INFLUENCE OF IRRIGATION SCHEDULING ON BERMUDAGRASS AND ZOYSIAGRASS PERFORMANCE DURING THE WARM SEASON

FINAL REPORT

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EXECUTIVE SUMMARY

Southern California receives an average of 10 inches rainfall per year while warm-season turfgrasses require an annual average of up to 45 inches of water (ET_{crop}/DU) to maintain acceptable turfgrass quality and function. Supplemental irrigation is necessary to make up this deficit. Acceptable turfgrass quality and function can be maintained at a deficit level of irrigation, i.e., applying less water than a plant can optimally use, but questions remain as to how this water can be best applied. The objective of this study was to determine if the performance of bermudagrass and zoysiagrass, when irrigated at 60% ET_{crop}/DU (≈51% ET_o) during the warm season, can be improved by altering irrigation frequency.

This study was conducted on a research plot which was sodded in December 1995 with Arizona Common bermudagrass and El Toro zoysiagrass. Soil at this location is classified as a Hanford Fine Sandy Loam. Twelve independently operated irrigation systems, defined as main plots, were split with the two species of turfgrass. Irrigation treatments consisted of applying 60% ET_{crop}/DU (51% ET_o) once, twice, and three times per week - frequencies thought to be common in residential and commercial landscapes. Irrigation frequency treatments were applied from May 7 through September 30, 1997 (146 days) during which time turfgrass performance and soil water content were measured.

Turfgrass performance was evaluated with ratings for visual turfgrass quality and color, percent brown and fired tissue, and percent rolled and wilted leaves within the turfgrass canopy. Clipping yields, clipping water content, relative leaf water content, and leaf water content were also measured on key dates during the study to evaluate turfgrass vigor and tissue water status. Root mass density and crown mass were determined at the end of the study. Soil water content was measured with neutron scattering and Watermark granular matrix sensors installed at various depths within each subplot.

Irrigation frequency treatments had a marginal and mixed effect on plant performance or soil water content. Unfortunately, our ability to test for the positive agronomic benefits associated with less frequent and deeper irrigations was diminished because 60% ET_{crop}/DU (≈ 51% ET_o) was not sufficient irrigation to adequately maintain bermudagrass and zoysiagrass during the warm season in Riverside. Considering this situation, it would be difficult to make conclusions with confidence concerning the effect of irrigation frequency.

However, our data did show that bermudagrass possesses a greater ability than zoysiagrass to extract water from the soil via a well-developed root system, and maintain a higher leaf water content. However, under the conditions of this study, zoysiagrass had acceptable turfgrass visual quality and color and bermudagrass did not, so zoysiagrass probably possesses a greater tissue tolerance to low leaf water contents during drought stress.

BACKGROUND

Fresh water is a particularly precious resource in Southern California where the average annual rainfall is approximately 10 inches. This is insufficient for plant needs, such as warm-season turfgrasses maintained in Riverside which theoretically require (ET_{crop}/DU) or 45.4 inches (80% ET_o) of irrigation water per year assuming: Riverside's historical annual ET_o = 56.7 inches (Goldhamer and Snyder, 1989); average annual crop coefficient (K_c) = 0.6; and DU = 0.75. It should be noted that there should be an opportunity to irrigate with less than ET_{crop}/DU, "deficit irrigation," and successfully maintain good turfgrass quality and function. Increasing demand for water, accentuated by growing urbanization and drought years, has generated a need for conservation and recommendations for landscape water application. While there is justification for landscape water allocation, there is a need to be more efficient with irrigation practices.

Water conservation research at UCR began in 1979 when a field plot facility was developed at the South Coast Research and Extension Center in Irvine, California. The facility was initially planted with six different turfgrass species and was utilized to test them when irrigated one time per week. The three warm-season grasses (hybrid bermudagrass, seashore *Paspalum*, and zoysiagrass) were irrigated at approximately 60, 48, and 36% ET_o, a range which represented both optimal and deficit irrigation conditions. Results from this study revealed that acceptable aesthetic quality could be maintained with less irrigation water than previously thought. 36% ET_o was found to be the lowest level of irrigation at which acceptable quality could be maintained, but no conclusions were made regarding application frequency.

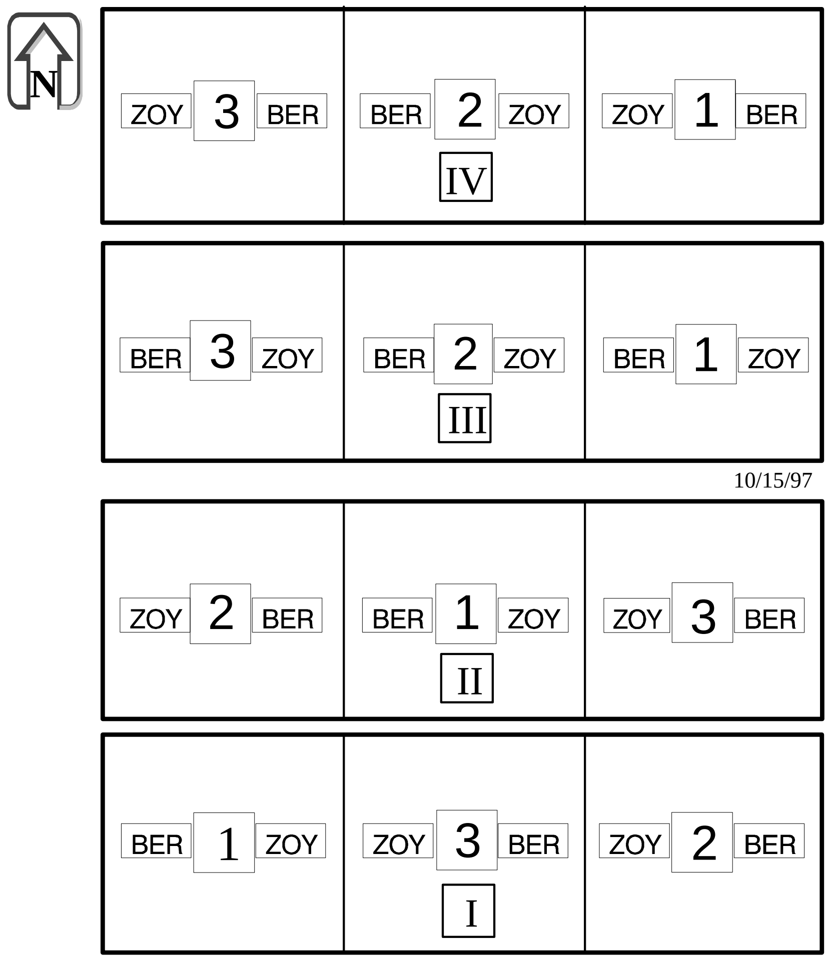
The objective of this study was to determine if the warm-season performance of bermudagrass and zoysiagrass, when irrigated at 60% ET_{crop}/DU ($\approx$ 51% ET_o), can be improved by altering irrigation frequency. In the current study, monthly warm-season turfgrass crop coefficients were used and irrigation levels were adjusted to compensate for irrigation system DU.

MATERIALS AND METHODS

The warm-season performance of two warm-season turfgrasses were evaluated when irrigated at 60% ET_{crop}/DU (an average of 51% ET_o) and applied in three frequencies (one, two, and three times per week) from May 7 to September 30, 1997 (Tables 1 to 4). Arizona Common bermudagrass and El Toro zoysiagrass, were sodded in winter of 1995 onto a special field plot designed to allow individual irrigation control of each of 12 main plots. Care was taken to assure that the root-zone soil of the sod was the same soil type as the field plot. Main plots measured 6.1 m x 6.1 m (20.0 ft x 20.0 ft) and were irrigated with Hunter PGM rotors located at the four corners of each main plot. Main plots are separated by 23-cm (9-inch) borders. Care was taken to maximize the DU of the 12 main-plot irrigation systems by ensuring that head alignment was vertical, and system operating pressures were within the manufacturer's recommended range. The average DU was 0.84 and ranged from 0.81 to 0.87.

Experimental design was a split-plot design with four complete blocks (replications) (Figure 1). Irrigation frequency treatments formed the main plots and genotypes formed subplots and measured 3.0 m x 6.1 m (10.0 x 20.0 ft). Species were separated by 23-cm (9-inch) borders.

Figure 1. Plot layout of 1997 Bermudagrass/Zoysiagrass Irrigation Frequency Study



Irrigation Treatments: 1=1x/wk 2 = 2x/wk 3 = 3x/wk
ZOY= Zoysiagrass BER= Bermudagrass
Total Irrigation/week=ETo x monthly Kc x 0.6 /DU ≈ 51% ETo

The plots were fertilized biweekly at a rate of 24 kg N/ ha per month (0.5 lb N/1000 ft^2 per month) with a 16N-6P_2O_5-8K_2O granular fertilizer starting April 25, 1997 and continuing through the study. Plots were mowed on Tuesday and Friday with a walk-behind seven-blade McClane reel mower starting March, 1997. Height of cut was set at 19 mm (0.75 inch).

