Performance of Florida Landscape Plants When Irrigated by ET-Based Controllers and Time-Based Methods[1]

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Abstract

The combination of inefficient irrigation of residential and commercial landscapes and prolonged drought conditions has overextended the water supply in many areas of Florida. New irrigation technologies including smart irrigation controllers have been shown to decrease outdoor water use. The objective of this study was to evaluate the effects of evapotranspiration (ET) controlled and time-based irrigation treatments on the growth and quality of three ornamental plant species grown in landscape settings in Florida. *Plumbago auriculata*, *Lagerstroemia* 'Natchez', and *Liriope muscari* 'Big Blue' were established in mixed irrigation plots in a completely randomized block design with four irrigation treatments: 1) Weathermatic ET controller treatment; 2) Toro ET controller treatment 3) time-based treatment (determined by month from 60% of historical net irrigation requirement specific to South Florida) and; 4) reduced time-based treatment (irrigation depth in treatment 3 was reduced by 40%). Results for the entire study period showed that the use of ET controllers did not result in water savings over the reduced time treatment. There was no irrigation treatment effect on plant growth (growth index or height) of *Plumbago auriculata*, *Lagerstroemia indica* 'Natchez', or *Liriope muscari* 'Big Blue' over the course of the study. Similarly, plant density and quality were unaffected by irrigation treatment throughout the study. These results suggest that all irrigation treatments applied more water than was needed and that these species would perform acceptably with less irrigation than supplied by the lowest treatment in the study.

Index words: landscape irrigation, landscape water management, mixed residential landscapes.

Significance to the Nursery Industry

Prolonged drought conditions in the southeastern United States have spurred efforts to reduce the volume of water used to irrigate urban landscapes. As a result, new technologies that control irrigation based on ET or soil moisture are being investigated as a possible means to reduce the amount of water applied to residential and commercial landscapes. Since many nurseries and landscape professionals offer a guarantee on newly transplanted ornamental plant material, this study is important as a method to determine the potential for plant failure when irrigated using these smart irrigation technologies. This research presents an evaluation of plant growth and quality performance in a landscape setting where irrigation is applied using ET-based irrigation controllers or reduced-time schedules. The results of this study indicate that these (and potentially other) commonly grown woody ornamental and herbaceous perennial plant species will grow well in Florida landscapes when irrigated using methods to reduce the total volume of water applied. However, the physiological characteristics of plants are variable and will ultimately affect the relative irrigation requirements of individual ornamental plant species.

Introduction

Rapid population growth and drought have placed considerable stress on the water supply throughout the Southeastern United States. Inefficient irrigation of residential and commercial landscapes (12), coupled with prolonged drought conditions, have overextended the water supply in many areas of Florida. As a result, water deficits are common in areas of central and south Florida, despite receiving average annual rainfall of 1400 mm (55 in)$\cdot$yr^{-1} (13). In an attempt to reduce water use in the urban sector, many areas of Florida are currently under mandatory watering restrictions for landscape irrigation. However, reductions in urban water use following the institution of water restrictions have been less effective than desired. For example, South Florida Water Management District decreased irrigation frequency during the 2007 drought from 2 days per week to 1 day per week and water use decreased no more than 26% rather than the 50% that was expected (South Florida WMD, personal communication). Therefore, there is a need for new technologies and strategies that will result in more efficient use of in-ground irrigation systems and a reduction of outdoor water use by homeowners.

New irrigation technologies have been shown to decrease outdoor water use. A central Florida study demonstrated that irrigation controlled by soil moisture sensors had a potential to save up to 90% of the irrigation water that would be used if irrigation was applied on a time-based schedule (5). Additionally, ET-based controllers have been shown to save water when used to control irrigation in the western United States (2, 3, 4, 9). Water savings averaged 20% in Nevada when irrigation applied to mixed landscapes using ET-based irrigation

[1]Received for publication January 29, 2009; in revised form August 9, 2009. This work was supported by the Florida Agricultural Experiment Station, Florida Department of Agriculture and Consumer Services, and Hillsborough County Water Department. The authors would like to thank Gitta Shurberg and David Crockett for their assistance with landscape plot maintenance and data collection.

