 40% Irrigation

Date	Deficient N					Adequate N				
	23	29	Ave	Cum	Q	9	18	Ave	Cum	Q
6- 18,19	4.07	3.88	3.98	7.96	9	4.26	4.86	4.56	9.12	9
20,21,22	5.52	5.48	5.50	24.45		5.70	6.67	6.19	27.68	
23,24	7.26	6.84	7.05	38.55		7.49	8.89	8.19	44.06	
25,26	7.33	7.16	7.25	53.04		7.52	8.76	8.14	60.34	
27,28,29	6.02	4.60	5.31	68.97		3.64	3.64	3.64	71.26	
7- 30, 1	3.08	2.42	2.75	74.47	6.5	4.04	3.30	3.67	78.60	8.5
2, 3	2.26	2.42	2.34	79.15		2.92	2.19	2.56	83.71	
4, 5, 6	5.91	5.33	5.62	96.01		6.64	7.19	6.92	104.45	
7, 8	4.26	4.08	4.17	104.35	6	5.17	5.27	5.22	114.89	8
9,10	2.96	3.18	3.07	110.49		3.78	3.98	3.88	122.65	
11,12,13	2.39	2.69	2.54	118.11		3.11	2.95	3.03	131.74	
14,15	2.37	2.59	2.48	123.07	2.5	2.78	2.53	2.66	137.05	1.5
16,17	2.11	2.12	2.12	127.31		2.21	2.11	2.16	141.37	
18,19,20	1.82	1.80	1.81	132.74		1.75	1.59	1.67	146.38	
21,22	2.37	2.34	2.36	137.45	3.5	2.19	2.48	2.34	151.05	2.5
23,24	2.26	2.32	2.29	142.03		2.11	2.42	2.27	155.58	
25,26,27	2.26	2.37	2.32	148.98		2.22	2.77	2.50	163.07	
28,29	2.30	2.39	2.35	153.68	2.5	2.40	2.94	2.67	168.41	1.5
30,31	2.26	2.32	2.29	158.26		2.01	2.68	2.35	173.10	
8- 1, 2, 3	2.35	2.44	2.40	165.44		2.12	2.77	2.45	180.43	
4, 5	1.74	1.92	1.83	169.10	1.5	1.68	2.17	1.93	184.28	1.5
6, 7	2.73	2.52	2.63	174.35		2.33	3.00	2.67	189.61	
8, 9,10	6.34	1.35	0.85	176.89		1.03	1.58	1.31	193.53	
11,12	2.64	2.50	2.57	182.03	1.5	2.06	2.88	2.47	198.47	1.5
13,14	3.06	2.44	2.75	187.53		1.86	2.73	2.30	203.07	
15,16,17	3.06	2.44	2.75	195.78		1.86	2.73	2.30	204.97	
18,19	3.06	2.44	2.75	201.28		1.86	2.73	2.30	214.56	
20,21	3.50	3.98	3.74	208.76	3.5	2.38	3.69	3.04	220.65	3.0
22,23,24	2.83	3.31	3.07	217.97	5.0	2.06	3.46	2.76	228.43	3.5
25,26	3.10	3.38	3.24	224.45	6.0	2.40	3.59	2.99	334.91	4.0
27,28	3.48	3.93	3.71	231.87	6.0	2.49	4.35	3.42	241.75	4.0
29,30	2.64	2.83	2.74	237.35	6.0	1.89	2.98	2.43	246.61	4.5

APPENDIX C CLIMATIC DATA. MAXIMUM AND MINIMUM TEMPERATURE, WIND, PRECIPITATION, AND SOLAR RADIATION.

Table C-1.

1979 Date	Temperature (°C) Max	Min	Wind (Km/day)	Precip (mm)	Solar ($MJm^{-2}day^{-1}$)
6-1	19	3			26.4
2	23	4	42		31.7
3	26	6	32		30.3
4	27	9	30		30.1
5	31	10	35		28.5
6	29	16	67		25.5
7	24	9	69	5.2	8.9
8	9	5	66	38.6	8.7
9	17	4	78	13.7	23.1
10	22	4	46		31.9
11	28	7	38		30.9
12	32	9	26		33.0
13	33	12	24		27.6
14	31	13	37		25.1
15	27	15	66		21.1
16	26	11	51		23.0
17	23	12	91		18.9
18	23	12	62	12.7	18.7
19	20	8	99		27.4
20	26	9	51		32.0
21	29	10	30		30.1
22	29	11	38		
23	21	15	45		
24	30	11	29		
25	31	12	27		
26	33	13	24		
27	28	16	34	1.8	
28	31	14	38		
29	30	13	27		27.2
30	31	13	29	5.1	18.3

Table C-2.

1979 Date	Temperature (°C) Max	Min	Wind (Km/day)	Precip (mm)	Solar ($MJm^{-2}day^{-1}$)
7-1	31	13	45	2.5	24.8
2	31	13	26	1.0	22.3
3	31	14	42		29/0
4	28	16	34	1.3	26.8
5	27	14	42		27.3
6	28	16	45		19.4
7	32	9	37		31.4
8	33	13	24		24.9
9	33	13	27		30.4
10	34	14	35		
11	34	11	22		
12	33	16	45		23.4
13	34	13	54		31.4
14	32	16	51		30.5
15	29	15	70		26.6
16	31	18	58		21.8
17	25	16	48		11.4
18	26	14	26		19.8
19	28	11	24		26.9
20	30	13	32		26.2
21	31	14	26	5.8	18.9
22	30	14	26		22.8
23	29	14	24		19.8
24	30	16	37	1.5	35.2
25	31	14	51		
26	30	13	46		
27	29	14	30		
28	32	17	40		
29	34	14	32		
30	28	17	45	1.8	
31	24	12	43	3.2	

Table C-3.

1979 Date	Temperature (°C) Max	Min	Wind (Km/day)	Precip (mm)	Solar ($MJm^{-2}day^{-1}$)
8-1	32	12	32		24.8
2	31	12	43		
3	33	12	56		
4	36	11	30		27.4
5	35	11	51		27.3
6	36	12	21		24.7
7	35	16	19		
8	32	17	37		
9	28	17	24	1.8	
10	20	12	30	20.0	
11	28	8	42		
12	31	12	8		
13	19	16	-		
14	18	11	66	3.3	
15	20	12	46	3.0	
16	26	12	26	17.5	
17	27	11	30	5.1	
18	24	14	26	4.3	
19	22	13	18	14.6	
20	21	10	10	4.3	
21	24	13	19		
22	26	12	19		24.9
23	25	11	30		22.7
24	24	12	34		19.1
25	23	9	21	3.8	22.2
26	24	11	42		19.9
27	24	9	34		
28	27	11	21		20.7
29	29	11	24		26.9
30	29	12	29		19.6
31	31	10	27		

Table C-4.

1979 Date	Temperature (°C) Max	Min	Wind (Km/day)	Precip (mm)	Solar ($MJm^{-2}day^{-1}$)
9-1	27	10	37		
2	29	9	21		
3	31	9	27		
4	32	11	37		
5	31	13	37		
6	27	15	37		
7	31	14	30		
8	33	11	21		
9	33	13	24		
10	31	15	14		
11	17	9	24	10.6	
12	17	9	42		
13	18	5	32	13.0	
14	17	4	34		
15	23	3	29		
16	27	4	27		
17	29	6	18		
18	23	9	50		23.7
19	27	7	26		22.3
20	21	12	43	4.1	17.2
21	21	10	32		20.9
22	29	7	19		19.5
23	28	8	18		19.5
24	26	12	32		18.5
25	27	9	21		
26	28	9	22		
27	25	8	27		
28	24	7	29		
29	28	6	19		
30	29	6	27		

Table C-5.

1979 Date	Temperature (°C) Max	Min	Wind (Km/day)	Precip (mm)	Solar ($MJm^{-2}day^{-1}$)
10-1	22	6	56		
2	29	6	50		
3	21	7	66		
4	21	1	40		17.7
5	26	5	46		17.2
6	27	6	38		17.2
7	29	6	21		17.1
8	29	6	35		15.5
9	12	1	50	2.0	
10	28	-1	30		14.9
11	27	7	27		14.8
12	21	4	27		15.8
13	17	4	54		14.5
14	25	6	6		8.0
15	24	8	34		
16	18	9	62	1.0	
17	16	7	34		8.3
18	19	4	30		10.2
19	23	5	48		
20	21	6	98		7.3
21	7	3	43		4.6
22	14	-3	43		14.6
23	18	-1	19	5.6	9.3
24	20	1	26		14.4
25	20	2	19		
26	26	2	50		11.4
27	17	4	48		13.1
28	15	-1	11		9.0
29	9	-1	58	13.7	
30	3	-1	88		
31	3	-4	109		14.0

Table C-6.

1980 Date	Temperature (°C) Max	Min	Wind (Km/day)	Precip (mm)	Solar ($MJm^{-2}day^{-1}$)
5-1	11	6	13	21.1	6.3
2	17	3	58		23.7
3	18	5	24		12.7
4	19	4	26		18.6
5	19	9	24		15.1
6	18	8	22	1.1	13.2
7	16	6	24		11.4
8	12	8	18	6.4	5.1
9	18	5	11		13.1
10	21	6	10		20.9
11	6	4	3	8.6	3.0
12	13	1	11	10.4	16.4
13	14	1	21		18.3
14	18	2	11		20.3
15	12	8	8	13.0	3.1
16	13	4	11	23.4	0.2
17	8	3	3	11.9	11.5
18	17	4	2		15.0
19	21	4	2		18.9
20	24	4	6		26.1
21	26	9	16		25.6
22	27	9	32		23.7
23	27	10	32		26.7
24	26	10	91		26.2
25	23	4	96		28.0
26	21	4	54		27.1
27	27	7	42		23.3
28	27	6	42		27.3
29	22	6	37		19.8
30	23	6	39		25.9
31	26	7	53		29.7

Table C-7.

1980 Date	Temperature (°C) Max	Min	Wind (Km/day)	Precip (mm)	Solar ($MJm^{-2}day^{-1}$)
6-1	24	6	50		26.7
2	25	6	56		22.9
3	29	6	43		29.2
4	30	9	62		30.3
5	31	10	46		30.1
6	31	7	77		30.0
7	22	9	78		20.2
8	23	12	66		26.9
9	24	8	38		28.1
10	29	11	64		23.2
11	33	12	43		28.5
12	33	11	53		30.7
13	31	12	66		30.7
14	32	14	54		30.6
15	27	11	67		27.6
16	24	9	59		27.6
17	29	12	43		28.6
18	32	13	29		23.4
19	21	12	38		9.0
20	29	8	37		26.3
21	31	12	37	1.8	24.8
22	31	12	35		27.4
23	35	13	40		29.3
24	32	18	64		30.0
25	34	16	54		29.8
26	34	15	54		22.6
27	33	15	72		30.0
28	31	16	62		30.5
29	34	12	30		25.4
30	35	12	30		19.7

Table C-8.

1980 Date	Temperature (°C) Max	Min	Wind (Km/day)	Precip (mm)	Solar ($MJm^{-2}day^{-1}$)
7-1	26	15	58		21.5
2	29	15	50	1.8	22.3
3	29	12	37		26.9
4	30	16	45		23.9
5	33	16	62		30.0
6	36	14	38		30.0
7	34	17	46		25.4
8	31	17	53	2.0	25.1
9	33	15	48		29.0
10	32	19	53		21.0
11	33	17	30		15.2
12	32	14	50		23.8
13	33	16	26		21.7
14	31	16			27.8
15	33	12			27.8
16	33	15			28.7
17	34	17			28.5
18	26	15		4.0	19.3
19	32	15			16.3
20	28	14			26.7
21	26	16			16.6
22	32	16			24.8
23	33	18			21.5
24	31	13			17.8
25	27	12			23.9
26	27	12			21.9
27	31	12			27.9
28	35	12			27.8
29	36	12			23.0
30	30	20	66		20.9
31	33	14	43		26.4

Table C-9.

1980 Date	Temperature (°C) Max	Min	Wind (Km/day)	Precip (mm)	Solar (Mjm^{-2} day^{-1})
8-1	33	16	27		19.8
2	31	13	50		25.1
3	34	13	51		23.3
4	27	10	88		27.5
5	29	11	32		16.8
6	36	13	61		25.9
7	36	17	48		26.1
8	26	17	56		9.8
9	29	16	38		13.2
10	29	12	30		24.5
11	29	16	78		25.0
12	33	14	46		23,3
13	24	17	38		14.5
14	24	15	56		10.3
15	24	16	93		15.7
16	26	11	46		18.9
17	29	10	51		23.0
18	32	10	51		22.2
19	31	12	46		20.0
20	24	12	99		25.8
21	27	8	37		23.6
22	32	10	48		23.6
23	31	14	37		16.8
24	30	14	30	1.0	19.2
25	26	14	26		20.4
26	24	12	46	5.0	18.5
27	28	11	34		18.3
28	32	12	45		24.4
29	29	14	14		13.0
30	18	12	61		10.0
31	22	8	56		14.1

Table C-10.