Routine maintenance included checking irrigation systems biweekly for proper operation, edging plots with roundup to prevent overgrowth and contamination between subplots, and hand weeding as necessary. In April 1997, zoysiagrass plots were vertical mowed (verticut) with six passes to reduce thatch, and the alleys were topdressed with field soil to level and smooth the surface.

Irrigation treatments were applied from May 7 to September 30, 1997. An equivalent amount of water was applied to each main plot and was calculated from the previous week's (7 day) ET_o accumulation which was determined from a CIMIS station located 85 m from the plot. Irrigation quantity (mm) for each main plot was calculated as:

Weekly irrigation quantity (mm) = (ET_o x monthly warm-season K_c x 0.6) / distribution uniformity.

Weekly irrigation quantity was multiplied by each plot's precipitation rate to determine irrigation run times. Catch can tests were conducted April 21 to May 5 to determine DU and application rates of each main plot. Weekly irrigation quantity was applied in three frequencies or main-plot treatments (one, two, and three times per week). Irrigation events were cycled to keep run times less than 12 minutes, thus avoiding run off.

Data collection

Visual turfgrass ratings were taken between May 22 and September 19, 1997. Visual turfgrass quality was rated every 3 weeks on a 1 to 9 scale with 1 = poorest and 9 = best turfgrass. A rating of 5 was considered minimally acceptable visual turfgrass quality. Visual turfgrass quality ratings are a composite of turfgrass density, texture, uniformity, color, growth habit, and smoothness. Visual turfgrass color was rated every 3 weeks on a 1 to 9 scale with 1 = poorest (brown) and 9 = best (dark green) turfgrass color. A rating of 5 was considered minimally acceptable visual turfgrass color. Ratings for percent brown and fired tissue, and percent rolled and wilted leaves within the turfgrass canopy were measured concurrently with visual quality ratings. These ratings were taken on a 1 to 100% of the total plot surface area.

Turfgrass clipping yields were collected three times during the 1997 season (May 20, July 15, Sept. 23) on weeks between fertilizer applications. Clippings were collected using a seven-blade McClane reel mower from an area representing 16.3% of the total subplot surface area (32.5 ft^2/200.0 ft^2). Clipping yields were always taken on Tuesday and represented growth since the previous Friday's mowing (4 days growth). Fresh and dry weights were recorded and provided measures of clipping water content (fresh weight – dry weight/dry weight) and dry weight yield. After the samples were weighed for fresh weight they were dried in a forced air oven (60 C) for 48 hr. Clipping yield provides a simple, yet accurate measure of turfgrass vigor along with drought stress. Three times during the season (July 1, Aug. 13, Sept. 9) samples were collected for relative leaf water content (RLWC), a measurement of turfgrass leaf water status. Approximately 10 fully expanded, nonsenescent, representative leaves were cut with scissors. Two subsamples were harvested from representative areas within each subplot. RLWC samples were collected between 10:30 am and 12:00 noon, immediately placed in small plastic petri dishes within a cooler, and subsequently weighed in the laboratory for fresh weights. Petri dishes were then filled with distilled water and placed in a refrigerator (4.4 C) for 12 to 16 hr. The water was then decanted and leaves blotted dry and weighed for rehydrated weights. Leaf tissue was then dried for 48 hr at 60 C and dry weights recorded. RLWC was calculated as (fresh weight - dry weight) / (rehydrated weight-dry weight) x 100. RLWC methodology was developed from papers by Hook et al. (1992) and Benett (1990). Leaf water content was also calculated as (fresh weight – dry weight)/dry weight.

Irrigation treatments were concluded on September 26, 1997. All plots were irrigated to field capacity over the next month and on October 31, soil sampling began for root and crown mass analysis. Four cores from representative areas within each subplot were taken with a Giddings Machine Co. hydraulic sampling rig mounted on a three-wheeled, self-propelled trailer. Cores, 4.13-cm (1.6-inch) diameter x 1.2-m (4.0-ft) deep were taken from zoysiagrass subplots and cores, 4.13-cm diameter x 1.8-m (6.0-ft) deep, were taken from bermudagrass plots. Zoysiagrass cores were taken in one sampling, measured for length, then divided equally into four segments. It should be noted that the depth of each hole was 4.0 ft. Segments were placed in 1-gallon, labeled ziploc bags and placed into a freezer (-15.6 C) for later analysis. Bermudagrass cores were taken in two samplings, 0- to 4.0-ft. deep and 4.0- to 6.0-ft deep. These cores were also measured for length, divided into four and two equal segments, respectively, and placed in bags for freezing. It should be noted that the depth of each hole was 4.0 ft following the first sampling and 6.0 ft following the second sampling. Surface segments included the crown tissue.

Soil samples were thawed, mixed with water within ziploc bags, then poured into an elutriation system. Air and water were slowly bubbled through the soil slurry. Roots floated to the top of the elutriation chamber and were decanted into a 250 µm USA standard testing sieve (No. 60). Remaining soil and organic matter particles were washed from the roots, and roots were then placed in small plastic vials for drying (forced draft oven, 60 C, 48 hr) and weighing. Roots were cut from crowns at the root/rhizome interface, and crowns placed in small paper bags for drying. Roots and crowns were weighed and dry mass recorded. Root dry mass was divided by core sample volume for each 1-ft depth zone (4.13 cm diameter, 30.5 cm long = 408.3 cm^3 sample volume). Resulting numbers equaled root mass density, i.e., mg dry weight of roots per cm^3 soil.

Soil water content levels were monitored in each subplot by two methods. Watermark granular matrix sensors installed at 30- and 60-cm (12- and 24-inch) depths measured soil water tension (centibars) differences due to irrigation frequency treatments. Sensors were installed in individual 2.5-cm (1-inch) diameter holes located approximately 20 cm (8 inches) south of neutron scattering access tubes (each subplot contained two Watermark sensors and one neutron scattering access tube). Care was taken during installation to ensure good soil-sensor contact. Sensors were read Wednesday and Thursday (before and after all treatments irrigated) from remote terminals (Watermark Remote Readers, Irrometer Co., Riverside, CA) installed in the center of the study area.

Volumetric soil water content ((cm^3 H_2O/cm^3 soil) x 100) was measured by neutron scattering (Boart Longyear CPN 503 DR Hydroprobe) in plot centers at 30-, 60-, 90-, 120-, 150-, and 180-cm depths (12-, 24-, 36-, 48-, 60-, and 72-inch depths). The neutron probe was lowered into 5-cm (2-inch) diameter CL200 PVC access tubes which were installed in February, 1997. A calibration curve relating neutron counts to volumetric soil water content was developed in spring, 1998. Undisturbed soil cores were extracted at 30.5-cm (12-inch) increments to a depth of 180 cm (72 inches). 39 Soil cores of known volume were extracted from the Tall Fescue Water Banking plot, the Southwest Consortium Bermudagrass plot, and the Warm-Season Irrigation Frequency plot. The cores were dried at 105 C (221 F) for 48 hr and weighed for gravimetric water content (g H_2O/g soil)and bulk density (g soil/cm^3 soil). Multiplied together, these numbers equaled volumetric water content. Volumetric soil water content was regressed against neutron probe counts and a regression equation of volumetric soil water content vs. count ratio developed for subsequent calculations. The resulting equation was:

$$\text{Volumetric soil water content} = (36.379 * \text{count ratio}) - 12.927;\ R^2 = 0.90.$$

Statistical Analyses

Data were subjected to a split-plot analysis of variance (ANOVA) with a general linear model procedure. Irrigation frequency constituted main plots and species formed subplots. Treatment means separations were conducted using a Fischer's protected LSD procedure. ANOVA was also performed by species as a randomized complete block (RCB) design with Fischer's protected LSD means separations. Watermark and neutron probe data also were subjected to a repeated-measures ANOVA (split-split plot design for split-plot ANOVA, and split-plot design for RCB ANOVA) and Fischer's protected LSD means separations.

Table 1. Materials and methods outline for the 1997 bermudagrass and zoysiagrass irrigation frequency study.

Objective:	To determine if the warm-season performance of bermudagrass and zoysiagrass, when irrigated at 60% ET_{crop}/DU (≈51% ET_o), can be improved by altering irrigation frequency.
Genotypes:	Arizona Common bermudagrass and El Toro zoysiagrass.
Location and root zone:	Block 12 E, plot No. 14, UCR Turfgrass Field Research Facility. Root zone soil is a well-drained native alluvial soil classified as a Hanford fine sandy loam with a sand, silt, and clay content of approximately 42, 43, and 15 %, respectively. Further soil characteristics are as follows: pH = 7.1; CEC = 16.5 meq/100 g soil; OM = 2.14%; SAR = 2.
Experimental Design:	Split-plot design with four blocks (replications). Irrigation treatments form the main plots which are 20.0 ft x 20.0 ft. Species form subplots which are 10.0 ft x 20.0 ft. Subplots and blocks are separated with a 9-inch border.
Fertilization:	16N-6P_2O_5-8K_2O granular fertilizer, 0.5 lb N/1000 ft^2 applied every 3 weeks during establishment, and 0.5 lb N/1000 ft^2 per month applied biweekly during the study.
Mowing:	Mowed Tuesday and Friday with a walk-behind, 20-inch, seven-blade McClane reel mower with clippings collected during the study. Height of cut set at 0.75 inch.
General Maintenance:	Irrigation systems checked biweekly for proper operation. Monthly edging with Roundup (2% glyphosate). Vertical mowing in early spring, six directions, zoysiagrass plots only. Hand weeding as necessary. Oxalis controlled with ammonium thiosulfate (Oxalis X). Aisles and plots leveled with field soil as needed.
Irrigation Treatments:	An equivalent amount of water is applied to each experimental plot, and is calculated from the previous week's ET_o (from CIMIS) x monthly warm-season turfgrass crop coefficient (K_c) x 0.6. This value is multiplied by each plot's precipitation rate and divided by the respective distribution uniformity (DU). Irrigation is applied in three frequencies or main treatments (one, two, and three times per week) and irrigation events are cycled to keep individual run times less than 12 minutes. All treatments irrigate Thursday morning.