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controllers were compared to landscapes where homeowners controlled irrigation (8). In one study that quantified plant responses, measurements of plant canopy temperature differential and chlorophyll index and homeowner survey data suggested that water savings improved or maintained landscape quality (8). However, most ET controller studies have not scientifically quantified plant responses to water savings. The objective of this study was to evaluate the effects of ET controlled and time-based irrigation on the growth and quality of three ornamental plant species commonly grown in Florida landscape settings.

Materials and Methods

Sixteen plots designed to simulate residential landscapes were constructed on a Zolfo fine sand soil (sandy, siliceous, hyperthermic Oxyaquic Alorthods) (23) at the University of Florida Gulf Coast Research and Education Center (GCREC) in Wimauma, FL. The plots were 7.6 × 12.2 m (25 × 40 ft) and were bordered by a 15.3 cm (6.0 in) tall black metal barrier, with 3.1 m (10.2 ft) buffer zones between adjacent plots. Container-grown *Plumbago auriculata* and *Liriope muscari* 'Big Blue' were planted from 3.8 liter (1 gal) pots and *Lagerstroemia* 'Natchez' was planted from 18.9 liter (5 gal) pots on March 17, 2006, to cover 32.5 m^2 (38.8 yd^2) of each plot. The remaining 60.5 m^2 (72.3 yd^2) of each plot was covered in St. Augustinegrass (*Stenotaphrum secundatum*). In each landscape plot, ornamentals were irrigated using 11 microspray emitters with a 340° nozzle pattern and two microspray emitters with a 180° nozzle pattern (Maxijet, Dundee, FL). Irrigation of the ornamentals for each plot was supplied through a 1-inch pipe equipped with a solenoid valve to enable irrigation control and a flow meter (11.4 mm V100 w/Pulse Output, AMCO Water Metering Systems, Ocala, FL). A pressure regulator was installed on the conduit at the entry point of the plot to maintain a pressure of 138 kPa and an application rate of 296 $cm^3 \cdot s^{-1}$.

Ornamental plant species were watered daily for 30 minutes during the first 60 days to establish the plant material in the landscape. This corresponds to the period of time allotted for the establishment of new landscape material under most Florida watering restriction regimes. At the conclusion of the 60-day establishment period (May 25, 2006), four irrigation treatments were initiated and replicated four times for a total of sixteen plots in a completely randomized block design. The irrigation treatments were: 1) Weathermatic — SL1600 ET-based controller with SLW15 weather monitor mounted on-site (Weathermatic, Inc., Dallas, TX); 2) Toro — Intelli-sense ET-based controller (Toro Company, Inc., Riverside, CA); 3) Time-based — irrigation schedule was determined monthly from 60% of the net irrigation requirement (Table 1), determined from historical ET and rainfall, specific to south Florida (10); 4) Reduced time-based — irrigation run time from treatment 3 was reduced by 40%. The Weathermatic SL1600 used temperature data collected from the on-site weather monitor and solar radiation estimates based on latitude to calculate ET using Hargreaves equation (19). The Toro Intelli-sense utilized the WeatherTRAK ET Everywhere service (Hydropoint Datasystems, Inc., Petaluma, CA) to gather weather information from local public weather stations, calculate ET using the ASCE standardized reference ET equation (1), and broadcast the ET value to the controller daily. The specific program settings (e.g., site and plant materials information) for both ET controllers are detailed in

Table 1. Runtimes and application amounts per irrigation event[z] for the time-based treatment used to irrigate *Plumbago auriculata*, *Liriope muscari* 'Big Blue' and *Lagerstroemia* 'Natchez' planted in the landscape in Florida operating on a twice weekly schedule[y].