1980 Date	Temperature (°C) Max	Min	Wind (Km/day)	Precip (mm)	Solar ($MJm^{-2}day^{-1}$)
9-1	24	7	67		23.7
2	30	7	53		23.3
3	32	9	43		20.7
4	26	9	58		21.3
5	32	9	35		21.0
6	31	11	30		22.2
7	32	11	34		21.5
8	24	13	35		8.3
9	14	10	69		7.2
10	23	10	61		17.8
11	28	9	51		21.1
12	24	12	34		12.2
13	22	7	29		14.0
14	26	10	34		21.1
15	29	9	40		19.3
16	18	8	62		16.7
17	29	5	56		21.1
18	30	7	53		20.4
19	33	13	77		20.4
20	22	8	61	17.0	20.0
21	27	7	59		20.9
22	16	7	77		17.5
23	22	3	40		19.7
24	19	8	61		16.5
25	18	6	46		19.2
26	24	4	32		19.5
27	29	6	24		18.0
28	29	6	29		18.6
29	26	11	34		18.9
30	30	6	29		18.9

Table C-11.

1980 Date	Temperature (°C) Max	Min	Wind (Km/day)	Precip (mm)	Solar ($MJm^{-2}day^{-1}$)
10-1	22	8	43		16.8
2	20	4	37		18.1
3	27	2	35		18.1
4	29	4	24		18.1
5	26	6	34		14.4
6	24	4	27		17.4
7	28	4	22		17.2
8	26	7	18		17.3
9	28	4	37		16.7
10	17	2	34		16.5
11	18	1	29		16.3
12	26	3	29		13.1
13	22	8	51		12.1
14	20	7	35		13.0
15	17	2	46	2.5	7.8
16	7	0	86	12.5	7.0
17	12	-3	48		12.9
18	13	1	50		10.2
19	18	-1	22		15.2
20	18	2	24		15.2
21	18	-1	24		15.1
22	19	2	43		8.0
23	7	-3	150		14.5
24	13	-7	32		13.7
25	14	-6	35		14.0
26	6	-2	21		4.5
27	3	-2	72		4.1
28	7	-6	43		12.8
29	17	-7	21		13.6
30	17	-7	42		13.3
31	13	1	8		

APPENDIX D EVAPOTRANSPIRATION AND TURF QUALITY VALUES FOR 1979 AND 1980 BERMUDA GRASS AND CLAY SOIL TREATMENTS

Table D-1. Turf evapotranspiration -------- Values represent average daily ET in millimeters over the period indicated

Date 1979	Clay Soil 11	12	Ave	Cum	Q	Bermuda Grass 28	32	Ave	Cum	Q
6- 20,21	7.06	7.02	7.04	14.08						
22,23,24	5.30	5.36	5.33	30.07						
25,26	5.56	5.85	5.71	41.49						
27,28	4.17	4.01	4.09	49.67						
29- 5	5.72	5.67	5.70	83.87						
7- 6, 7, 8	6.42	6.39	6.41	103.10						
9,10	8.12	8.08	8.10	119.30						
11,12	7.42	7.61	7.52	134.34						
13,14,15	7.51	7.69	7.60	157.14						
16,17	3.74	4.28	4.01	165.16		2.91	2.69	2.80	5.60	
18,19	4.47	4.58	4.53	174.22		3.92	3.50	3.71	13.02	
20,21,22	4.82	4.39	4.61	188.05	10	4.16	3.66	3.91	24.75	10
23,24	4.72	4.67	4.70	197.45		4.23	3.98	4.11	32.97	
25,26	5.11	5.41	5.26	207.97		5.06	4.71	4.89	42.75	
27,28,29	5.31	5.25	5.28	223.81	10	4.49	4.03	4.26	55.53	10
30,31	3.10	1.59	2.35	228.51		2.72	2.58	2.65	60.83	
8- 1, 2	6.65	6.73	6.69	241.89		5.78	5.28	5.53	71.89	
3, 4, 5	7.95	7.67	7.81	265.32	10	6.46	5.80	6.13	90.28	10
6, 7	7.33	7.02	7.18	279.68		6.03	5.48	5.76	101.80	
8-12	3.57	3.54	3.56	297.48	10	2.55	2.32	2.44	114.00	10
22,23						3.39	3.14	3.27	120.54	10
24,25,26	2.85	2.88	2.87	306.09		2.50	2.23	2.37	127.65	
27,28	3.51	3.59	3.55	313.19	10	3.17	2.83	3.00	133.65	10
29,30	4.20	4.39	4.30	321.79		3.51	3.43	3.47	140.59	
9-31, 1, 2	5.46	5.39	5.43	338.08		4.69	4.24	4.47	154.00	
3, 4	6.65	6.87	6.76	351.60	10	5.29	4.95	5.12	164.24	10
5, 6	5.72	5.49	5.61	362.82		4.24	3.99	4.12	172.48	
7, 8, 9	4.69	4.74	4.72	376.98		3.94	3.74	3.84	184.00	
10,11	1.98	2.00	1.99	380.96		1.54	1.64	1.59	187.18	
12,13	1.33	0.30	1.32	383.60		0.39	0.49	0.44	188.06	
14,15.15	4.29	4.34	4.32	396.56		3.20	3.08	3.14	197.48	
17,18	4.75	5.87	5.31	407.18		3.78	3.64	3.71	204.90	
19,20	4.12	3.63	3.88	414.94		2.99	2.87	2.93	210.76	
21,22,23	4.12	4.12	4.12	427.30		3.03	2.77	2.90	219.46	
24,25	3.70	3.77	3.74	434.78		2.67	2.48	2.58	224.62	
26,27	3.82	3.82	3.82	442.42		2.67	2.44	2.56	229.74	
28,29,30	4.47	4.65	4.56	456.10	10	3.19	2.89	3.04	238.86	9
10- 1, 2	5.25	5.33	5.29	466.68		3.48	3.19	3.34	345.54	
3, 4	3.93	3.97	5.95	478.58		2.42	2.33	2.38	250.30	
5, 6, 7	4.93	4.81	4.87	493.19	10	2.53	2.27	2.40	257.50	7.5

Table D-1. Turf evapotranspiration -------- Values represent average daily ET in millimeters over the period indicated

(Continued)

Date	Clay Soil 11	Clay Soil 12	Clay Soil Ave	Clay Soil Cum	Clay Soil Q	Bermuda Grass 28	Bermuda Grass 32	Bermuda Grass Ave	Bermuda Grass Cum	Bermuda Grass Q
8, 9	3.20	3.20	3.20	499.59		1.62	1.62	1.62	260.74	1.5
10,11	3.78	3.78	3.78	507.15		1.97	2.02	2.00	264.74	
15,16	3.58	3.58	3.58	514.31		2.16	2.12	2.14	269.02	
17,18	1.73	1.80	1.77	517.85		1.05	1.04	1.05	271.12	
19,20,21	1.79	1.70	1.75	523.10	10	1.01	1.10	1.06	274.30	2
22,23	1.71	1.71	1.71	526.52		0.77	0.66	.72	275.74	
24,25	2.66	2.62	2.64	531.80		0.84	0.79	.82	277.38	
11- 16,17	1.23	1.26	1.25	534.30	7	0.44	0.54	.49	278.36	0
18	1.18	1.28	1.23	535.53		0.34	0.34	.37	278.73	
1980										
3- 12,13	1.10	1.71	1.41							
18,19,20	2.10	2.00	2.05							
21,22,23	1.45	1.46	1.48							
4-11,12,13	2.50	2.56	2.53	7.59						
14,15	4.61	4.39	4.50	16.59						
16,17	4.40	4.09	4.25	25.08	6					
18,19,20	4.78	4.77	4.78	39.42						
5- 3, 4	2.11	2.27	2.19	42.86	7.5	1.16	1.25	1.21	2.41	3
5, 6	2.01	1.88	1.95	46.75		1.24	1.99	1.62	5.64	
7, 8, 9	0.92	0.92	0.92	49.51		0.73	0.65	0.69	7.71	
10,11,12	3.91	0.32	2.11	55.86		0.00	2.58	1.29	10.29	
15-18						2.06	0.63	1.35	18.36	
19,20	4.14	4.14	4.14	64.14		3.19	4.01	3.60	25.56	
21,22	5.36	5.37	5.37	74.88		4.52	4.75	4.64	34.83	
23-26	5.83	5.95	5.89	98.44		4.49	5.01	4.75	53.83	
27,28,29	5.36	5.45	5.41	114.65		3.86	4.70	4.28	66.67	
30, 1	7.40	7.44	7.41	136.88		5.53	6.16	5.85	84.21	
6- 2, 3	8.32	8.40	8.36	153.60		6.54	6.98	6.76	97.73	
4, 5	10.70	10.92	10.81	175.22		8.19	8.75	8.46	114.65	
6, 7, 8	8.09	8.00	8.05	199.37		5.88		5.88	132.29	
9,10		6.48	6.48	212.33		4.93	5.84	5.39	143.06	
11,12	7.31	7.76	7.64	227.60		7.49	8.09	7.79	158.64	
13,14,15	7.51	7.76	7.64	250.52		6.00	6.41	6.21	177.27	
16,17	7.51	7.76	7.64	265.80	9	5.61	6.06	5.84	188.94	9
18,19	4.54	4.44	4.49	274.78		3.26	3.37	3.32	195.57	
20,21,22	6.12	6.04	6.08	293.02		4.75	5.12	4.94	210.37	
23,24	8.39	8.96	8.68	310.37		6.42	6.66	6.54	223.45	

Table D-1. Turf evapotranspiration -------- Values represent average daily ET in millimeters over the period indicated

(Continued)

Date	Clay Soil					Bermuda Grass				
	11	12	Ave	Cum	Q	28	32	Ave	Cum	Q
25,26	8.55	8.22	8.39	327.14		6.70	6.72	6.71	236.87	
27,28,29	8.44	8.46	8.45	352.49		6.65	6.54	6.60	256.66	
30, 1	5.37	5.48	5.43	363.34		3.85	3.72	3.79	264.23	
7- 2, 3	3.35	2.85	3.10	369.54		3.48	2.63	3.06	270.34	
4, 5, 6	8.27	8.13	8.20	394.14		6.72	6.66	6.69	290.41	
7, 8	6.87	6.88	6.88	407.90	10	4.73	4.86	4.80	299.99	10
9,10	5.82	6.15	5.99	419.87		5.01	4.88	4.95	309.89	
11,12,13	4.93	5.11	5.02	434.93		4.37	4.18	4.28	322.71	
14,15	7.73	7.30	7.52	449.96	10	6.35	6.22	6.29	335.28	10
16,17	7.79	7.22	7.51	464.97		6.55	6.31	6.43	348.14	
18,19,20	4.02	3.80	3.91	476.70		3.31	3.08	3.20	357.73	
21,22	4.66	4.65	4.66	486.02	10	4.40	4.29	4.35	366.42	10
23,24	5.03	4.72	4.88	495.77		4.44	4.11	4.28	374.97	
25,26,27	4.90	5.19	5.05	510.91		4.73	4.52	4.63	388.84	
28,29	7.86	7.50	7.68	526.27	10	6.73	6.36	6.55	401.93	10
30,31	6.43	5.86	6.15	538.55		5.89	5.17	5.53	412.99	
8- 1, 2. 3	6.33	5.77	6.05	556.71		5.15	4.64	4.90	427.68	
4, 5	5.20	4.75	4.98	566.66	10	4.43	4.13	4.28	436.24	9
6, 7	7.64	7.18	7.41	581.48		6.85	6.56	6.71	449.65	
8, 9,10	3.37	3.15	3.26	591.26		2.74	2.56	2.65	457.60	
11,12	6.93	6.50	6.72	604.69	10	5.37	5.26	5.42	468.43	10
18,19	6.20		6.20	617.09		4.83	4.45	4.64	477.71	
20,21	6.61	6.31	6.46	630.01	10	5.41	5.15	5.28	488.27	9
22,23,24	5.51	5.32	5.42	646.25		4.38	4.09	4.24	500.97	
25,26	5.10	4.72	4.91	656.07		3.87	3.45	3.66	508.29	
27,28	5.36	4.83	5.10	666.26		3.90	3.50	3.70	515.69	
29,30,31	3.36	3.21	3.29	676.12	10	2.83	2.70	2.77	523.99	
9- 1, 2						4.26	4.26	4.26	532.51	8
3, 4						4.64	4.39	4.52	541.55	
5, 6, 7						4.01	3.96	4.01	553.58	
8, 9						1.19	0.95	1.07	555.72	
10,11						3.59	3.14	3.37	562.46	
12,13,14						2.43	2.27	2.35	569.51	
15,16						3.32	3.05	3.19	575.89	
17,18						4.12	3.19	3.66	583.21	6
19,20,21						3.45	2.65	3.05	592.36	
22,23						2.57	1.97	2.27	596.90	
24,25						2.12	1.74	1.93	600.76	
26,27,28						2.78	2.21	2.50	608.26	
29,30						2.94	2.34	2.64	613.54	
10- 1, 2						2.01	1.70	1.86	617.26	4

Table D-1. Turf evapotranspiration -------- Values represent average daily ET in millimeters over the period indicated

(Continued)

Date	Clay Soil					Bermuda Grass				
	11	12	Ave	Cum	Q	28	32	Ave	Cum	Q
3, 4, 5						2.25	1.74	2.00	623.26	
6, 7						2.11	2.73	2.42	628.10	
8, 9,10						1.97	1.01	1.49	632.57	
11,12						1.51	1.26	1.39	635.35	
13-20						0.17	0.14	0.16	636.63	
21- 2						0.40	0.35	0.38	641.19	
11- 3-11						0.34	0.27	0.31	643.98	

APPENDIX E RELATIVE EVAPOTRANSPIRATION AND TURF QUALITY VALUES, PLOTTED AS A FUNCTION OF TIME, FOR THE IRRIGATION STUDIES. 1979 MOWING HEIGHTS ARE COMPARED IN FIGURES E-1 TO E-7.