Measurements: **Turfgrass visual ratings:**

- Visual turfgrass quality measured on a 1 to 9 scale with 1 = poorest and 9 = best turfgrass. A rating of 5 would constitute minimum acceptable quality. Visual turfgrass quality ratings are a composite of turfgrass density, texture, uniformity, color, growth habit, and smoothness.

-Visual turfgrass color measured on a 1 to 9 scale with 1 = brown and 9 = best dark green turfgrass color. A rating of 5 would constitute minimum acceptable color.

-% brown and fired leaf tissue. Scale is 1 to 100% of total plot surface area.

-% rolled and wilted leaf tissue. Scale is 1 to 100% of total plot surface area affected.

All visual ratings are taken every third Friday.

Other Plant Measurements:

- Clipping yields measured in May, July, and September and collected on weeks between fertilizer applications. Clippings are collected from an area representing 16.3% of the subplot surface area.

-Clipping water content (measured concurrently with clipping yields (fresh weight-dry weight/dry weight).

- Relative leaf water content (RLWC) measured three times during the season. Sampling is conducted between 11:00 am and 12:00 noon each day (after dew has evaporated). Ten to 12 fully expanded, nonsenescent, representative leaves were cut with scissors. Two subsamples were harvested from representative areas within each subplot. Leaves are immediately placed in small plastic petri dishes within a cooler, and subsequently weighed in the laboratory for fresh weights. Petri dishes were then filled with distilled water and placed in a refrigerator (4.4 C) for 12 to 16 hr. Water was then decanted and leaves blotted dry and weighed for rehydrated weights. Leaf tissue was then dried in a forced draft oven maintained at 60 C for 48 hr and dry weights recorded. RLWC was calculated as (fresh weight - dry weight) / (rehydrated weight-dry weight) x 100. *Leaf water content* was also calculated from these samples as (fresh weight – dry weight)/dry weight.

- Root and crown mass: Four cores from representative areas within each subplot were taken with a Giddings Machine Co.

hydraulic sampling rig mounted on a three-wheeled self-propelled trailer. 4.13-cm (1.6-inch) x 1.2-m (4.0-ft) cores were taken from zoysiagrass subplots and 4.13-cm x 1.8-m (6.0-ft) cores were taken from bermudagrass subplots. Zoysiagrass cores were taken in one sampling, measured for length, then divided equally into four segments. It should be noted that the depth of each hole was 4.0 ft. Segments were placed in 1-gallon labeled ziploc bags and frozen (-15.6 C) for later analysis. Bermudagrass cores were taken in two samplings - a 4.0-ft and a 2.0-ft sampling. These cores were also measured for length, divided into four and two equal segments, respectively, and placed in bags for freezing. It should be noted that the depth of each hole was 4.0 ft following the first sampling and 6.0 ft following the second sampling. Surface segments included the crown tissue. Soil samples were thawed, mixed with water within ziploc bags, then poured into an elutriation system. Air and water were slowly bubbled through the soil slurry. Roots floated to the top of the elutriation chamber and were decanted into a 250 µm USA standard testing sieve (No. 60). Remaining soil and organic matter particles were washed from the roots, and roots were then placed in small plastic vials for drying (forced draft oven, 60 C, 48 hr) and weighing. Roots were cut from crowns at the root/rhizome interface, and crowns placed in small paper bags for drying. Roots and crowns were weighed and dry mass recorded.

Soil Water Content

- Soil water tension at 12- and 24-inch depths using Watermark granular matrix sensors connected to remote readers at the plot center. Sensors are located in each subplot (24 locations) and are read weekly on Wednesday and Thursday (before and after irrigation).

- Volumetric soil water content is measured with neutron scattering to a 6.0-ft (1.8-m) depth (readings are taken at each of 9-, 12-, 24-, 36-, 48-, 60-, and 72-inch depths) in each bermudagrass and zoysiagrass subplot (24 locations). Readings are taken pre-irrigation (Wednesday) once every 2 weeks. The calibration curve relating count ratio to volumetric soil water content is derived from 39 soil samples extracted from the Tall Fescue Water Banking plot, the Southwest Consortium Bermudagrass plot, and the Bermudagrass/Zoysiagrass Irrigation Frequency plots. The soil classification from each plot is the same and is considered to have equivalent ratios of sand, silt, clay, and organic matter. The equation is:
Volumetric soil water content ((cm^3 H_2O/cm^3 soil) x 100) =
(36.379 * count ratio) - 12.927. $R^2 = 0.90$

Statistical Analyses of Measurements: Data were subjected to a split-plot analysis of variance (ANOVA) with a general linear model procedure. Irrigation frequency constituted main plots and species formed subplots. Treatment means separations were conducted using a Fischer's protected LSD procedure. ANOVA was also performed by species as a randomized complete block (RCB) design with Fischer's protected LSD means separations. Watermark and neutron probe data also were subjected to a repeated-measures ANOVA (split-split plot design for split-plot ANOVA, and split-plot design for RCB ANOVA) and Fischer's protected LSD means separations.

Table 2. Weekly calendar of events for 1997 bermudagrass and zoysiagrass irrigation frequency study.

<u>Monday</u> Treatment 2 Treatment 3	<u>Tuesday</u> Mowing Clipping yields RLWC sampling	<u>Wednesday</u> Program Controller Neutron Probe readings Read Watermark Sensors Fertilization (16N-6P_2O_5-8K_2O) 0.25 lb N/1000 ft^2/2 weeks
<u>Thursday</u> Treatments 1,2,3 Read Watermark Sensors Neutron Probe (periodically)	<u>Friday</u> Mowing Data Entry Color, Quality, Leaf rolling and wilting, % brown ratings	<u>Saturday</u> Treatment 3

Research Activity Assignment	
Watermark Readings (Akil) Neutron Probe Readings (Akil; once/3wk) Visual Ratings (Bill; once/3wk) Clipping Yields, RLWC (Bill, Akil, Francisco, Eliseo)	Program Controller (Bill) Irrigation Maintenance (biweekly; Bill, Akil) Mowing (Akil) Weed Control, Roundup in aisles as needed Fertilization (biweekly; Akil) Data Entry (Bill, Akil)

Table 3. Monthly warm-season turfgrass crop coefficients used for weekly irrigation scheduling.

Month	Monthly Warm-season Turfgrass Crop Coefficient
May	0.79
June	0.68
July	0.71
August	0.71
September	0.62

Table 4. Calendar of Events for the 1997 bermudagrass and zoysiagrass irrigation frequency study plus the 1995 and 1996 plot history.

Date	1995 Activity
Summer:	Installation of 12 irrigation systems and research plot preparation.
Dec. 7 - 14:	Establishment from sod. Bermudagrass and zoysiagrass sod cut from adjacent plots.
	1996 Activity
March 1:	Initiate biweekly mowing with seven- blade reel mower; cutting ht. = 0.75 inch.
March 4:	Begin field soil topdressing program, installation of Hunter PGM heads. Initiate 0.5 lb N/1000 ft^2 (16N-6P_2O_5-8K_2O) applied every 3 weeks. Begin biweekly rolling program with a 630-lb roller.
March - June 7:	Continue field soil topdressing program (1 wheel-barrow load per sub-plot).
June 24:	Begin Watermark sensor installation.
June 31:	Change fertility regime to 0.5 lb N/1000ft^2 per month applied every other week (0.25 lb N/1000ft^2 per app.) using 16N-6P_2O_5-8K_2O fertilizer.
July 1:	Adjust irrigation to apply 100% July historical ET_o in four irrigation events/week.
July 15 – 19:	Insure proper operation of all systems, can tests.
July 25:	Initiate irrigation treatments (80% ET_{crop}/DU (≈57% ET_o) applied two and four times per week).
July 25 - Oct. 25:	Program irrigation controller weekly, check system operation bi-weekly, record plant response and soil moisture (Watermark) data.
November 6:	1996 study conclusion (103 days)
	1997 Activities
February:	Neutron probe access tube installation and initial calibration.
February 14:	Green-up fertilizer (6N-20P_2O_5-20K_2O, 1 lb N/1000ft^2).