	0 to 26 WAT		27 to 52 WAT	
Month	**Time (min)[x]**	**Depth (mm)**	**Time (min)**	**Depth (mm)**
January	19	6	31	10
February	20	6	33	11
March	28	9	47	15
April	30	10	50	16
May	28	9	46	15
June	25	8	42	13
July	39	12	65	21
August	43	14	72	23
September	26	8	43	14
October	27	3	43	5
November	27	8	44	14
December	24	7	39	12
Total[w]	**669**	**202**	**1112**	**336**

[z]Assumed 60% system efficiency and estimated effective rainfall for south Florida with 60% ET replacement.

[y]Two irrigation events were scheduled per week.

[x]Application rate used to calculate runtimes was 19 $mm \cdot hr^{-1}$.

[w]Total was calculated for the year including both irrigation events.

Table 2. All treatments utilized rain sensors to bypass irrigation after 6 mm (0.24 in) of rainfall. The Toro Intelli-sense was not installed until August 8, 2006; the treatment began on August 13, 2006. Prior to the installation of the controller, this treatment was irrigated the same as treatment 3.

Water application by each treatment was compared to the irrigation maximum demand, which is defined as the theoretical maximum amount of irrigation required to maintain plant quality. Maximum demand was estimated by using a daily soil water balance with an input of rainfall and an output of reference ET (ET_O; 1) assuming no drainage or runoff. The soil water balance was calculated using the following equation:

$$WL_i = WL_{i-1} - ET_O + R_E + I$$

where WL is the water level in the root zone (mm) on day i or (i – 1), ET_O is the reference ET (mm) on day i, R_E is effective rainfall (mm) on day i, and I is the irrigation demand (mm) on day i. Effective rainfall included only the depth that filled the root zone; additional rainfall was assumed to be lost as drainage or surface runoff. Irrigation demand (I) had a value of 0 until such time that 50% (or more) of the available water in the root zone was depleted. Once water level in the root zone was < 50% of field capacity, I was equal to the amount of irrigation (mm) needed to bring the soil water to field capacity. Maximum demand was defined as the theoretical maximum amount of irrigation required to maintain the soil water at field capacity, which was calculated as the total amount of irrigation (mm) needed to replenish soil water over the course of the study. Actual plant demand would likely be lower than this maximum demand estimate since most plants transpire at rates lower than ET_O on average. Thus, the maximum demand is a high estimate of the irrigation volume needed.

Table 2. Program settings for each brand of evapotranspiration (ET) irrigation controller used to irrigate *Plumbago auriculata*, *Liriope muscari* 'Big Blue' and *Lagerstroemia* 'Natchez' planted in the landscape in Florida.

Controller	0 to 26 WAT		27 to 52 WAT	
	Weathermatic	Toro	Weathermatic	Toro
Sprinkler type[z]	5 mm/hr[y], 18 mm/hr	19 mm/hr	18 mm/hr	19 mm/hr
Plant type[x]	Shrubs	Mixed low water use	Shrubs	Mixed low water use
Root depth	NA[w]	305 mm	NA	305 mm
Soil type[v]	Sandy	Sandy	Sandy	Sandy
Slope	0°	0°	0°	0°
Efficiency[u]	100%	95%	80%	80%
Zip code[t]	33598	NA	33598	NA
Microclimate	NA	Full Sun	NA	Full sun
Days allowed[s]	Wed, Sat	Wed, Sat	Everyday	Everyday

[z]Application rate or precipitation rate is termed sprinkler type for some ET controllers.

[y]The application rate for the Weathermatic was incorrectly set at 5.1 mm·hr^{-1} from 0 to 10 WAT causing more irrigation to be applied than required.

[x]The plant type setting is used to choose crop coefficients to calculate plant evapotranspiration.

[w]NA applies to controller settings that were not applicable that a particular controller.

[v]The soil type setting is used to determine the depth of available water for the root zone.

[u]Scheduling efficiency is used to calculate gross irrigation once net irrigation is determined.

[t]Zip code is used to find the latitude to determine the monthly solar radiation for ET calculations.