1980 NITROGEN LEVELS ARE COMPARED IN FIGURES E-8 to E-21.

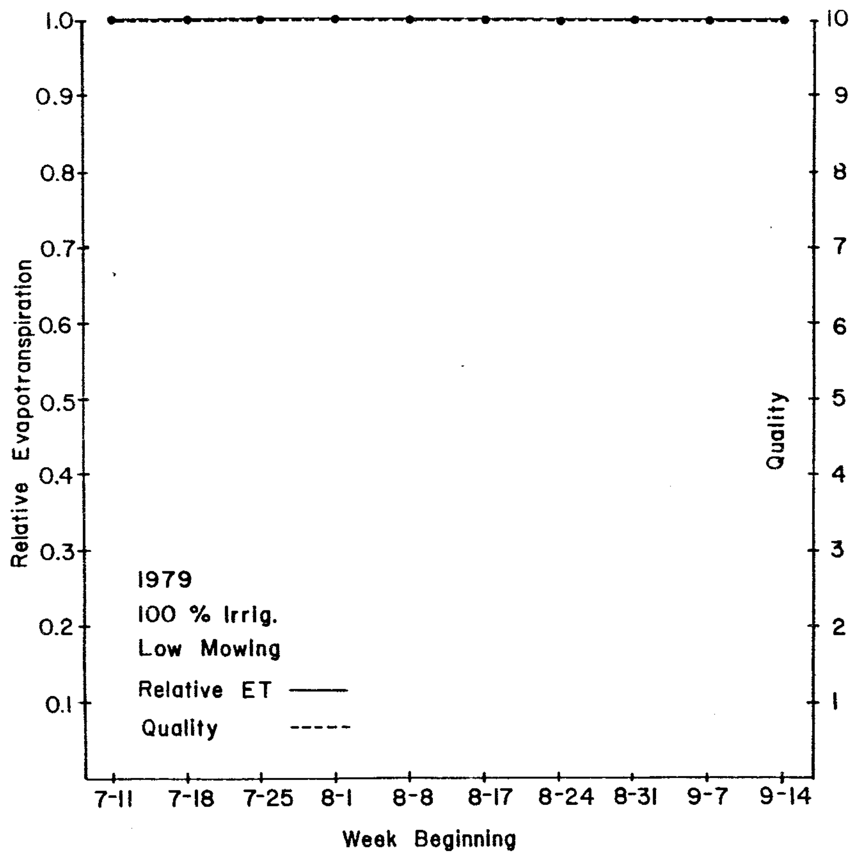


Figure E-1.

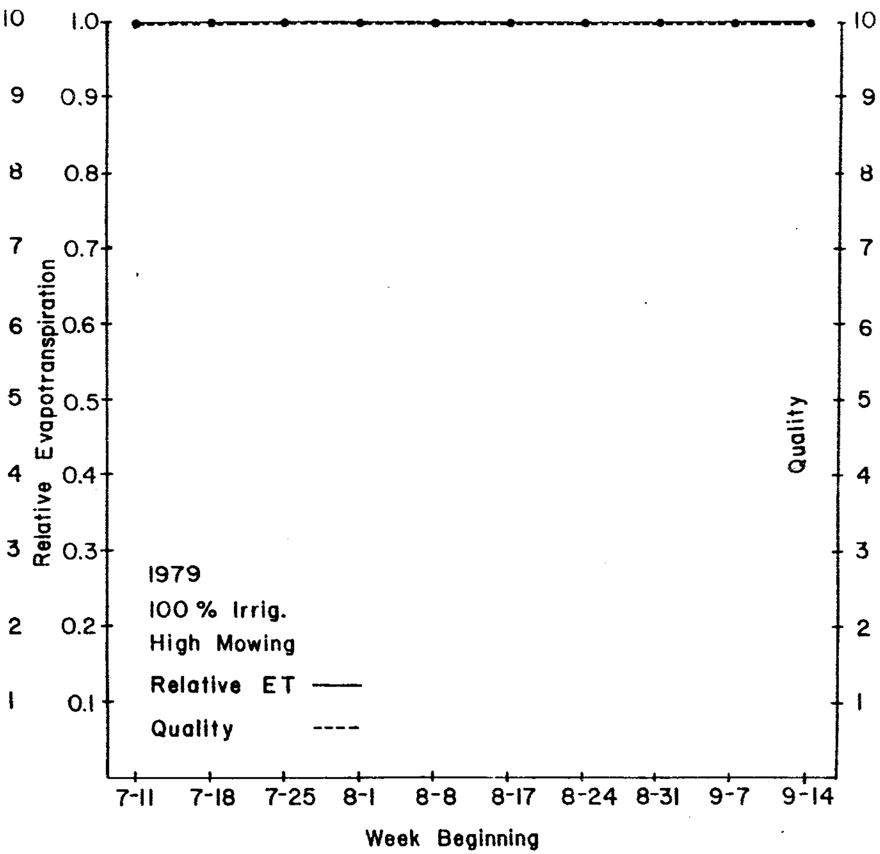


Figure E-2.

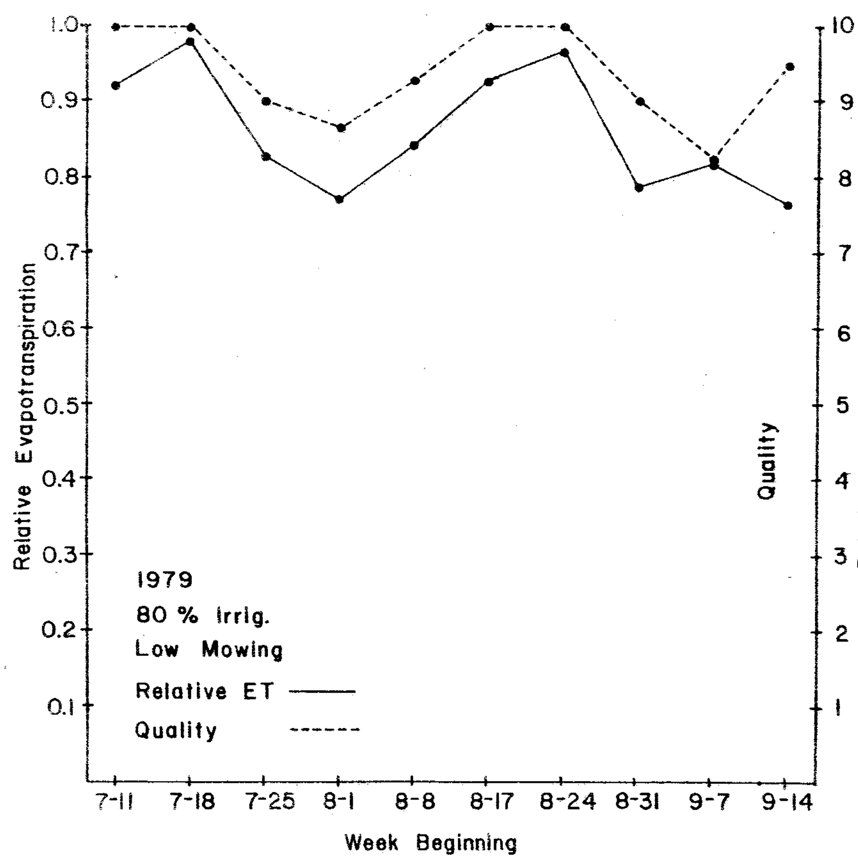


Figure E-3.

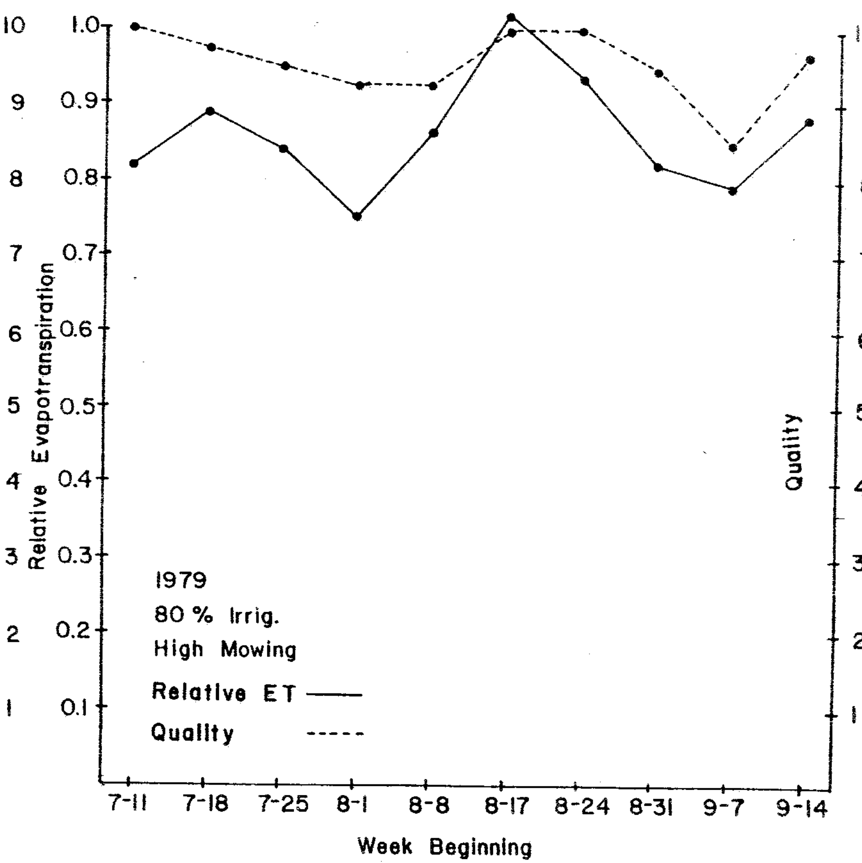


Figure E-4.

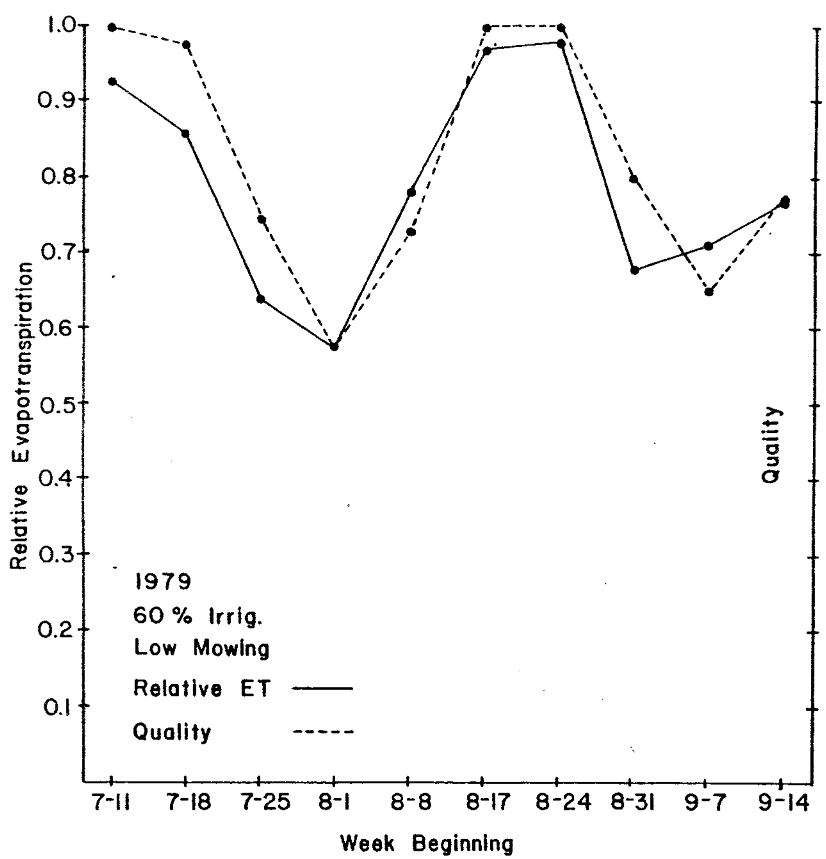


Figure E-5.