March 18:	Begin biweekly mowing; 0.75-inch ht. of cut.
April 10:	Verticut zoysiagrass plots, six passes, three directions.
April 21-May 5:	Check vertical of heads, operation, catch can tests for application rate and DU of all irrigation systems.
April 25:	Begin study fertility program (0.25 lb N/1000 ft^2 per bimonthly application; Rate = 0.5 lb N/1000 ft^2 per month).
April 30:	Start of 7-day ET_o accumulation for May 7 program date.
May 7:	Initiate irrigation treatments, first program date.
May 7-Sept. 30:	Apply irrigation treatments, biweekly mowing and plot maintenance, collect plant and soil measurements according to protocol.
September 30:	Terminate 1997 data collection period.
October 31:	Begin crown and root mass core sampling.
November 20:	Conclude root core sampling.
December:	Start root elutriation, sample analysis, neutron probe calibration.

1998 Activity

May:	Finish root elutriation, sample analysis, neutron probe calibration.
August:	Begin Final Report for 1997 study.
December:	Complete Final Report for 1997 study.

8/12/98

RESULTS AND DISCUSSION

Irrigation application

Irrigation frequency treatments were applied from may 7 through September 30, 1997 (146 days), during which time a 12-plot average 410 mm net irrigation was applied according to: ET_o x monthly K_c x 0.6/DU for each individual irrigation system. The ET_o from the adjacent CIMIS station for this period was 803.5 mm. Thus, the 12-plot average experimental irrigation amount was 51% ET_o.

Turfgrass Performance

The data concerning the effect of irrigation frequency treatments on turfgrass performance was mixed. One irrigation event/week compared to three irrigation events/week resulted in: more bermudagrass visual turfgrass color on two of eight dates (Table 6); more zoysiagrass clipping yields (Table 9); lower zoysiagrass relative leaf water content (Table 11); and lower bermudagrass and zoysiagrass leaf water content on one of three dates (Table 12).

Irrigation frequency treatments did not affect: bermudagrass and zoysiagrass visual turfgrass quality (Table 5); zoysiagrass visual turfgrass color (Table 6); bermudagrass and zoysiagrass percent brown leaves (Table 7) and percent leaves rolled and wilted (Table 8); bermudagrass clipping yield (Table 9); bermudagrass and zoysiagrass clipping water content (Table 10); and bermudagrass relative leaf water content (Table 11).

The data concerning the effect of turfgrass species on turfgrass performance also was mixed. Zoysiagrass had acceptable visual turfgrass quality and color (rating $\geq$ 5.5) and bermudagrass did not (Tables 5 and 6). Zoysiagrass had more leaves rolled and wilted than bermudagrass (Table 8) and bermudagrass had more clipping yield (Table 9), higher clipping water content (Table 10), higher relative leaf water content (Table 11), higher leaf water content (Table 12), and a greater root mass density along with deeper rooting (Table 13).

Soil Water Content

Data concerning the effect of irrigation frequency soil water tension showed that soil at the 12-inch depth was drier (higher Watermark readings) for the three irrigation events/week treatment than the one irrigation event/week treatment on several dates and for the overall, season mean soil water tension (Tables 14 and 16). However, the irrigation frequency treatments generally did not affect soil water tension at the 24-inch depth (Table 15). It should be noted that the 12-plot average experimental irrigation amount of 51% ET_o did caused the soil to become drier as the 146-day study progressed during the warm season (Tables 14 and 15). It also should be noted that soil water tension values greater than 80 to 100 centibars are normally considered dry for turfgrasses.

The data concerning the effect of turfgrass species on soil water tension showed that bermudagrass caused the soil to be drier at the 24-inch depth than zoysiagrass on numerous dates (Table 15 only shows the statistical effect of species). The overall, season-mean soil water tension at the 24-inch depth for bermudagrass and zoysiagrass showed a nonsignificant trend of bermudagrass causing the soil at the 24-inch depth to be drier than zoysiagrass (Table 17). Turfgrass species generally did not affect the soil water tension at the 12-inch depth (Table 14).

Soil water tension data for bermudagrass and zoysiagrass are consistent with root-mass density data (Table 13). That is, bermudagrass had greater root mass density than zoysiagrass for all depths deeper than 12 inches. If root mass density is (+) associated with soil water extraction, then drier soil for bermudagrass at the 24-inch depth but not the 12-inch depth would be expected, and that is what was observed.

Data concerning the effect of irrigation frequency treatments on volumetric soil water content showed there was generally no effect at all depths which ranged from 12 inches to 72 inches (Tables 18 to 23).

Data concerning the effect of turfgrass species on volumetric water content showed that bermudagrass caused the soil to be drier on numerous dates at the 24-, 36-, and 72-inch depths. These data are consistent with root mass density data and presumed soil water extraction.

Conclusions

Irrigation frequency treatments had a marginal and mixed effect on plant performance or soil water content. Unfortunately, our ability to test for the positive agronomic benefits associated with less frequent and deeper irrigations was diminished because 60% ET_{crop}/DU (≈ 51% ET_o) was not sufficient irrigation to maintain quality bermudagrass and zoysiagrass during the warm-season in Riverside. Considering this situation, it would be difficult to make conclusions with confidence concerning the effect of irrigation frequency.

However, our data does show that bermudagrass possesses a greater ability than zoysiagrass to extract water from the soil via a well-developed root system, and maintain a higher leaf water content. However, under the conditions of this study, zoysiagrass had acceptable turfgrass visual quality and color and bermudagrass did not, so zoysiagrass probably possesses a greater tissue tolerance to low leaf water contents during drought stress.

ACKNOWLEDGMENT

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Table 5. Bermudagrass and zoysiagrass visual turfgrass quality ratings (1 to 9 scale).

Visual turfgrass quality of bermudagrass and zoysiagrass averaged over irrigation treatments

Species	May 22	June 6	June 20	June 27	July 18	Aug 8	Aug 29	Sept 19
Bermuda	5.9	6.4	5.7	5.5	5.1	4.9	4.6	4.8
Zoysia	7.5	7.0	6.4	6.4	6.1	5.4	5.9	6.1
LSD $P \leq 0.05$	0.2	0.2	0.1	0.2	0.4	NS	0.7	0.8

Bermudagrass visual turfgrass quality for three irrigation treatments

Irrigation frequency	May 22	June 6	June 20	June 27	July 18	Aug 8	Aug 29	Sept 19
1x/wk	5.9	6.4	5.6	5.4	5.1	5.0	4.9	4.8
2x/wk	5.8	6.3	5.8	5.6	5.3	5.1	4.8	5.0
3x/wk	6.1	6.4	5.7	5.4	5.0	4.6	4.1	4.5
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Zoysiagrass visual turfgrass quality for three irrigation treatments

Irrigation frequency	May 22	June 6	June 20	June 27	July 18	Aug 8	Aug 29	Sept 19
1x/wk	7.5	7.0	6.5	6.5	6.3	5.6	5.9	5.9
2x/wk	7.5	7.0	6.4	6.4	6.1	5.5	6.1	6.1
3x/wk	7.5	7.0	6.3	6.4	6.0	5.1	5.7	6.4
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Visual turfgrass quality split-plot effects

Effect	May 22	June 6	June 20	June 27	July 18	Aug 8	Aug 29	Sept 19
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS
Species	***	***	***	***	***	NS	**	**
Irr. x Species	NS	NS	NS	NS	NS	NS	NS	NS

*,**,***,NS: Significant at P≤ 0.05, 0.01, 0.001 and nonsignificant, respectively.

Table 6. 1997 Bermudagrass and zoysiagrass visual turfgrass color ratings (1 to 9).

Visual turfgrass color of bermudagrass and zoysiagrass averaged over irrigation treatments

Species	May 22	June 6	June 20	June 27	July 18	Aug 8	Aug 29	Sept 19
Bermuda	6.5	6.5	5.6	5.7	5.1	5.1	4.6	5.0
Zoysia	7.5	7.0	6.2	6.1	5.6	5.0	5.6	6.0
LSD $P \leq 0.05$	0	0.1	0.1	0.3	0.4	NS	0.4	0.5

Visual turfgrass color of three irrigation treatments averaged over turfgrass species

Irrigation frequency	May 22	June 6	June 20	June 27	July 18	Aug 8	Aug 29	Sept 19
1x/wk	7.0	6.7	5.9	5.8	5.4	5.3	5.3	5.4
2x/wk	7.0	6.7	5.9	5.9	5.5	5.3	5.4	5.7
3x/wk	7.0	6.8	5.8	5.9	5.3	4.5	4.7	5.4
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	0.3	0.2

Bermudagrass visual turfgrass color for three irrigation treatments

Irrigation Frequency	May 22	June 6	June 20	June 27	July 18	Aug 8	Aug 29	Sept 19
1x/wk	6.5	6.5	5.6	5.7	5.0	5.4	5.0	5.1
2x/wk	6.5	6.4	5.6	5.8	5.3	5.4	4.9	5.3
3x/wk	6.5	6.5	5.6	5.7	5.1	4.5	4.0	4.6
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	0.7	0.5	NS

Note: Separate RCB ANOVA for each date.

Zoysiagrass visual turfgrass color for three irrigation treatments

Irrigation frequency	May 22	June 6	June 20	June 27	July 18	Aug 8	Aug 29	Sept 19
1x/wk	7.5	6.9	6.3	6.0	5.8	5.3	5.5	5.8
2x/wk	7.5	7.0	6.2	6.1	5.7	5.3	6.0	6.1
3x/wk	7.5	7.0	6.1	6.1	5.4	4.5	5.4	6.1
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Visual turfgrass color split-plot effects

Effect	May 22	June 6	June 20	June 27	July 18	Aug 8	Aug 29	Sept 19
Irrigation	NS	NS	NS	NS	NS	NS	**	*
Species	***	***	***	*	**	NS	***	**
Irr. x Spec	NS	NS	NS	NS	NS	NS	NS	NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001 and nonsignificant, respectively.

Table 7. Bermudagrass and zoysiagrass ratings for percent brown and fired leaves.

Percent brown leaves of bermudagrass and zoysiagrass averaged over irrigation treatments

Species	July 21	August 8	August 29	Sept 19
Bermuda	31	60	59	50
Zoysia	44	60	38	45
LSD $P \leq 0.05$	10	NS	9	NS

Bermudagrass percent brown leaves ratings for three irrigation treatments

Irrigation frequency	July 21	August 8	August 29	Sept 19
1x/wk	25	51	55	50
2x/wk	35	50	55	40
3x/wk	33	78	68	59
LSD $P \leq 0.05$	NS	NS	10	NS

Note: Separate RCB ANOVA for each date.

Zoysiagrass percent brown leaves ratings for three irrigation treatments

Irrigation frequency	July 21	August 8	August 29	Sept 19
1x/wk	34	48	36	53
2x/wk	50	61	34	38
3x/wk	48	73	45	45
LSD $P \leq 0.05$	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Percent brown leaves ratings split-plot effects

Effect	July 21	August 8	August 29	Sept 19
Irrigation	NS	NS	NS	NS
Species	**	NS	***	NS
Irr. x Species	NS	NS	NS	NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001 and nonsignificant, respectively.

Table 8. Bermudagrass and zoysiagrass ratings for percent leaves rolled and wilted.

Percent leaves rolled and/or wilted of bermudagrass and zoysiagrass averaged over three irrigation treatments

Species	July 23	Sept 3	Sept 23
Bermuda	52	48	84
Zoysia	70	75	100
LSD $P \leq 0.05$	16	14	3

Bermudagrass percent leaves rolled and/or wilted for three irrigation treatments

Irrigation frequency	July 23	Sept 3	Sept 23
1x/wk	58	55	85
2x/wk	39	28	79
3x/wk	60	63	88
LSD $P \leq 0.05$	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Zoysiagrass percent leaves rolled and/or wilted for three irrigation treatments

Irrigation frequency	July 23	Sept 3	Sept 23
1x/wk	96	91	100
2x/wk	49	60	99
3x/wk	65	74	100
LSD $P \leq 0.05$	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Split-plot effects for percent leaves rolled and/or wilted

Effect	July 23	Sept 3	Sept 23
Irrigation	NS	NS	NS
Species	*	**	***
Irr. * Spec	NS	NS	NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001 and nonsignificant, respectively.

Table 9. Bermudagrass and zoysiagrass clipping yield summary: dry weight (g/32.50 ft^2) per 4 days.

Clipping yield of bermudagrass and zoysiagrass averaged over irrigation treatments

Species	May 20	July 15	Sept 23
Bermuda	50	25	20
Zoysia	27	12	12
LSD $P \leq 0.05$	5	4	4

Clipping yield of three irrigation treatments, averaged over turfgrass species

Irrigation	May 20	July 15	Sept 23
1x/wk	37	24	20
2x/wk	41	14	15
3x/wk	38	18	14
LSD $P \leq 0.05$	NS	7	5

Bermudagrass clipping yield for three irrigation treatments

Irrigation frequency	May 20	July 15	Sept 23
1x/wk	51	27	24
2x/wk	52	21	19
3x/wk	48	28	18
LSD $P \leq 0.05$	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Zoysiagrass clipping yield for three irrigation treatments

Irrigation frequency	May 20	July 15	Sept 23
1x/wk	24	21	16
2x/wk	30	7	10
3x/wk	28	8	10
LSD $P \leq 0.05$	NS	7	4

Note: Separate RCB ANOVA for each date.

Clipping yield split-plot effects

Effect	May 20	July 15	Sept 23
Irrigation	NS	*	*
Species	***	***	***
Irr. x Species	NS	NS	NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001, and non-significant, respectively.

Table 10. Bermudagrass and zoysiagrass clipping water content (Fresh Weight – Dry Weight)/Dry Weight.

Clipping water content of bermudagrass and zoysiagrass averaged over three irrigation treatments

Species	May 20	July 15	Sept 23
Bermuda	2.3	1.2	0.3
Zoysia	1.6	0.6	0.1
LSD $P \leq 0.05$	0.2	0.3	0.1

Bermudagrass clipping water content for three irrigation treatments

Irrigation frequency	May 20	July 15	Sept 23
1x/wk	2.3	1.2	0.3
2x/wk	2.4	1.2	0.3
3x/wk	2.2	1.3	0.3
LSD $P \leq 0.05$	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Bermudagrass clipping water content for three irrigation treatments

Irrigation frequency	May 20	July 15	Sept 23
1x/wk	1.5	0.6	0.1
2x/wk	1.7	0.4	0.1
3x/wk	1.6	0.8	0.1
LSD $P \leq 0.05$	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Clipping water content split-plot effects

Effect	May 20	July 15	Sept 23
Irrigation	NS	NS	NS
Species	**	**	***
Irr. x Species	NS	NS	NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001, and nonsignificant, respectively.

Table 11. Bermudagrass and zoysiagrass relative leaf water content (RLWC) (Fresh Weight – Dry Weight/Rehydrated Weight – Dry Weight).

RLWC for bermudagrass and zoysiagrass averaged over three irrigation treatments

Species	July 1	August 13	Sept 9
Bermuda	91	82	80
Zoysia	86	76	73
LSD $P \leq 0.05$	3	4	6

RLWC of three irrigation treatments, averaged over turfgrass species

Irrigation frequency	July 1	August 13	Sept 9
1x/wk	85	77	67
2x/wk	88	75	83
3x/wk	91	85	80
LSD $P \leq 0.05$	NS	6	11

Bermudagrass RLWC for three irrigation treatments

Irrigation frequency	July 1	August 13	Sept 9
1x/wk	92	82	78
2x/wk	89	78	84
3x/wk	91	85	78
LSD $P \leq 0.05$	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Zoysiagrass RLWC for three irrigation treatments

Irrigation frequency	July 1	August 13	Sept 9
1x/wk	79	71	56
2x/wk	88	72	82
3x/wk	90	86	81
LSD $P \leq 0.05$	5	9	8

Note: Separate RCB ANOVA for each date.

RLWC Split-Plot Effects

Effect	July 1	August 13	Sept 9
Irrigation	NS	*	*
Species	***	*	*
Irr. x Species	***	NS	**

*,**,***,NS: Significant at P≤0.05, 0.01, 0.001, and non- significant, respectively.

Table 12. Bermudagrass and zoysiagrass leaf water content (Fresh Weight – Dry Weight/Dry Weight) from RLWC sampling.

Leaf water content of bermudagrass and zoysiagrass averaged over three irrigation treatments

Species	July 1	August 13	Sept 9
Bermuda	1.9	1.9	1.7
Zoysia	1.5	1.3	1.1
LSD $P \leq 0.05$	0.1	0.1	0.2

Leaf water contents of three irrigation treatments averaged over turfgrass species

Irrigation frequency	July 1	August 13	Sept 9
1x/wk	1.6	1.6	1.3
2x/wk	1.7	1.4	1.4
3x/wk	1.8	1.8	1.5
LSD $P \leq 0.05$	NS	0.1	NS

Bermudagrass leaf water content for three irrigation treatments

Irrigation frequency	July 1	August 13	Sept 9
1x/wk	1.9	1.9	1.6
2x/wk	1.9	1.6	1.6
3x/wk	1.9	2.1	1.8
LSD $P \leq 0.05$	NS	0.3	NS

Note: Separate RCB ANOVA for each date.

Zoysiagrass leaf water content for three irrigation treatments

Irrigation frequency	July 1	August 13	Sept 9
1x/wk	1.4	1.2	1.0
2x/wk	1.5	1.3	1.2
3x/wk	1.6	1.4	1.2
LSD $P \leq 0.05$	0.1	0.2	0.2

Note: Separate RCB ANOVA for each date.

Leaf water content split-plot effects

Effect	July 1	August 13	Sept 9
Irrigation	NS	**	NS
Species	***	***	***
Irr. x Spec	*	*	NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001, and nonsignificant, respectively.

Table 13. Bermudagrass and zoysiagrass root mass density (mg dry weight/cm^3 soil) and crown mass (g dry weight/13.4 cm^2) data summary.

Root mass density (mg dry weight/cm^3 soil) and crown mass (g dry weight/13.4 cm^2) for two species, averaged over three irrigation treatments.