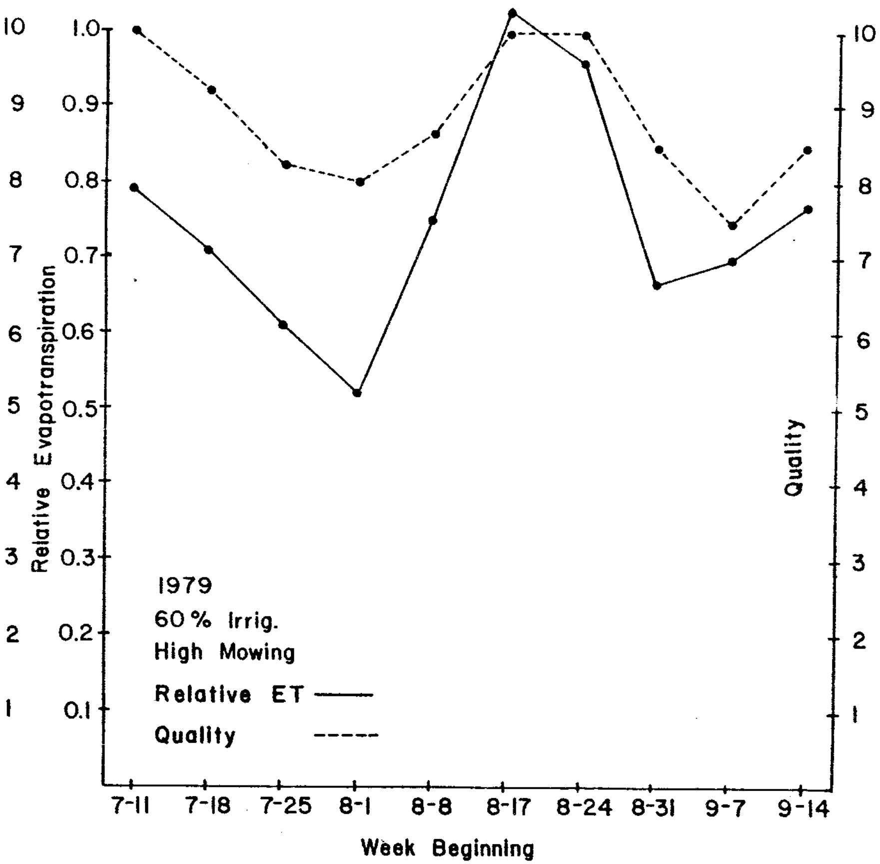
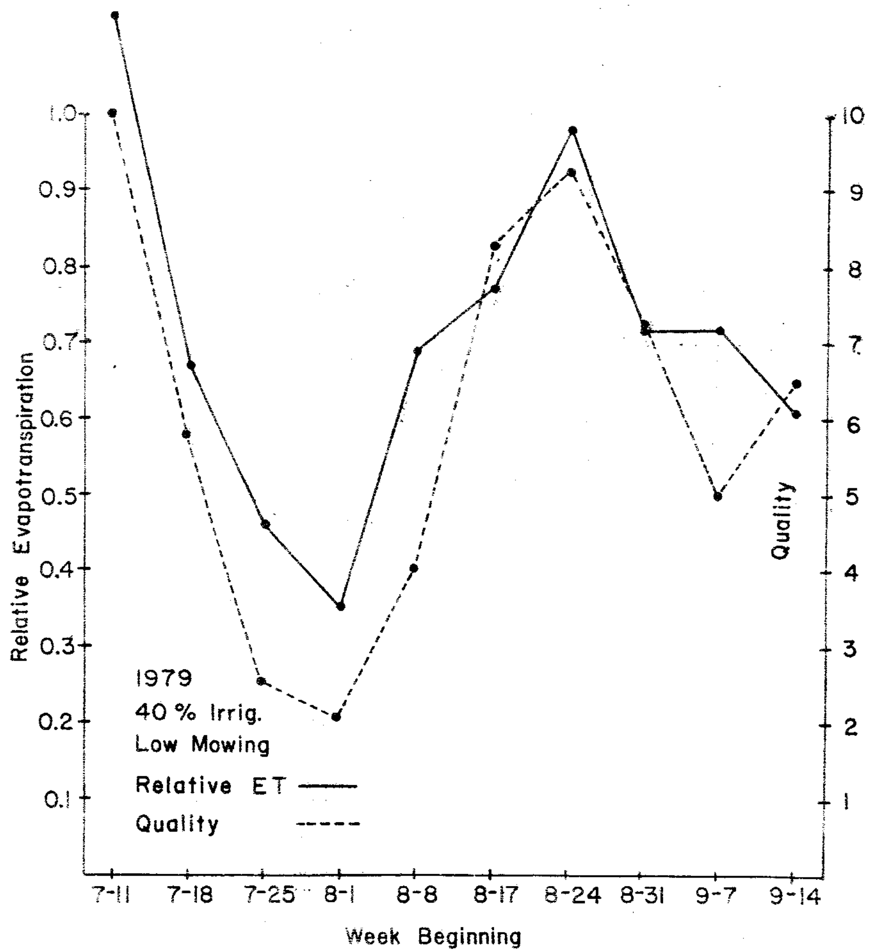


Figure E-6.



1979
40 % Irrig.
Low Mowing
Relative ET
Quality
Relative Evapotranspiration
Quality
Week Beginning
7-11
7-18
7-25
8-1
8-8
8-17
8-24
8-31
9-7
9-14

Figure E-7.

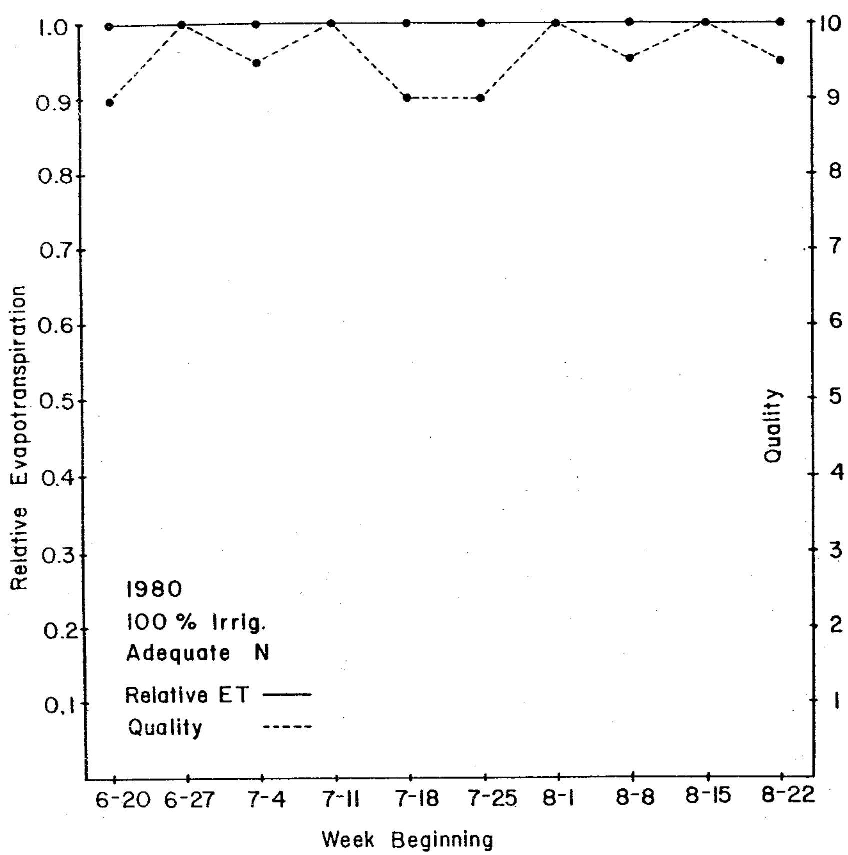


Figure E-8.

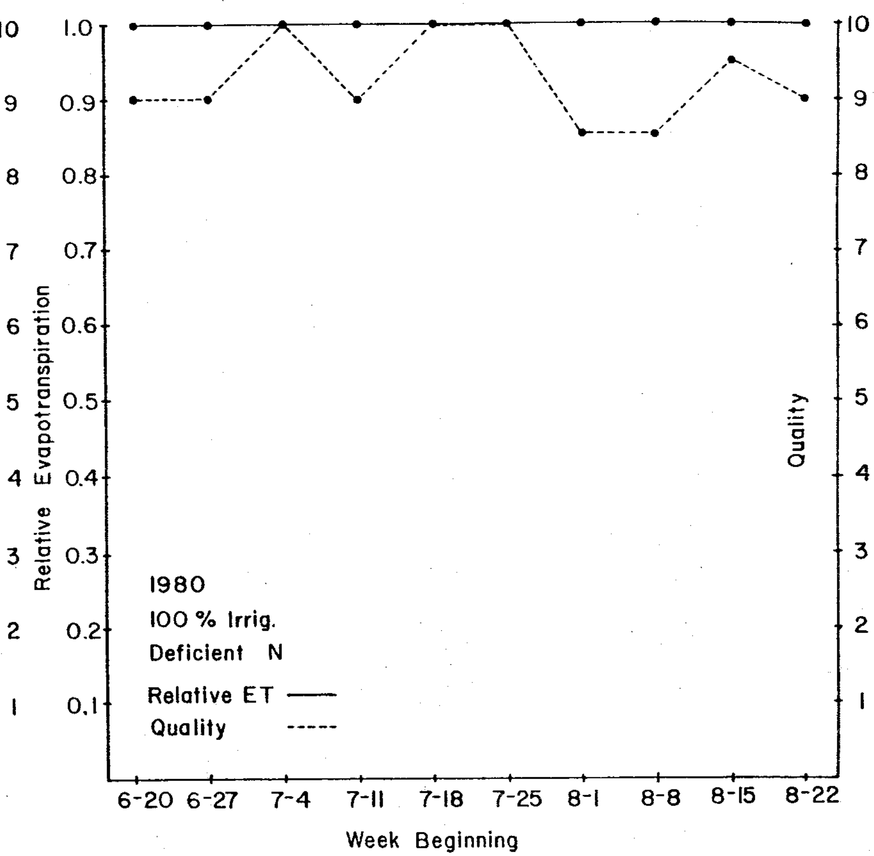


Figure E-9.

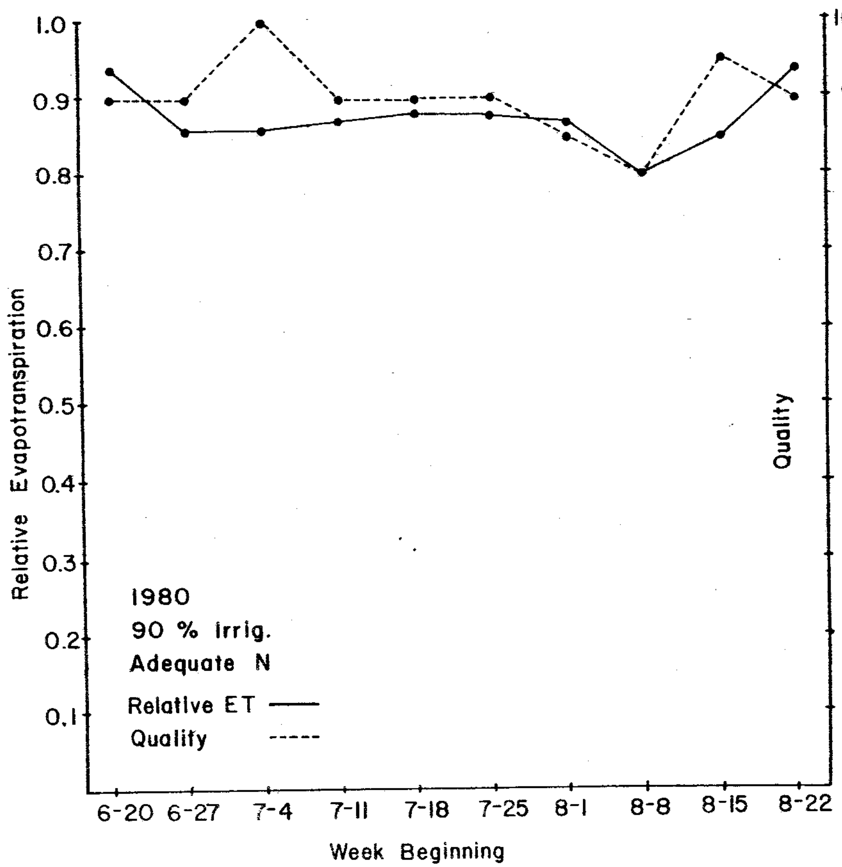


Figure E-10.

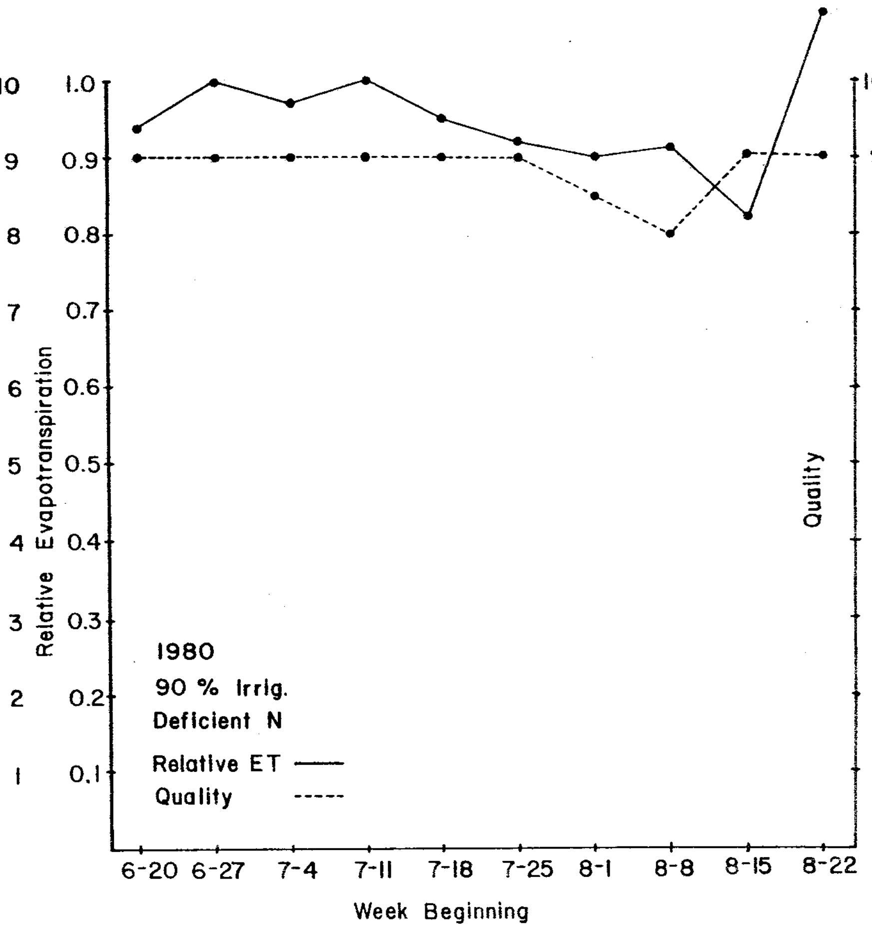


Figure E-11.