Species	Crown mass	Root-zone depth						
		0-12 inches	12-24 inches	24-36 inches	36-48 inches	48-60 inches	60-72 inches	Total(0-72 inches)
Bermudagrass	2.52	1.200	0.216	0.114	0.048	0.028	0.014	0.270
Zoysiagrass	2.88	0.955	0.091	0.021	0.007	0.000	0.000	0.179
LSD $P \leq 0.05$	NS	NS	0.077	0.038	0.022	0.007	0.006	0.042

Root mass density and crown mass split-plot statistical effects.

Effect	Crown mass	Root-zone depth						
		0-12 inches	12-24 inches	24-36 inches	36-48 inches	48-60 inches	60-72 inches	Total(0-72 inches)
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS
Species	NS	NS	**	***	**	***	***	***
Irr. X Species	NS	NS	NS	NS	NS	NS	NS	NS

*,**,***,NS: Significant at P≤0.05, 0.01, 0.001, and nonsignificant, respectively.

Table 14. Bermudagrass and zoysiagrass 12-inch (30-cm) Watermark sensor data summary (centibars).

Bermudagrass soil water tension at a 12-inch depth for three irrigation treatments

Irrigation frequency	5/7	5/8	5/14	5/15	5/21	5/22	5/28	5/29	6/4	6/6	6/11	6/12	6/18	6/19	6/25	6/26	7/2	7/3	7/9	7/10	7/16	7/17	7/23
1x/wk	0	0	8	2	12	2	17	8	25	18	33	16	39	42	66	35	71	48	82	54	39	74	95
2x/wk	1	0	2	2	5	1	10	3	19	20	27	31	35	38	54	51	64	68	83	74	72	79	93
3x/wk	1	1	2	0	8	6	13	13	19	22	27	30	38	43	68	76	88	93	117	122	100	115	130
LSD $P \le 0.05$	NS	1	3	NS	4	NS	5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Zoysiagrass soil water tension at a 12-inch depth for three irrigation treatments

Irrigation frequency	5/7	5/8	5/14	5/15	5/21	5/22	5/28	5/29	6/4	6/6	6/11	6/12	6/18	6/19	6/25	6/26	7/2	7/3	7/9	7/10	7/16	7/17	7/23
1x/wk	0	0	7	0	9	3	14	6	27	18	30	25	35	39	63	26	57	49	90	14	44	26	59
2x/wk	2	1	6	1	7	6	11	11	23	23	26	28	36	39	65	70	82	93	102	103	99	109	108
3x/wk	8	7	2	6	11	12	21	22	31	33	40	45	49	53	72	76	88	91	107	114	113	124	137
LSD $P \le 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Soil water tension at a 12-inch depth split-plot effects

Effect	5/7	5/8	5/14	5/15	5/21	5/22	5/28	5/29	6/4	6/6	6/11	6/12	6/18	6/19	6/25	6/26	7/2	7/3	7/9	7/10	7/16	7/17	7/23
Irrigation	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Species	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Irr. x Spec.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*,**,***,NS: Significant at $P \le 0.05$, 0.01, 0.001, and nonsignificant, respectively.

Continued . . .

Table 14, continued. Bermudagrass and zoysiagrass 12-inch (30-cm) Watermark sensor data summary (centibars).

Bermudagrass soil water tension at a 12-inch depth for three irrigation treatments

Irrigation frequency	7/24	7/30	7/31	8/6	8/7	8/13	8/14	8/20	8/21	8/27	8/28	9/3	9/4	9/10	9/11	9/17	9/18	9/24	9/25	10/1	10/2	10/8	10/9	Over all
1x/wk	82	103	59	82	67	101	83	103	99	121	106	114	116	116	111	118	122	158	160	86	67	62	69	67
2x/wk	97	80	83	60	62	66	51	69	74	95	91	96	96	145	137	134	135	157	155	134	125	112	112	69
3x/wk	137	127	86	144	108	122	130	146	147	167	170	164	173	199	199	180	169	199	197	149	148	142	143	102
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Zoysiagrass soil water tension at a 12-inch depth for three irrigation treatments

Irrigation frequency	7/24	7/30	7/31	8/6	8/7	8/13	8/14	8/20	8/21	8/27	8/28	9/3	9/4	9/10	9/11	9/17	9/18	9/24	9/25	10/1	10/2	10/8	10/9	Over all
1x/wk	72	118	79	109	98	142	122	121	109	141	63	87	98	142	180	188	191	199	196	185	137	122	123	79
2x/wk	122	141	150	127	125	141	116	124	139	164	147	146	149	194	199	171	176	199	198	195	194	178	181	102
3x/wk	141	163	168	198	198	194	194	195	197	199	199	197	199	186	199	179	184	199	186	171	165	151	153	119
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Soil water tension at a 12-inch depth split-plot effects and overall ANOVA effects

Effect	7/24	7/30	7/31	8/6	8/7	8/13	8/14	8/20	8/21	8/27	8/28	9/3	9/4	9/10	9/11	9/17	9/18	9/24	9/25	10/1	10/2	10/8	10/9	Over all[z]
Irrigation	NS	NS	NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Species	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
Irr. x Spec.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date																								***
Date x Irr.																								**
Date x Spec.																								**
Date x Irr. x Spec.																								NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001, and nonsignificant, respectively.

[z] Overall ANOVA was a split-split plot, repeated measures design.

Table 15. Bermudagrass and zoysiagrass 24-inch (60-cm) Watermark sensor data summary (centibars).

Bermudagrass soil water tension at a 24-inch depth for three irrigation treatments

Irrigation frequency	5/7	5/8	5/14	5/15	5/21	5/22	5/28	5/29	6/4	6/6	6/11	6/12	6/18	6/19	6/25	6/26	7/2	7/3	7/9	7/10	7/16	7/17	7/23
1x/wk	4	1	4	3	8	5	12	7	15	14	18	20	26	29	45	51	70	73	90	104	111	117	116
2x/wk	3	2	4	2	8	3	13	13	19	14	26	27	33	35	48	51	68	74	97	107	114	121	137
3x/wk	2	3	6	5	8	5	11	11	14	21	16	16	19	20	28	30	42	46	67	76	91	91	111
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date.

Zoysiagrass soil water tension at a 24-inch depth for three irrigation treatments

Irrigation frequency	5/7	5/8	5/14	5/15	5/21	5/22	5/28	5/29	6/4	6/6	6/11	6/12	6/18	6/19	6/25	6/26	7/2	7/3	7/9	7/10	7/16	7/17	7/23
1x/wk	1	1	1	1	2	1	3	3	6	7	10	9	12	13	15	13	17	14	21	13	20	20	26
2x/wk	6	5	5	4	5	4	6	6	10	10	12	12	14	15	19	20	27	29	44	50	65	98	97
3x/wk	16	16	16	16	17	18	23	25	31	33	38	43	48	50	64	67	73	74	82	85	88	91	96
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	69

Note: Separate RCB ANOVA for each date.

Soil water tension at a 24-inch depth split-plot effects

Effect	5/7	5/8	5/14	5/15	5/21	5/22	5/28	5/29	6/4	6/6	6/11	6/12	6/18	6/19	6/25	6/26	7/2	7/3	7/9	7/10	7/16	7/17	7/23
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Species	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Irr. x Spec.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001, and nonsignificant, respectively.

Continued . . .

Table 15, continued. Bermudagrass and zoysiagrass 24-inch (60-cm) Watermark sensor data summary (centibars).

Bermudagrass soil water tension at a 24-inch depth for three irrigation treatments

Irrigation frequency	7/24	7/30	7/31	8/6	8/7	8/13	8/14	8/20	8/21	8/27	8/28	9/3	9/4	9/10	9/11	9/17	9/18	9/24	9/25	10/1	10/2	10/8	10/9	Over all
1x/wk	99	112	106	162	158	172	177	178	180	178	152	150	153	198	166	169	172	199	195	199	199	183	182	104
2x/wk	138	146	152	165	164	181	189	170	173	157	152	158	159	170	176	199	199	199	199	199	199	197	197	110
3x/wk	114	140	144	169	171	177	179	178	146	199	195	194	197	197	199	199	199	199	199	199	199	196	196	107
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Zoysiagrass soil water tension at a 24-inch depth for three irrigation treatments

Irrigation frequency	7/24	7/30	7/31	8/6	8/7	8/13	8/14	8/20	8/21	8/27	8/28	9/3	9/4	9/10	9/11	9/17	9/18	9/24	9/25	10/1	10/2	10/8	10/9	Over all
1x/wk	26	37	37	54	50	66	60	64	64	71	61	66	66	117	76	117	83	101	100	104	103	96	96	42
2x/wk	85	96	97	74	73	116	83	119	139	147	143	152	156	186	174	189	187	199	197	199	193	182	182	85
3x/wk	95	99	101	116	116	118	118	119	121	126	127	132	135	153	159	156	156	165	165	165	164	153	153	92
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	83	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Soil water tension at a 24-inch depth split-plot effects and overall ANOVA effects

Effect	7/24	7/30	7/31	8/6	8/7	8/13	8/14	8/20	8/21	8/27	8/28	9/3	9/4	9/10	9/11	9/17	9/18	9/24	9/25	10/1	10/2	10/8	10/9	Over all[z]
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	*	NS	**	NS	NS	NS	NS	NS	NS	NS
Species	NS	NS	NS	**	**	**	**	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	*	*	*	*	NS
Irr. x Spec.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date																								***
Date x Irr.																								NS
Date x Spec.																								***
Date x Irr. x Spec.																								NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001, and nonsignificant, respectively.

[z] Overall ANOVA was a split-split plot, repeated measures design.

Table 16. Overall, season-mean, soil water tension data (centibars) at a 12-inch depth for three irrigation treatments averaged over turfgrass species.

Irrigation frequency	Overall Mean
1x/wk	73
2x/wk	86
3x/wk	110
LSD $P \leq 0.05$	26

Note: From Table 14, Soil water tension at a 12-inch depth split-plot effects and overall ANOVA effects.

Table 17. Overall, season-mean soil water tension (centibars) at a 24-inch depth for bermudagrass and zoysiagrass averaged over three irrigation treatments.

Species	Overall Mean
Bermuda	107
Zoysia	73
LSD $P \leq 0.05$	NS

Note: From Table 15, Soil water tension at a 24-inch depth split-plot effects and overall ANOVA effects.

Table 18. Bermudagrass and zoysiagrass 12-inch (30-cm) neutron probe volumetric soil water content ((cm^3 H_2O/cm^3 soil) x 100) data summary.

Bermudagrass 12-inch (30-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	22.4	20.6	18.9	18.4	19.6	16.7	15.8	15.1	12.7	12.1	11.7	11.2	10.5	12.7	10.0	9.4	9.4	9.3	8.8	10.7	13.8
2x/wk	22.9	21.5	20.7	19.8	20.3	17.5	16.0	14.6	13.2	12.0	11.7	11.2	10.8	11.2	9.1	9.3	9.6	8.8	8.2	10.3	13.9
3x/wk	20.5	20.1	18.3	17.8	17.3	16.4	14.8	14.6	12.2	11.1	11.0	10.1	9.9	10.1	9.3	8.7	8.4	8.5	7.9	9.9	12.9
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Zoysiagrass 12-inch (30-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	22.6	21.5	20.6	20.1	20.1	17.6	16.9	16.4	13.9	13.1	12.6	12.0	11.6	13.5	10.6	11.2	10.0	8.3	8.6	10.7	14.6
2x/wk	21.2	20.9	19.5	19.2	18.8	17.2	16.2	16.0	12.7	11.8	11.9	11.1	10.9	11.1	9.3	10.2	9.2	8.6	7.8	9.0	13.6
3x/wk	23.1	22.6	20.9	20.4	20.5	17.7	17.4	16.3	14.1	13.0	12.3	11.6	11.0	11.3	10.6	11.1	9.4	8.7	8.2	9.2	14.5
LSD $P \leq 0.05$	1.5	1.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Bermudagrass and zoysiagrass 12-inch (30-cm) volumetric soil water content averaged over three irrigation treatments.

Species	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
Bermuda	21.9	20.7	19.3	18.6	19.1	16.9	15.2	14.8	12.7	11.7	11.5	10.8	10.4	11.4	9.4	9.1	9.2	8.8	8.3	10.3	13.5
Zoysia	22.3	21.7	20.4	19.9	19.8	17.5	16.8	16.2	13.6	12.6	12.2	11.6	11.2	11.9	10.2	10.8	9.5	8.5	8.2	9.7	14.3
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.6	NS	NS	NS	NS	NS

12-inch (30-cm) volumetric soil water content split-plot statistical effects and overall ANOVA effects.

Effect	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall[z]
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
Species	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Irr. x Spec	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date																					***
Date x Irr.																					NS
Date x Spec.																					**
DatexIrr.xSpec.																					NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001, and nonsignificant, respectively.

[z] Overall ANOVA was a split-split plot, repeated measures design.

Table 19. Bermudagrass and zoysiagrass 24-inch (60-cm) neutron probe volumetric soil water content ((cm^3 H_20/cm^3 soil) x 100) data summary.

Bermudagrass 24-inch (60-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	19.1	18.2	17.1	16.9	16.8	15.1	14.6	14.0	12.1	11.3	11.2	10.6	10.3	10.8	9.8	10.9	9.2	10.1	8.4	9.5	12.8
2x/wk	20.8	19.9	18.6	18.5	17.9	16.4	15.6	14.5	13.1	12.6	12.2	11.8	11.3	11.4	10.5	11.7	10.5	10.0	9.2	9.4	13.8
3x/wk	18.9	18.6	16.8	16.6	16.3	16.6	14.7	14.3	12.7	12.0	12.1	10.9	10.8	10.7	10.1	10.1	9.6	10.8	9.1	9.6	13.1
LSD $P \leq 0.05$	NS	1.1	1.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Zoysiagrass 24-inch (60-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	20.1	19.5	18.3	18.5	18.7	17.6	17.2	16.8	16.1	15.5	15.8	15.2	14.5	14.9	13.2	14.2	13.4	11.4	12.5	11.9	15.8
2x/wk	20.1	20.3	19.1	19.2	19.2	18.3	17.8	18.2	16.3	15.1	15.4	14.3	13.5	13.3	12.6	11.6	11.5	11.3	10.1	10.2	15.4
3x/wk	20.6	19.9	19.0	18.9	18.8	16.4	17.7	17.4	16.2	15.3	15.4	13.1	13.5	13.1	12.9	11.6	12.9	10.4	10.6	10.4	15.2
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Bermudagrass and zoysiagrass volumetric soil water content averaged over three irrigation treatments.

Species	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
Bermuda	19.6	18.9	17.5	17.3	17.0	16.0	15.0	14.3	12.6	12.0	11.8	11.1	10.8	11.0	10.1	10.9	9.8	10.3	8.9	9.5	13.2
Zoysia	20.2	19.9	18.8	18.8	18.9	17.5	17.6	17.5	16.2	15.3	15.5	14.2	13.8	13.7	12.9	12.5	12.6	11.0	11.1	10.8	15.5
LSD $P \leq 0.05$	NS	NS	1.1	1.3	1.1	NS	1.5	1.3	1.8	1.7	1.9	1.8	1.8	1.9	2.4	NS	2.1	NS	1.9	NS	1.4

24-inch (60-cm) volumetric soil water content split-plot statistical effects and overall ANOVA effects.

Effect	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall[Z]
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Species	NS	NS	*	*	**	NS	**	***	**	**	**	**	**	**	*	NS	**	NS	*	NS	**
Irr. x Spec.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date																					***
Date x Irr.																					NS
Date x Spec.																					***
DatexIrr.xSpec.																					NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001, and nonsignificant, respectively.
[Z] Overall ANOVA was a split-split plot, repeated-measures design.

Table 20. Bermudagrass and zoysiagrass 36-inch (90-cm) neutron probe volumetric soil water content ((cm^3 H_2O/cm^3 soil) x 100) data summary.

Bermudagrass 36-inch (90-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	13.6	12.2	11.2	11.2	11.7	10.3	9.9	9.6	8.7	8.1	8.1	6.8	6.1	6.0	5.4	7.2	4.6	5.9	4.1	3.7	8.2
2x/wk	16.4	14.9	13.7	13.6	13.5	12.6	13.5	11.4	10.7	10.1	9.7	9.3	8.2	8.0	7.4	9.1	7.1	6.3	6.1	5.8	10.4
3x/wk	14.4	13.7	12.8	12.9	12.7	12.6	11.8	11.6	10.8	10.4	10.1	9.2	8.4	8.5	7.9	10.7	6.3	8.2	6.3	6.1	10.3
LSD $P \le 0.05$	NS	2.4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Zoysiagrass 36-inch (90-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	16.2	14.6	13.8	13.8	14.1	13.4	12.9	12.6	12.2	12.1	12.9	11.8	11.9	11.8	11.8	9.5	11.5	9.1	10.8	10.5	12.4
2x/wk	15.4	15.1	14.4	14.2	14.5	13.9	14.0	14.0	13.2	12.8	13.5	12.4	12.7	12.6	12.8	10.8	11.9	11.4	11.1	10.6	13.1
3x/wk	16.0	15.2	14.5	14.6	14.3	13.7	13.6	13.4	13.3	12.8	13.7	13.3	12.5	12.4	12.8	10.5	11.8	9.8	11.1	10.5	13.0
LSD $P \le 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Bermudagrass and zoysiagrass 36-inch (90-cm) volumetric soil water content averaged over three irrigation treatments.

Species	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
Bermuda	14.8	13.6	12.6	12.6	12.6	11.8	11.7	10.9	10.1	9.5	9.3	8.4	7.6	7.5	6.9	9.0	6.0	6.8	5.5	5.2	9.6
Zoysia	15.9	15.0	14.2	14.2	14.3	13.6	13.5	13.3	12.9	12.5	13.4	12.5	12.4	12.3	12.5	10.2	11.7	10.1	11.0	10.5	12.8
LSD $P \le 0.05$	NS	NS	NS	NS	NS	NS	NS	2.4	2.6	2.4	2.5	2.5	2.3	2.5	2.3	NS	2.6	NS	2.4	2.3	2.2

36-inch (90-cm) volumetric soil water content split-plot statistical effects and overall ANOVA effects.