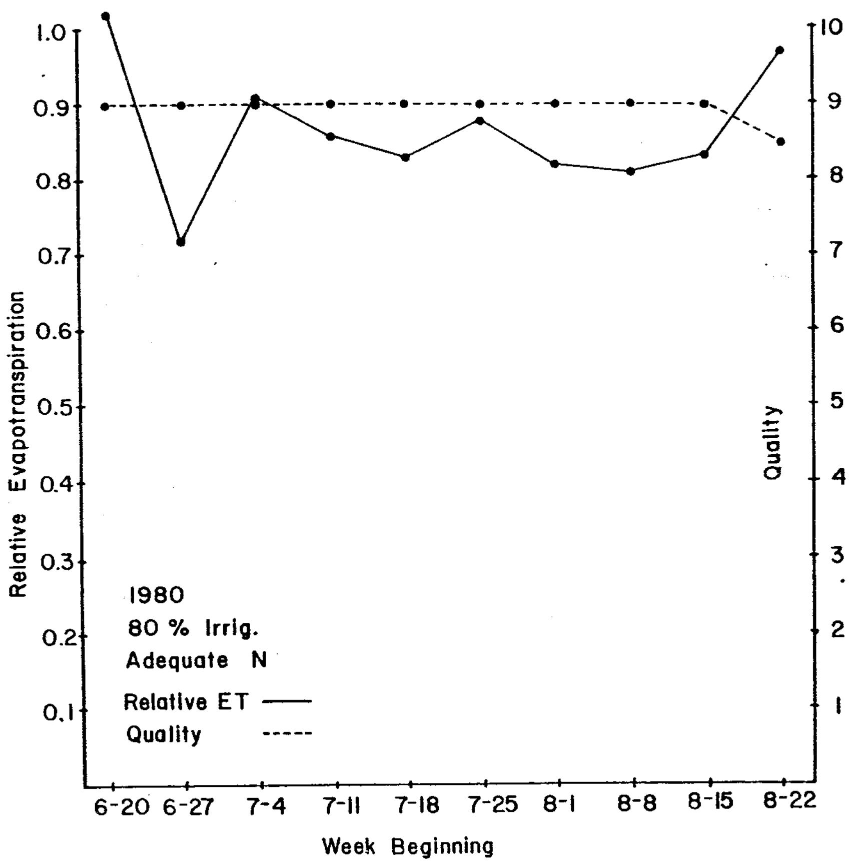


Figure E-12.

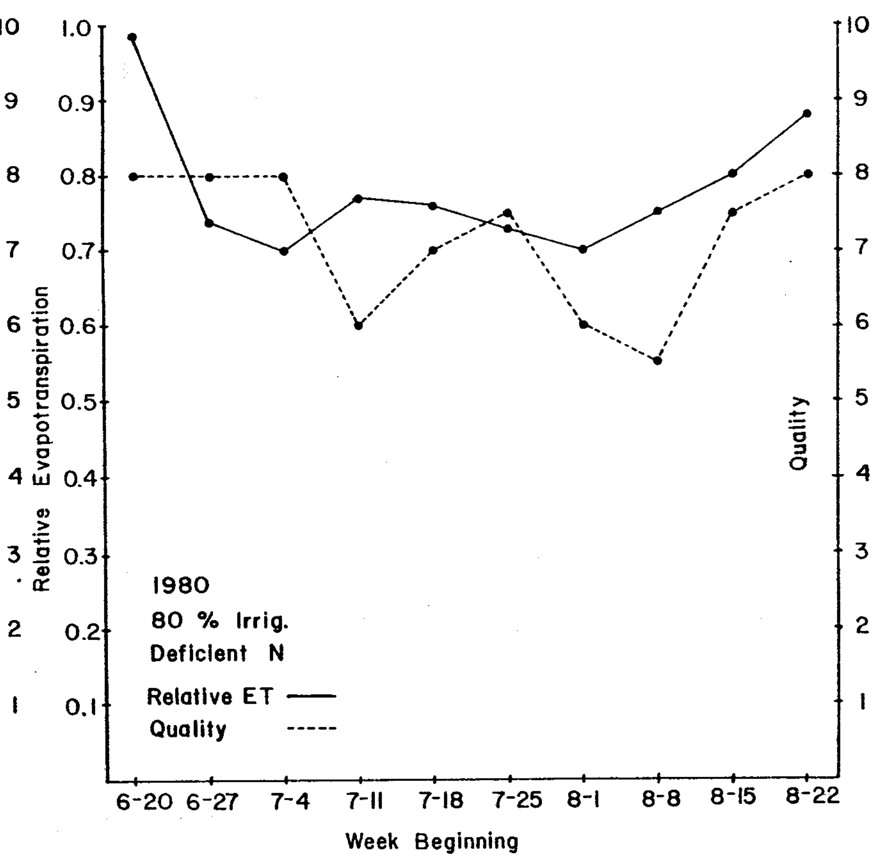


Figure E-13.

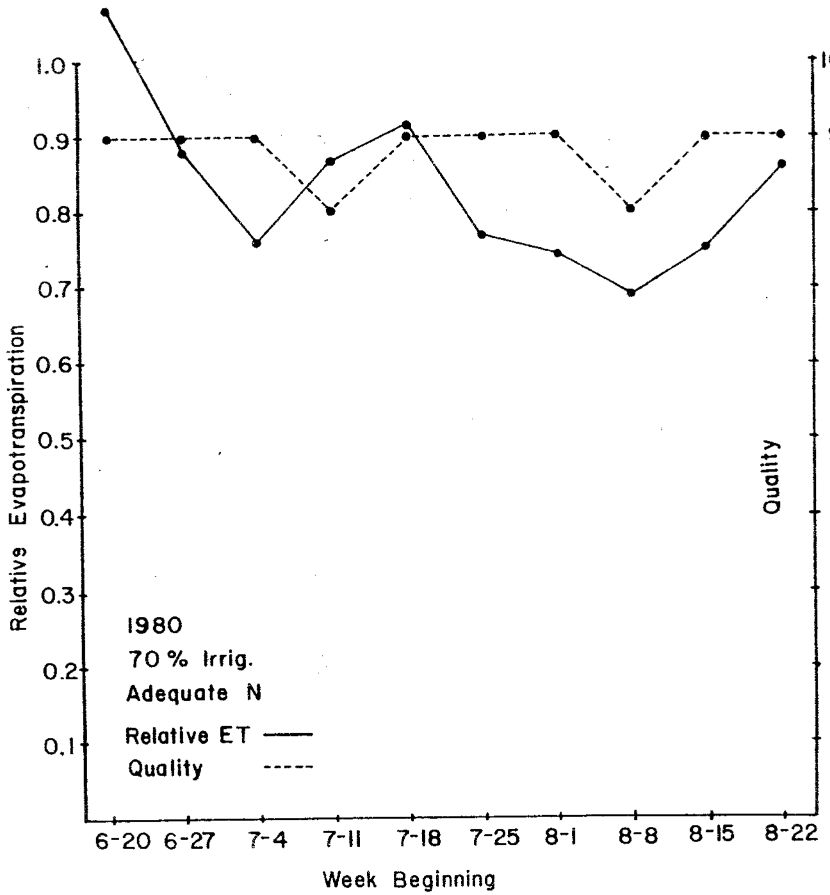


Figure E-14.

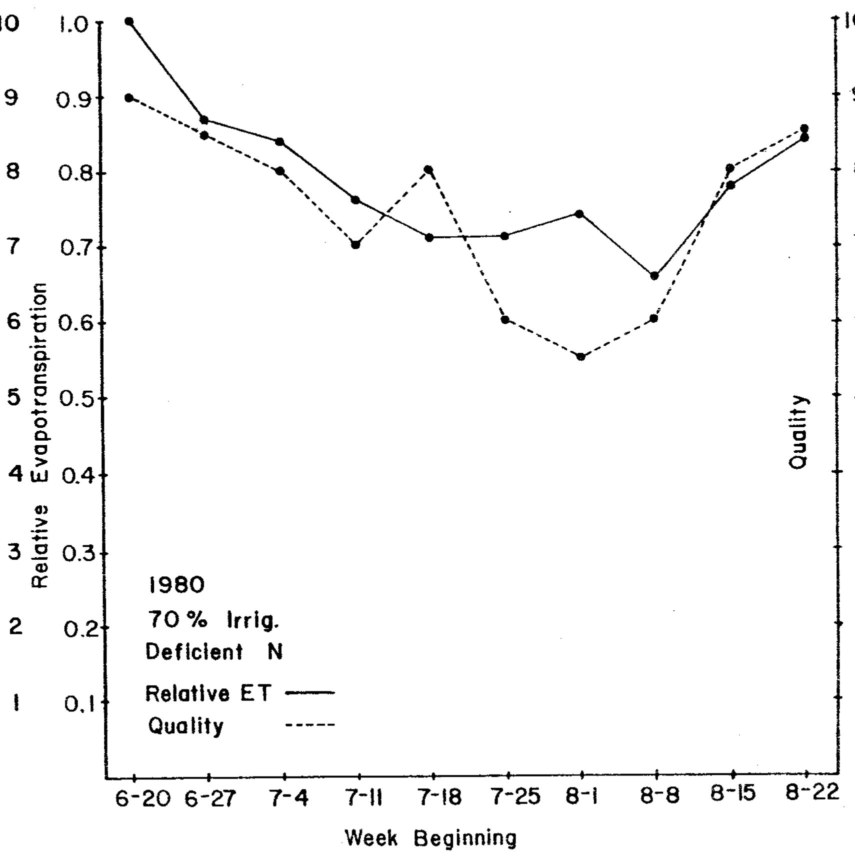


Figure E-15.

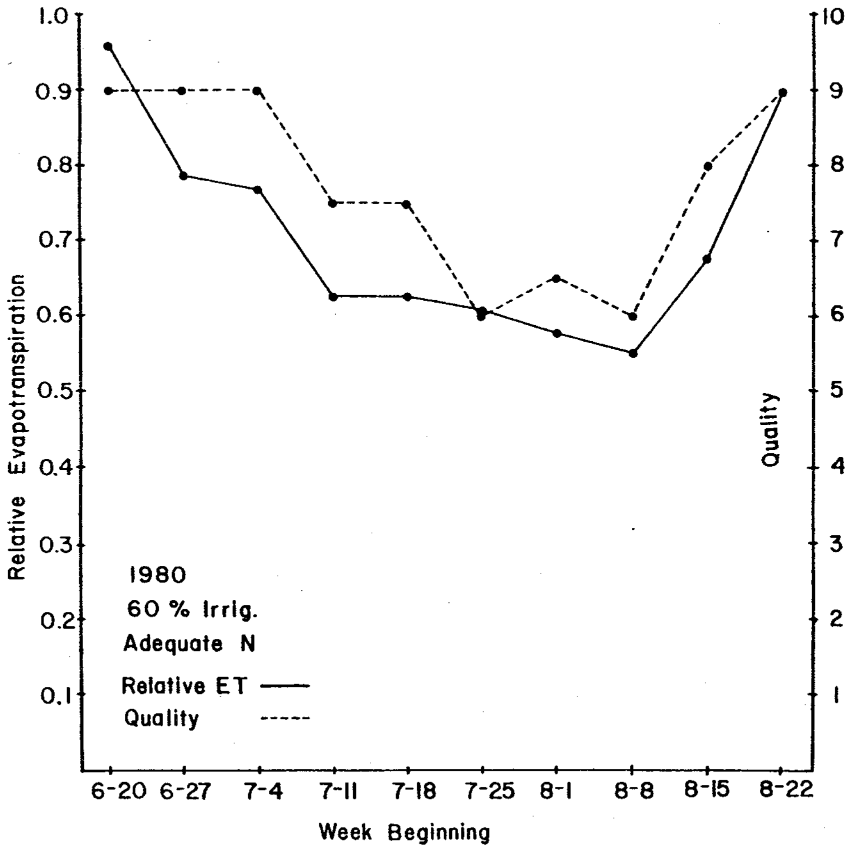


Figure E-16.

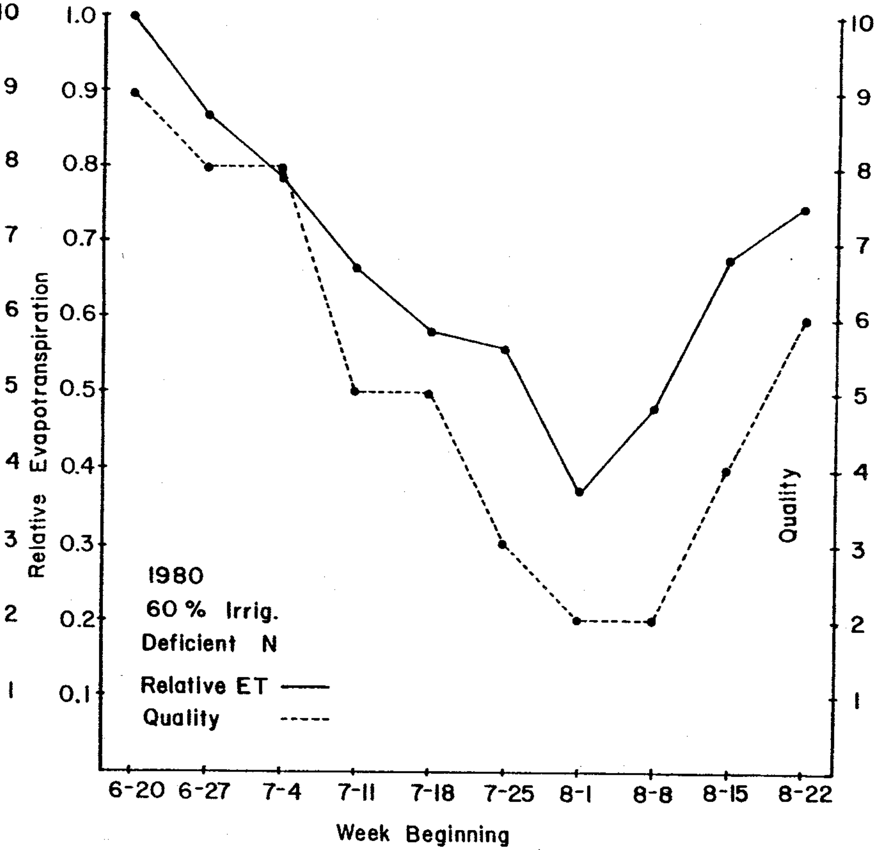


Figure E-17.

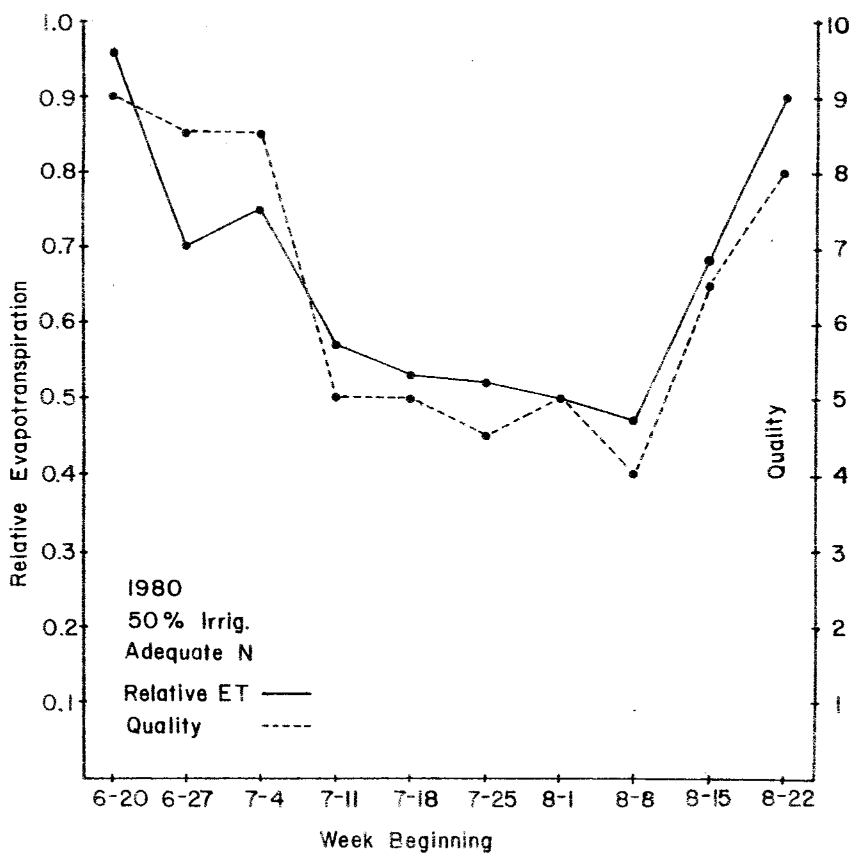


Figure E-18.

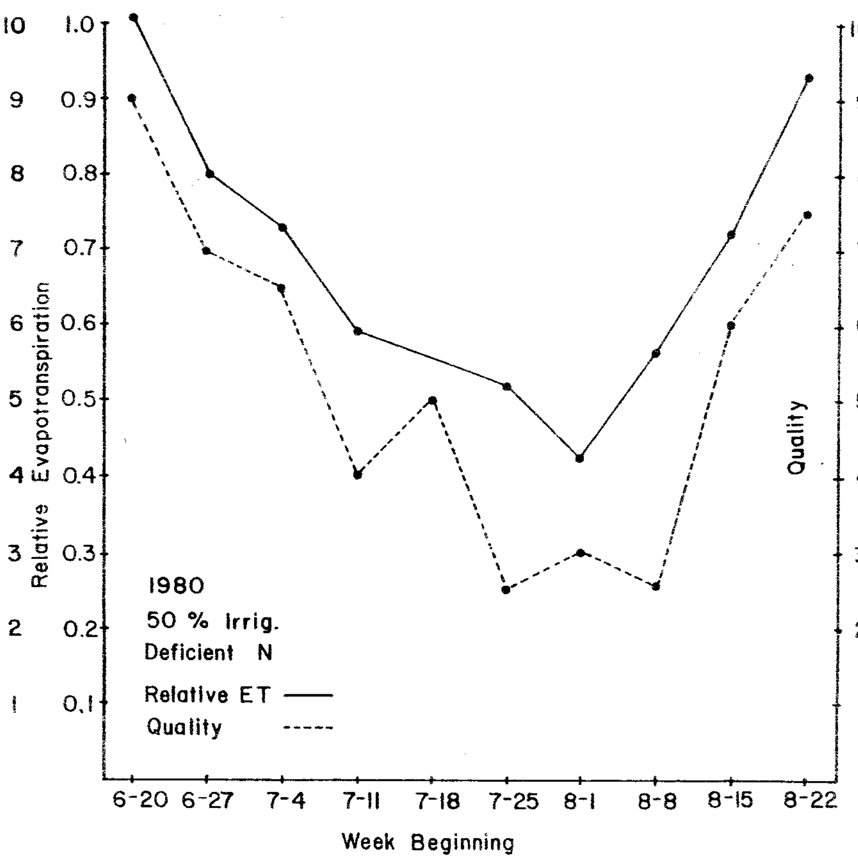


Figure E-19.

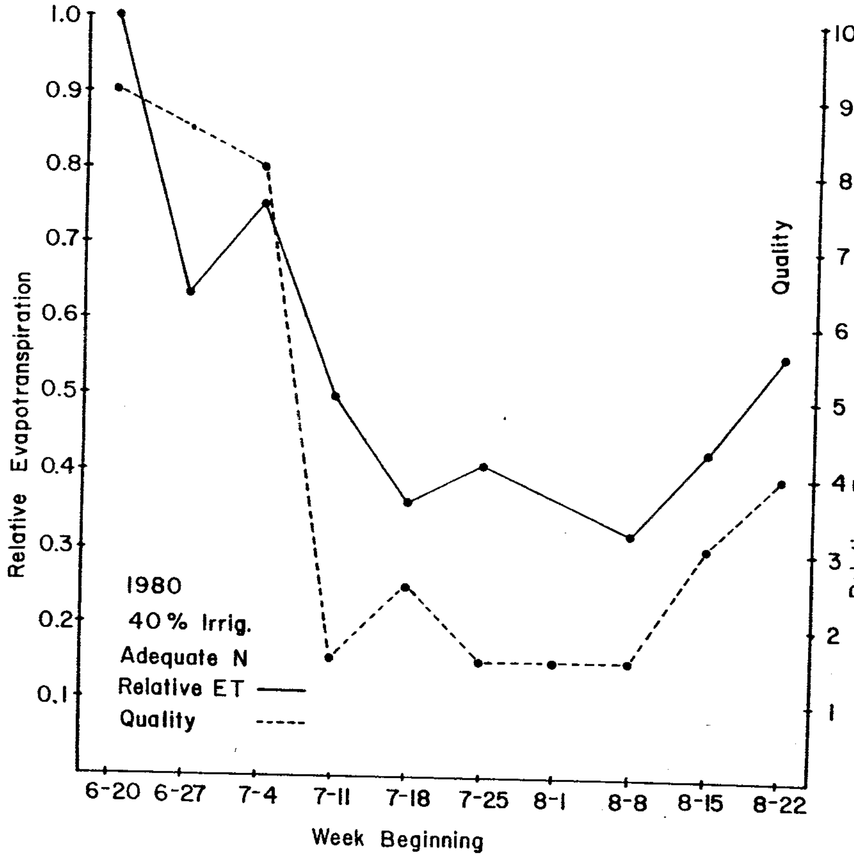


Figure E-20.

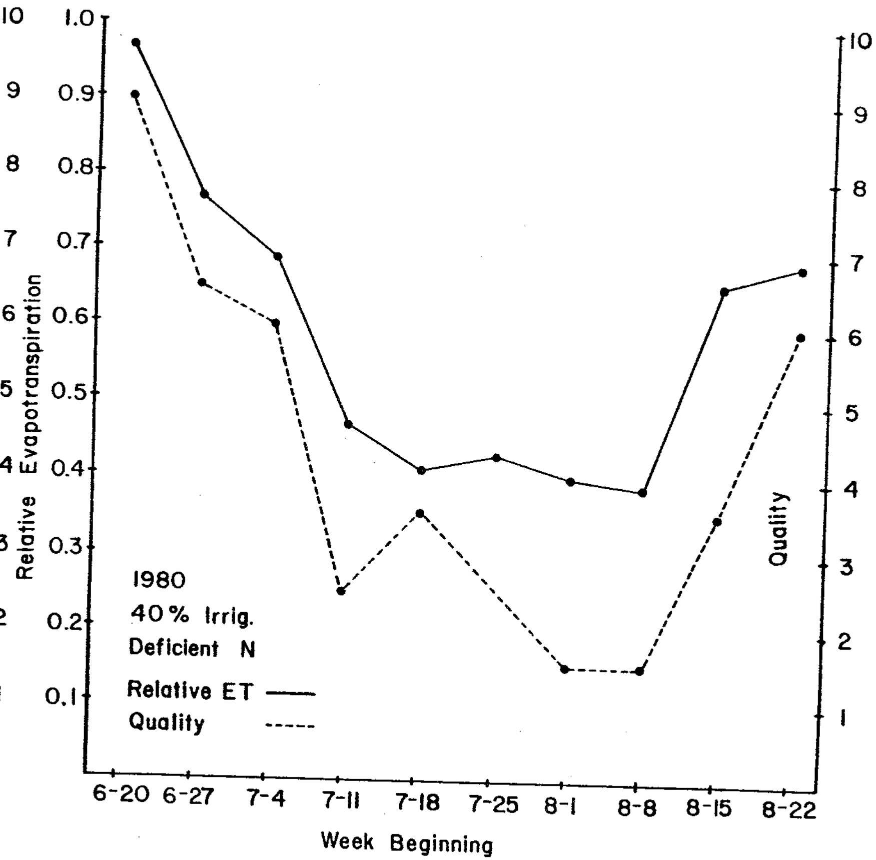


Figure E-21.

APPENDIX F MEASURED ET FOR 1979
AND 1980 FROM SOLAR RADIATION LEVEL STUDIES

Table F-1. Turf evapotranspiration - 1980. Values represent average ET in millimeters over the period indicated. Each value is the average of 4 replications.