Effect	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall[z]
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Species	NS	NS	NS	NS	NS	NS	NS	*	*	*	**	**	***	**	***	NS	***	NS	***	***	**
Irr. x Spec.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date																					***
Date x Irr.																					NS
Date x Spec.																					***
DatexIrr.xSpec.																					NS

*,**,***,NS: Significant at $P \le 0.05$, 0.01, 0.001, and nonsignificant, respectively.

[z] Overall ANOVA was a split-split plot, repeated-measures design.

Table 21. Bermudagrass and zoysiagrass 48-inch (120-cm) neutron probe volumetric soil water content ((cm^3 H_2O/cm^3 soil) x 100) data summary.

Bermudagrass 48-inch (120-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	15.3	14.4	13.7	13.9	14.0	13.1	12.7	12.4	12.1	11.6	12.1	10.9	10.2	10.3	9.5	10.6	8.3	9.3	6.5	6.9	11.4
2x/wk	13.3	13.7	13.0	12.8	12.8	12.3	11.9	11.9	11.5	10.7	11.3	9.6	9.6	9.3	8.5	9.8	7.7	7.0	6.6	6.5	10.5
3x/wk	13.4	13.2	12.4	12.6	12.7	12.9	12.3	12.0	11.2	11.1	11.9	10.7	10.3	9.7	10.1	12.7	7.8	9.0	7.7	7.8	11.1
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Zoysiagrass 48-inch (120-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	15.5	15.1	14.3	14.1	14.5	13.9	13.3	13.3	12.9	12.7	13.6	12.6	12.6	12.5	12.8	9.3	12.4	10.3	12.0	11.7	13.0
2x/wk	14.5	15.0	14.2	14.2	14.0	13.8	13.6	14.0	13.2	13.2	13.7	12.9	12.7	13.0	13.3	11.7	12.9	12.2	12.3	11.6	13.3
3x/wk	13.5	13.4	12.7	12.6	12.7	11.8	12.3	11.9	11.7	11.5	12.3	11.3	11.4	11.3	11.7	9.6	10.2	10.5	10.8	10.1	11.7
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Bermudagrass and zoysiagrass 48-inch (120-cm) volumetric soil water content averaged over three irrigation treatments.

Species	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
Bermuda	14.0	13.8	13.0	13.1	13.2	12.8	12.3	12.1	11.6	11.1	11.7	10.4	10.1	9.8	9.3	11.0	7.9	8.4	7.0	7.0	11.0
Zoysia	14.5	14.5	13.7	13.6	13.7	13.1	13.1	13.1	12.6	12.4	13.2	12.2	12.2	12.3	12.6	10.2	12.0	11.7	11.7	11.1	12.7
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	3.6	3.7	NS

48-inch (120-cm) volumetric soil water content split-plot statistical effects and overall ANOVA effects.

Effect	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall[z]
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Species	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	NS
Irr. x Spec.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date																					***
Date x Irr.																					NS
Date x Spec.																					***
DatexIrr.xSpec.																					NS

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001, and nonsignificant, respectively.

[z] Overall ANOVA was a split-split plot, repeated-measures design.

Table 22. Bermudagrass and zoysiagrass 60-inch (150-cm) neutron probe volumetric soil water content ((cm^3 H_2O/cm^3 soil) x 100) data summary.

Bermudagrass 60-inch (150-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	17.4	17.5	16.9	17.2	17.1	16.7	16.5	16.5	15.8	15.8	16.5	15.1	14.8	14.6	14.6	15.6	13.6	13.5	11.9	11.5	15.5
2x/wk	15.1	15.3	14.9	15.4	15.0	14.8	14.7	14.9	14.0	13.2	14.0	12.0	12.6	12.2	12.1	12.1	11.5	10.1	9.3	9.1	13.1
3x/wk	18.3	18.6	17.8	18.2	17.7	16.7	17.6	17.5	17.0	16.7	17.5	16.3	16.5	16.4	16.4	17.1	15.3	13.2	14.2	13.9	16.7
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	3.3	NS	4.0	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Zoysiagrass 60-inch (150-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	15.9	16.4	15.8	16.0	15.6	14.5	15.1	15.0	14.4	14.4	15.1	14.2	14.1	13.9	14.6	13.7	13.9	13.0	13.8	12.8	14.6
2x/wk	16.6	16.9	16.3	16.7	16.5	16.2	16.2	15.7	15.7	15.6	16.2	15.3	15.3	15.0	15.5	15.3	14.9	14.6	14.4	13.9	15.6
3x/wk	16.6	17.1	16.4	16.8	16.4	17.0	16.2	16.1	15.4	15.4	16.4	14.9	15.4	15.0	15.7	14.6	14.4	15.4	14.8	14.0	15.7
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Bermudagrass and zoysiagrass 60-inch (150-cm) volumetric soil water content averaged over three irrigation treatments.

Species	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
Bermuda	16.9	17.1	16.5	16.9	16.6	16.0	16.3	16.3	15.6	15.3	16.0	14.5	14.6	14.4	14.4	15.0	13.5	12.2	11.8	11.5	15.1
Zoysia	16.4	16.8	16.2	16.5	16.2	15.9	15.8	15.6	15.2	15.1	15.9	14.8	14.9	14.6	15.3	14.5	14.4	14.3	14.3	13.6	15.3
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

60-inch (150-cm) volumetric soil water content split-plot statistical effects and overall ANOVA effects.

Effect	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall[z]
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Species	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Irr. x Spec.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date																					***
Date x Irr.																					NS
Date x Spec.																					***
DatexIrr.xSpec.																					*

*,**,***,NS: Significant at P≤0.05, 0.01, 0.001, and nonsignificant, respectively.

[z] Overall ANOVA was a split-split plot, repeated-measures design.

Table 23. Bermudagrass and zoysiagrass 72-inch (180-cm) neutron probe volumetric soil water content ((cm^3 H_20/cm^3 soil) x 100) data summary.

Bermudagrass 72-inch (180-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	16.1	16.1	16.2	16.7	15.9	15.7	15.4	15.1	14.8	14.4	15.1	13.8	13.5	13.6	14.0	13.8	13.2	14.1	12.7	12.2	14.6
2x/wk	15.8	15.8	15.4	15.7	15.7	15.3	15.2	15.1	14.5	14.5	15.1	13.9	13.5	14.2	13.8	13.4	13.3	12.7	12.5	12.0	14.4
3x/wk	18.6	18.6	18.0	18.5	18.4	17.2	17.9	17.9	17.7	17.3	18.6	17.4	17.4	17.7	17.9	18.2	17.6	17.6	17.0	16.6	17.8
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.4	NS	3.6	NS	NS	3.3	3.8	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Zoysiagrass 72-inch (180-cm) volumetric soil water content for three irrigation treatments.

Irrigation frequency	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
1x/wk	18.9	19.4	18.7	19.3	18.6	18.5	19.1	18.6	17.5	17.5	19.1	18.0	18.0	18.1	18.4	18.1	18.0	16.7	17.6	17.0	18.3
2x/wk	16.5	16.8	16.4	16.8	16.6	16.5	15.8	15.7	15.8	15.6	16.5	15.3	15.2	15.1	16.2	15.7	15.4	15.6	15.2	15.0	15.9
3x/wk	17.1	17.1	16.7	16.9	16.8	17.6	16.3	16.3	15.8	15.7	16.7	15.6	16.0	15.6	16.6	16.7	16.9	15.6	15.8	15.4	16.4
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Separate RCB ANOVA for each date. Overall ANOVA was a split-plot, repeated-measures design.

Bermudagrass and zoysiagrass 72-inch (180-cm) volumetric soil water content averaged over three irrigation treatments.

Species	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall
Bermuda	16.8	16.8	16.5	17.0	16.6	16.1	16.2	16.0	15.7	15.4	16.3	15.1	14.8	15.2	15.2	15.2	14.5	14.8	14.1	13.6	15.6
Zoysia	17.5	17.8	17.3	17.6	17.3	17.5	17.1	16.9	16.4	16.3	17.4	16.3	16.4	16.3	17.1	16.8	16.8	15.9	16.2	15.8	16.8
LSD $P \leq 0.05$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.7	1.7	10.5	NS	1.6	1.7	NS

72-inch (180-cm) volumetric soil water content split-plot statistical effects and overall ANOVA effects.

Effect	5/7	5/14	5/21	5/28	5/29	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/30	7/31	8/13	8/20	8/27	9/10	9/24	10/8	Overall[z]
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Species	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	**	NS	*	*	NS
Irr. x Spec.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	*	*	*	*	**	NS	*	*	NS
Date																					***
Date x Irr.																					*
Date x Spec.																					***
DatexIrr.xSpec.																					**

*,**,***,NS: Significant at $P \leq 0.05$, 0.01, 0.001, and nonsignificant, respectively.

[z] Overall ANOVA was a split-split plot, repeated-measures design.

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