Date	% Solar Level 100	73	54	33	Precip.
6 - 18,19	4.02	3.41	2.86	2.55	
20,21,22	5.65	4.70	3.99	3.29	1.8
23,24	7.82	6.48	5.10	4.45	
25,26	7.46	6.16	5.16	4.51	
27,28,29	7.80	6.32	5.17	4.49	
7 - 30, 1	4.70	3.97	3.31	2.92	
2, 3	3.12	4.11	4.72	5.71	* 1.8
4, 5, 6	8.65	7.38	5.89	4.98	
7, 8	6.77	5.69	4.90	4.25	2.6
9,10	6.34	5.52	4.50	3.80	
11,12,13	4.90	4.24	3.66	3.07	
14,15	7.52	6.58	5.43	4.46	
16,17	7.35	6.22	5.20	4.30	
18,19,20	3.68	3.16	2.63	2.53	4.0
21,22	4.71	3.67	3.05	2.32	
23,24	4.27	3.75	2.96	2.59	
25,26,27	5.57	4.41	3.66	2.93	
28,29	7.55	6.29	5.30	4.51	
30,31	6.12	4.44	4.39	3.66	
8 - 1, 2, 3	5.87	5.00	4.31	3.81	
4, 5	4.60	3.84	3.14	2.66	
6, 7	7.60	6.37	5.29	4.35	
8, 9,10	3.37	2.43	2.41	1.87	
11,12	6.83	5.72	4.45	3.61	
13-17	1.20	1.24	1.48	1.57	8.9
18,19	6.04	5.42	4.57	3.79	
20,21	7.39	6.00	4.79	4.13	
22,23,24	5.16	4.46	3.92	3.28	1.0
25,26	4.30	3.73	3.47	3.58	5.0
27,28	4.98	4.15	3.74	2.91	
29,30,31	3.24	2.79	2.68	2.28	

Table F-2. Turf evapotranspiration - 1980. Values represent average ET in millimeters over the period indicated

Treatment: 100% Solar

Date	33	34	35	36	Ave
6 - 18,19	4.06	4.02	3.94	4.06	4.02
20,21,22	5.56	5.78	5.54	5.72	5.65
23,24	7.47	7.89	7.89	8.02	7.82
25,26	7.64	7.48	7.33	7.37	7.46
27,28,29	8.01	7.77	7.59	7.81	7.80
7 - 30, 1	4.89	4.67	4.57	4.68	4.70
2, 3	3.74	3.62	2.59	2.54	3.12
4, 5, 6	8.70	8.78	8.43	8.67	8.65
7, 8	6.78	7.03	6.57	6.71	6.77
9,10	6.28	6.39			6.34
11,12,13	4.86	4.97	4.92	4.83	4.90
14,15	7.39	7.46	7.77	7.44	7.52
16,17	7.12	7.29	7.61	7.38	7.35
18,19,20	3.62	3.76	3.66	3.69	3.68
21,22	4.59	4.78	4.65	4.81	4.71
23,24	4.30	4.20	4.25	4.33	4.27
25,26,27	5.31	5.29	5.87	5.82	5.57
28,29	7.36	7.28	7.51	8.04	7.55
30,31	6.13	6.11			6.12
8 - 1, 2, 3	5.78	5.43	6.04	6.22	5.87
4, 5	4.71	4.34	4.64	4.70	4.60
6, 7	7.68	7.53	7.44	7.76	7.60
8, 9,10	3.43	3.18	3.41	3.47	3.37
11,12	7.29	6.54	6.97	6.52	6.83
13-17	1.08	1.19	1.16	1.37	1.20
18,19	6.11	5.74	6.28	6.01	6.04
20,21	7.01	6.61	8.04	7.89	7.39
22,23,24	5.13	5.17	5.10	5.22	5.16
25,26	4.53	4.18	4.21	4.27	4.30
27,28	5.03	4.86	4.89	5.13	4.98
29,30,31	3.37	3.37	3.07	3.14	3.24

Table F-3. Turf evapotranspiration - 1980. Values represent average ET in millimeters over the period indicated

Treatment: 73% Solar

Date	41	42	43	44	Ave
6 - 18,19	3.62	3.31	3.22	3.49	3.41
20,21,22	4.98	4.83	4.61	4.40	4.70
23,24			6.31	6.64	6.48
25,26	6.66	6.41	5.70	5.87	6.16
27,28,29	6.87	6.34	5.88	6.19	6.32
7 - 30, 1	4.52	3.92	3.62	3.83	3.97
2, 3	4.28	4.02	4.03	4.10	4.11
4, 5, 6	7.87	7.51	6.71	7.41	7.38
7, 8	6.13	5.86	5.34	5.44	5.69
9,10	5.54	5.50			5.52
11,12,13	4.37	4.23	4.07	4.27	4.24
14,15	7.30	6.22	6.15	6.63	6.58
16.17	6.33	6.14	5.99	6.14	6.22
18,19,20	3.20	3.02	3.06	3.35	3.16
21,22	3.68	3.62	3.45	3.93	3.67
23,24			3.32	3.74	3.75
25,26,27	4.73	4.27	3.91	4.72	4.41
28,29	6.49	6.40	5.79	6.49	6.29
30,31	5.43	4.98			4.44
8 - 1, 2, 3	5.29	4.62	4.78	5.30	5.00
4, 5	3.99	3.75	3.65	3.96	3.84
6, 7	6.56	6.36	5.89	6.68	6.37
8, 9,10	1.41	2.53	2.69	3.08	2.43
11,12	5.98	5.31	5.42	6.16	5.72
13-17	1.40	1.32	1.04	1.21	1.24
18,19	5.89	5.15	4.88	5.75	5.42
20,21	6.28	5.82	5.56	6.32	6.00
22,23,24	4.55	4.48	4.13	4.67	4.46
25,26	3.99	3.70	3.56	3.67	3.73
27,28	4.23	3.95	3.98	4.44	4.15
29,30,31	2.68	2.83	2.65	3.00	2.79

Table F-4. Turf evapotranspiration - 1980. Values represent average ET in millimeters over the period indicated

Treatment: 54% Solar

Date	45	46	47	48	Ave
6 - 18,19	2.88	2.96	2.81	2.78	2.86
20,21,22	4.15	4.04	3.86	3.90	3.99
23,24			5.14	5.05	5.10
25,26	5.58	5.27	4.86	4.94	5.16
27,28,29	5.58	5.21	4.87	5.01	5.17
7 - 30, 1	3.54	3.37	3.04	3.27	3.31
2, 3	5.16	4.84	4.40	4.47	4.72
4, 5, 6	6.15	5.97	5.83	5.59	5.89
7, 8	5.15	4.88	4.93	4.64	4.90
9,10	4.61	4.49			4.50
11,12,13	3.98	3.63	3.63	3.39	3.66
14,15	5.87	5.10	5.58	5.17	5.43
16,17	5.37	5.25	5.14	5.05	5.20
18,19,20	2.38	2.37	3.02	2.74	2.63
21,22	3.06	3.10	3.04	2.99	3.05
23,24			3.10	2.82	2.96
25,26,27	3.66	3.66	3.79	3.52	3.66
28,29	5.46	5.37	5.30	5.07	5.30
30,31	4.53	4.25			4.39
8 - 1, 2, 3	4.42	4.05	4.50	4.27	4.31
4, 5	3.15	3.25	3.06	3.08	3.14
6, 7	5.47	5.34	5.18	5.17	5.29
8, 9,10	2.37	2.36	2.65	2.26	2.41
11,12	4.54	4.76	4.80	3.68	4.45
13-17	1.40	1.36	1.36	1.81	1.48
18,19	4.67	4.17	4.80	4.63	4.57
20,21	4.96	4.33	5.12	4.75	4.79
22,23,24	4.15	4.19	3.77	3.85	3.92
25,26	3.79	3.02	3.54	3.52	3.47
27,28	3.76	4.01	3.68	3.51	3.74
29,30,31	2.83	2.65	2.68	2.54	2.68

Table F-5. Turf evapotranspiration - 1980 . Values represent average ET in millimeters over the period indicated

Treatment: 33% Solar

Date	37	38	39	40	Ave
6 - 18,19	2.68	2.69	2.43	2.39	2.55
20,21,22	3.46	3.69	3.18	2.82	3.29
23,24			4.46	4.44	4.45
25,26	4.72	4.79	4.32	4.21	4.51
27,28,29	4.56	4.42	4.73	4.23	4.49
7 - 30, 1	3.00	2.88	2.94	2.85	2.92
2, 3	5.74	5.49	5.76	5.84	5.71
4, 5, 6	5.05	4.77	5.36	4.72	4.98
7, 8	4.77	3.95	4.28	4.00	4.25
9,10	4.03	3.57			3.80
11,12,13	3.10	3.02	3.14	3.02	3.07
14,15	4.46	4.54	4.57	4.26	4.46
16,17	4.49	4.44	4.22	4.07	4.31
18,19,20	2.54	2.64	2.60	2.32	2.53
21,22	2.35	2.38	2.41	2.15	2.32
23,24			2.67	2.50	2.59
25,26,27	2.81	2.93	3.13	2.85	2.93
28,29	4.68	4.38	4.61	4.35	4.51
30,31	3.71	3.60			3.36
8 - 1, 2, 3	3.77	3.73	3.94	3.79	3.81
4, 5	2.70	2.73	2.69	2.51	2.66
6, 7	4.40	4.37	4.31	4.33	4.35
8, 9,10	1.90	1.80	1.87	1.90	1.87
11,12	3.73	3.51	3.62	3.58	3.61
13-17	1.42	1.60	1.60	1.66	1.57
18,19	3.76	3.72	3.81	3.87	3.79
20,21	4.30	3.70	4.11	4.40	4.13
22,23,24	3.39	3.21	3.34	3.18	3.28
25.26	3.70	3.55	3.52	3.56	3.58
27,28	2.91	2.87	2.96	2.88	2.91
29,30,31	2.36	2.26	2.19	2.30	2.28

Table F-6. Turf evapotranspiration - 1979. Values represent average ET in millimeters over the period indicated. Each value is the average of 4 replications.

Date	% Solar level 100	73	54	33	Precip
7 - 13,14,15	7.62	5.77	4.97	4.00	
16,17	3.78	2.81	2.62	2.22	
18,19	4.87	3.80	3.20	2.50	5.8
20,21,22	4.94	4.09	3.91	3.33	1.5
23,24	4.83	3.91	3.50	2.96	
25,26	5.74	4.61	3.74	2.84	
27,28,29	5.14	4.06	3.57	3.07	
30,31	2.31	2.83	2.92	1.97	
8 - 1, 2	6.46	5.43	4.69	3.40	
3, 4, 5	7.64	6.19	5.20	4.35	
6, 7	6.83	5.57	4.70	3.81	
8,9,10,11,12	3.01	2.86	3.07	2.72	21.8
24,25,26	2.78	2.21	2.15	1.81	3.8
27,28	3.11	2.85	2.40	1.90	
29,30	4.38	3.45	2.90	2.34	
9 - 31, 1, 2	5.34	4.30	3.77	3.06	
3, 4	6.80	5.61	5.04	3.83	
5, 6	5.23	4.20	3.58	2.34	
7, 8, 9	4.86	3.93	3.14	3.05	
10,11	1.43	1.35	2.24	2.30	10.6
12,13	0.72	0.30	1.15		13.0
14,15,16	4.39	3.68	2.77	2.20	

Table F-7. Turf evapotranspiration - 1979. Values represent average ET in millimeters over the period indicated

Treatment: 100% Solar

Date	33	34	35	36	Ave
7 - 13,14,15			7.59	7.64	7.62
16,17			3.82	3.74	3.78
18,19			4.88	4.85	4.87
20,21,22			4.95	4.92	4.94
23,24			4.82	4.84	4.83
25,26			5.79	5.67	5.74
27,28,29			4.97	5.10	5.14
30,31			2.12	2.50	2.31
8 - 1, 2			6.24	6.67	6.46
3, 4, 5			7.60	7.67	7.64
6, 7			6.78	6.88	6.83
8,9,10,11,12			2.99	3.02	3.01
24,25,26			2.75	2.81	2.78
27,28			3.70	2.52	3.11
29,30			4.35	4.41	4.38
9 - 31, 1, 2			5.31	5.37	5.34
3, 4			6.74	6.85	6.80
5, 6			5.11	5.35	5.23
7, 8, 9			4.79	4.92	4.86
10, 11			1.27	1.56	1.43
12,13			0.54	0.89	0.72
14,15,16			4.42	4.35	4.39

Table F-8. Turf evapotranspiration - 1979. Values represent average ET in millimeters over the period indicated

Treatment: 73% Solar

Date	41	42	43	44	Ave
7 - 13,14,15	5.52	5.68	5.96	5.92	5.77
16,17	2.73	2.72	2.94	2.84	2.81
18,19	3.71	3.63	3.97	3.87	3.80
20,21,22	3.87	4.01	4.27	4.19	4.09
23,24	3.88	3.66	4.14	3.96	3.91
25,26	4.34	4.83	4.71	4.56	4.61
27,28,29	3.96	4.20	4.03	4.06	4.06
30,31	2.16	3.01	3.28	2.88	2.83
8 - 1, 2	5.19	5.44	5.57	5.53	5.43
3, 4, 5	5.96	6.11	6.36	6.31	6.19
6, 7	5.42	5.58	5.60	5.66	5.57
8,9,10,11,12	2.77	2.73	3.03	2.89	2.86
24,25,26	2.20	2.18	2.20	2.26	2.21
27,28	2.67	2.86	2.78	3.09	2.85
29,30	3.40	3.45	3.44	3.49	3.45
9 - 31, 1, 2	4.38	4.35	4.24	4.21	4.30
3, 4	5.59	5.63			5.61
5, 6	4.16	4.28	4.09	4.28	4.20
7, 8, 9	3.89	3.98	3.87	3.99	3.93
10,11	1.21	1.68	1.14	1.38	1.35
12,13				0.30	0.30
14,15,16	3.31	3.22	4.76	3.43	3.68

Table F-9. Turf evapotranspiration - 1979. Values represent average ET in millimeters over the period indicated

Treatment: 54% Solar

Date	45	46	47	48	Ave
7 - 13,14,15	5.11	5.00	4.97	4.79	4.97
16,17	2.60	2.78	2.59	2.49	2.62
18,19	3.25	3.32	3.09	3.14	3.20
20,21,22	4.01	3.94	3.81	3.87	3.91
23,24	3.64	3.31	3.53	3.53	3.50
25,26	4.08	3.73	3.67	3.49	3.74
27,28,29	3.98	3.42	3.51	3.38	3.57
30,31	3.09	2.97	2.94	2.69	2.92
8 - 1, 2	4.74	4.70	4.67	4.65	4.69
3, 4, 5	5.19	5.46	5.14	5.00	5.20
6, 7	4.63	4.67	4.84	4.65	4.70
8,9,10,11,12	2.93	2.72	3.29	3.34	3.07
24,25,26	2.35	2.12	2.08	2.06	2.15
27,28	2.64	2.23	2.33	2.41	2.40
29,30	3.16	2.76	2.86	2.81	2.90
9 - 31, 1, 2	4.09	3.68	3.70	3.59	3.77
3, 4	5.17	4.90			5.04
5, 6	3.84	3.42	3.55	3.52	3.58
7, 8, 9	3.26	2.83	3.23	3.24	3.14
10,11	2.47	2.20	1.98	2.30	2.24
12,13	1.38	0.94	1.08	1.18	1.15
14,15,16	2.96	2.62	2.87	2.61	2.77

Table F-10. Turf evapotranspiration - 1979. Values represent average ET in millimeters over the period indicated

Treatment: 33% Solar

Date	37	38	39	40	Ave
7 - 13,14,15	4.00	3.89	4.35	3.74	4.00
16,17	2.17	2.07	2.42	2.19	2.22
18,19	2.43	2.45	2.75	2.38	2.50
20,21.22	3.41	3.20	3.63	3.06	3.33
23,24	2.91	2.78	3.37	3.79	2.96
25,26	3.16	2.89	3.08	2.21	2.84
27,28,29	3.18	3.03	3.18	2.89	3.07
30,31	1.83	1.94	1.92	2.17	1.97
8 - 1, 2	2.56	3.71	3.75	3.56	3.40
3, 4, 5	4.33	4.34	4.34	4.39	4.35
6, 7	3.80	3.82	3.81	3.80	3.81
8,9,10,11,12	2.41	1.25	3.72	3.50	2.72
24,25,26	1.87	1.73	1.95	1.70	1.81
27,28	1.95	1.86	1.95	1.85	1.90
29,30	2.35	2.24	2.46	2.29	2.34
9 - 31, 1, 2	3.19	3.06	3.03	2.94	3.06
3, 4	4.01	3.66			3.83
5, 6	2.85	1.81	2.90	1.80	2.34
7, 8, 9	2.87	3.27	2.83	3.22	3.05
10,11	2.32	1.97	2.42	2.50	2.30
12,13	----	----	----	----	----
14,15,16	2.25	2.08	2.23	2.23	2.20

APPENDIX G CANOPY TEMPERATURE AND LEAF WATER POTENTIAL DATA FROM SOLAR RADIATION ADAPTATION STUDY

Table G-1. Canopy temperature (°C) of grass from solar radiation treatments on two dates. Two of the four lysimeters in each treatment were exposed to full sun on these days. Ambient air temperature is also listed.

Treatment		100% Solar				73% Solar				54% Solar				33% Solar				Ambient Air
Test Level		100%		100%		100%		73%		100%		54%		100%		33%		
Site No.		33	34	35	36	41	42	43	44	45	46	47	48	37	38	39	40	°C
6-24	7:00	11	11	11	11	12	12	12	12	13	13	13	13	12	12	13	12	20
	9:00	26	26	26	26	26	26	23	22	26	26	21	20	26	26	18	18	24
	10:00	27	28	27	28	27	27	25	25	27	25	20	20	27	25	20	20	23
	11:00	28	28	29	29	29	29	26	26	26	27	22	22	28	29	20	20	27
	12:00	28	28	29	28	31	31	27	27	26	27	22	22	31	29	20	20	28
	1:00	29	29	32	32	32	21	26	26	27	29	24	24	32	30	22	21	28
	2:00	29	29	32	32	33	32	30	29	28	29	24	24	30	32	21	21	31
	3:00	28	28	29	29	29	28	25	25	26	27	23	23	29	28	20	20	31
	4:00	26	26	26	26	26	26	24	24	24	26	22	22	25	24	20	20	32
	5:00	24	24	24	24	23	24	23	23	24	26	22	22	24	23	20	20	33
	6:00	20	20	20	20	20	20	19	19	20	21	20	20	20	20	18	18	33
	7:00	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	31
7-24	9:00	26	26	26	26	26	26	24	24	26	26	22	22	26	26	20	20	24
	10:00	29	29	29	29	29	29	26	26	29	29	24	24	29	29	22	22	29
	11:00	32	32	32	32	32	32	30	30	32	32	27	28	32	32	24	24	34
	12:00	32	32	32	32	32	32	30	30	32	32	28	28	32	32	24	24	33
	1:00	19	19	19	19	19	19	19	19	19	19	18	18	19	19	18	18	30
	4:00	29	30	30	30	26	27	26	24	27	27	23	23	26	26	21	22	26

Table G-2. Canopy temperature (°C) of grass from solar radiation treatments on two dates. Two of the four lysimeters in each treatment were exposed to full shade on these days. Ambient air temperature is also listed.

Treatment		100% Solar				73% Solar				54% Solar				33% Solar				Ambient Air
Test Level		100%		0%		73%		0%		54%		0%		33%		0%		
Site No.		33	34	35	36	41	42	43	44	45	46	47	47	37	38	39	40	°C
7-10	9:00	23	24	20	20	22	22	20	20	20	20	20	20	20	20	20	20	24
	10:00	28	28	21	21	26	26	22	22	22	24	22	22	20	20	21	20	27
	11:00	33	31	24	24	30	28	24	22	26	26	23	23	24	24	22	22	30
	12:00	32	32	23	23	26	26	23	23	24	24	23	23	23	23	23	23	31
	1:00	28	28	21	21	25	25	21	21	23	23	21	21	21	21	21	21	32
	2:00	32	32	24	24	28	28	24	24	26	26	24	24	24	24	24	24	33
	3:00	25	25	21	21	22	22	21	21	21	21	21	21	21	21	21	21	32
7-31	9:00	29	29	23	23	29	29	23	23	26	26	23	23	23	23	23	23	29
	10:00	29	29	22	22	26	26	22	22	24	24	22	22	22	22	22	22	30
	11:00	28	28	21	21	24	24	21	21	22	22	21	21	21	21	21	21	32
	12:00	27	27	22	22	24	24	22	22	23	23	22	22	22	22	22	22	31
	1:00	26	26	22	22	24	24	22	22	23	23	22	22	22	22	22	22	32
	2:00	24	24	21	21	22	22	21	21	21	21	21	21	20	20	21	21	33
	3:00	34	34	26	26	31	31	26	26	28	28	26	26	26	26	26	26	34
	4:00	24	24	20	20	22	22	20	20	21	21	20	20	20	20	20	20	33
	5:00	24	24	21	21	22	22	21	21	21	21	21	21	20	20	21	21	32

Table G-3. Leaf Water potential, in negative bars, of grass from solar radiation treatments on two dates. Two of the four lysimeters in each treatment were exposed to full sun on these days. Each value is the average of duplicate determinations.

Treatment		100% Solar				73% Solar				54% Solar				33% Solar			
Test Level		100%		100%		100%		73%		100%		54%		100%		33%	
Site No.		33	34	35	36	41	42	43	44	45	46	47	48	37	38	39	40
6-24	7:00	6.8	5.8	7.5	7.5	7.8	8.2	7.1	7.5	7.1	8.2	8.2	7.5	6.8	5.8	7.1	6.1
	10:00	9.5	8.8	8.5	8.8	8.8	9.2	8.5	8.8	8.2	8.8	9.5	10.2	7.8	7.5	6.5	6.8
	12:00	9.9	9.2	9.5	10.5	8.2	8.5	9.2	9.5	8.5	8.5	8.5	9.2	7.1	9.5	7.5	6.1
	2:00	11.2	9.5	11.6	10.2	10.9	10.5	10.5	10.2	9.5	10.9	9.9	9.9	8.8	9.9	7.5	7.8
	4:00	10.5	10.9	10.5	11.2	8.8	10.2	9.5	9.5	9.5	10.2	9.2	9.5	8.8	9.2	7.1	7.5
	6:00	9.9	9.2	9.9	9.9	9.9	10.2	9.9	9.5	9.2	10.2	9.5	9.2	8.2	9.2	7.5	7.8
	Ave.	9.3		9.6		9.3		9.2		9.1		9.2		8.2		7.1	
7-24	11:00	8.5	7.5	8.5	9.2	8.2	7.8	7.8	7.8	8.2	7.8	7.8	7.1	6.8	7.1	7.1	7.5
	4:00	10.5	9.2	9.2	9.5	10.2	9.9	8.8	9.2	9.9	9.5	9.9	9.2	8.8	8.8	7.8	8.5
	Ave.	9.0		9.2		9.1		8.4		8.9		8.6		7.9		7.7	

Table G-4. Leaf water potential, in negative bars, of grass from solar radiation treatments on two dates. Two of the four lysimeters in each treatment were exposed to full shade on these days. Each value is the average of duplicate determinations

Treatment		100% Solar				73% Solar				54% Solar				33% Solar			
Test Level		100%		0%		73%		0%		54%		0%		33%		0%	
Site No.		33	34	35	36	41	42	43	44	45	46	47	48	37	38	39	40
7-10	9:00	7.5	8.2	7.1	7.8	6.8	7.5	7.8	7.1	7.1	7.1	6.8	6.5	5.1	6.8	6.1	5.4
	11:00	9.5	9.5	7.5	6.8	7.1	7.1	6.8	7.5	7.8	7.1	7.1	6.1	5.1	6.8	5.8	6.8
	1:00	8.8	9.7	8.2	7.8	8.8	8.2	7.8	7.5	8.2	7.8	8.2	6.8	6.5	7.5	6.5	6.8
	Ave.	8.9		7.5		7.6		7.4		7.5		6.8		6.3		6.2	
7-31	11:00	8.8	10.2	9.2	8.5	9.5	8.8	9.2	9.5	9.9	9.5	8.8	8.8	7.1	8.2	7.8	8.2
	1:00	9.9	9.5	8.8	7.1	9.5	9.2	8.8	8.2	9.5	9.5	7.8	8.5	7.1	7.8	8.2	7.5
	3:00	9.9	10.2	9.5	9.5	9.9	9.2	8.8	9.5	9.5	9.5	8.8	9.5	8.8	8.8	8.2	7.8
	5:00	11.2	10.5	9.5	10.5	9.9	10.5	9.9	9.9	11.2	10.2	9.5	10.2	9.2	8.8	8.2	7.8
	Ave.	10.0		9.1		9.6		9.3		9.9		9.0		8.3		8.0	

APPENDIX H ELECTRICAL CONDUCTIVITY

DATA FROM HEAT TOLERANCE TESTS

Table H-1. Electrical Conductivity (E.C.) in mmhos, due to electrolyte leakage, of grass samples from each solar treatment after exposure to increasing temperatures.
R is the ratio of EC for each temperature treatment to EC for the 80°, treatment

		Temperature Treatment (°C)																			
		43		45		47		49		51		53.1		56		58.5		61		80	
Solar Level	Site	EC	R	EC	R	EC	R	EC	R	EC	R	EC	R	EC	R	EC	R	EC	R	EC	R
100%	35	0.09	0.05	0.10	0.06	0.13	0.07	0.18	0.11	0.44	0.25	0.92	0.52	1.35	0.77	1.64	0.93	1.75	0.99	0.76	1.00
	36	0.08	0.04	0.11	0.06	0.12	0.06	0.16	0.08	0.42	0.21	1.03	0.52	1.63	0.82	1.85	0.93	2.00	1.00	2.00	1.00
73%	43	0.10	0.05	0.11	0.05	0.16	0.08	0.22	0.10	0.44	0.21	1.13	0.54	1.56	0.74	1.88	0.90	1.98	0.94	2.10	1.00
	44	0.15	0.06	0.08	0.07	0.21	0.08	0.32	0.13	0.78	0.31	1.50	0.60	2.06	0.83	2.22	0.90	2.48	1.00	2.48	1.00
54%	47	0.14	0.06	0.16	0.05	0.22	0.09	0.28	0.11	0.72	0.29	1.40	0.57	2.28	0.92	2.30	0.93	2.47	1.00	2.47	1.00
	48	0.17	0.08	0.17	0.08	0.21	0.09	----	----	0.59	0.26	1.30	0.58	2.03	0.90	----	----	2.26	1.00	2.26	1.00
33%	40	0.12	0.04	0.14	0.05	0.18	0.07	0.27	0.10	0.55	0.20	1.39	0.51	2.05	0.75	2.25	0.83	2.30	0.85	2.70	1.00

Table H-2. Electrical Conductivity (E.C.) in mmhos, due to electrolyte leakage, of grass samples from each solar treatment after prolonged exposure to high temperature. R is the ratio of EC at 51°C to EC at 80°C.

		Temperature Treatment			
		51°C	80°C		
Solar Treatment	Site	EC	EC	R	Ave.
100%	33	0.39	1.00	0.39	
	34	0.45	1.15	0.39	
	35	0.71	1.46	0.49	
	36	0.63	1.38	0.46	0.43
73%	41	0.72	1.41	0.51	
	42	0.85	1.43	0.59	
	43	0.70	1.42	0.49	
	44	1.00	1.74	0.57	0.54
54%	45	0.76	1.64	0.46	
	46	0.90	1.66	0.54	
	47	0.78	1.68	0.46	
	48	0.85	1.80	0.47	0.48
33%	37	0.88	1.38	0.64	
	38	0.80	1.53	0.52	
	39	0.84	1.49	0.56	
	40	0.76	1.35	0.56	0.57

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