[s]Days allowed refers to the days irrigation was allowed to occur per week.

The soil at the study site was a Zolfo fine sand (sandy, siliceous, hyperthermic Grossarenic Entic Haplohumods) using a USDA soil survey (18). According to the soil survey, the Zolfo soil is somewhat poorly drained (18) and the field capacity and permanent wilting point (determined from laboratory samples) has been published as 13 and 3% (all soil moisture values here presented on a volumetric basis), respectively (6). Root zone depth was assumed to be 610 mm (24.0 in) for the established plant material.

Weather data used in the soil water balance was collected from an on-site weather station monitored by the Florida Automated Weather Network (FAWN); these data included measured values of wind speed, solar radiation, temperature, and relative humidity for ET_O calculations and measured depth of rainfall. Thirty year historical rainfall averages were calculated from monthly rainfall data collected by the National Oceanic and Atmospheric Administration (17) from 1975 through 2005. The closest NOAA weather station from the project site with available rainfall data was located approximately 28 km (17.3 mi) away, in Parrish, FL.

Ornamental plant data were collected (following the 60-day establishment period) at 0, 26 and 52 weeks after commencement of the irrigation treatments (WAT). Growth index (GI) was used as a quantitative indicator of plant growth rate and to compare size of the plants grown under different irrigation treatments. Growth index for each plant was calculated as: GI (cm^3) = H × W1 × W2 [1], where H is the plant height (cm), W1 is the widest width of the plant, and W2 is the width perpendicular to the widest width (21). In addition to GI, plant quality and density were visually rated on a scale of 0 (dead) to 5 (very good quality; dense canopy). The cumulative volume of irrigation water applied (mm) to each landscape plot was determined at 26 and 52 WAT.

The experiment was conducted as a randomized complete block design with four blocks of landscape plots as replicates. Each block contained all four irrigation treatments and the same plant material. Each landscape plot contained 11 *Plumbago auriculata*, 1 *Lagerstroemia indica* 'Natchez', and 17 *Liriope muscari* 'Big Blue'. Growth index was analyzed with SAS statistical software using the PROC MIXED procedure with date of measurement as a repeated measure (20). Initial GI (0 WAT) was included in the model as a covariate. Cumulative irrigation volume was analyzed separately for each time period (establishment, 0–26 WAT, 27–52 WAT) using the PROC MIXED procedure in SAS (20). Plant quality and density data were analyzed separately at 26 and 52 WAT using the PROC GLIMMIX program in SAS (20) using the multinomial distribution and the cumulative logit link function. In all models, irrigation treatment was included in the model as a fixed effect, while block and block x treatment were included as random effects. All pair-wise comparisons were completed using the Tukey test with a significance level of $\alpha = 0.05$.

Results and Discussion

Irrigation applied during the establishment period (March 21–May 24, 2006) exceeded the maximum demand to ensure that plants were adequately watered before the commencement of treatments. Overall, the study period had less precipitation than the historical mean with a total of 1,261 mm (49.6 in) of rainfall for the approximate 12-month study period occurring from May 2006 to May 2007 (Fig. 1), with the exceptions of July 2006, 112% higher than average, and April 2007, 69% higher than average (17). This amount was 15% less than the historical total (17) and 17% less when compared to the Florida average of 1,400 mm (55.1 in)·yr^{-1} (13). There were 106 rain events over 349 days; there were 244 days without rain events (70% of the study period).

The portion of the study period between 0 to 26 WAT (May 25–November 22, 2006) corresponded with the wet season, totaling 947 mm (37.3 in) of rainfall and 60% dry days. During this period, water application amount ranged from 378 mm (14.9 in) for the reduced time-based treatment to 768 mm (30.2 in) for the Weathermatic controller treatment (Table 3). Over-irrigation compared to the maximum demand was greatest for the Weathermatic controller treatment because runtimes were longer than necessary due to an incorrect setting for precipitation rate (Table 2). The Toro controller

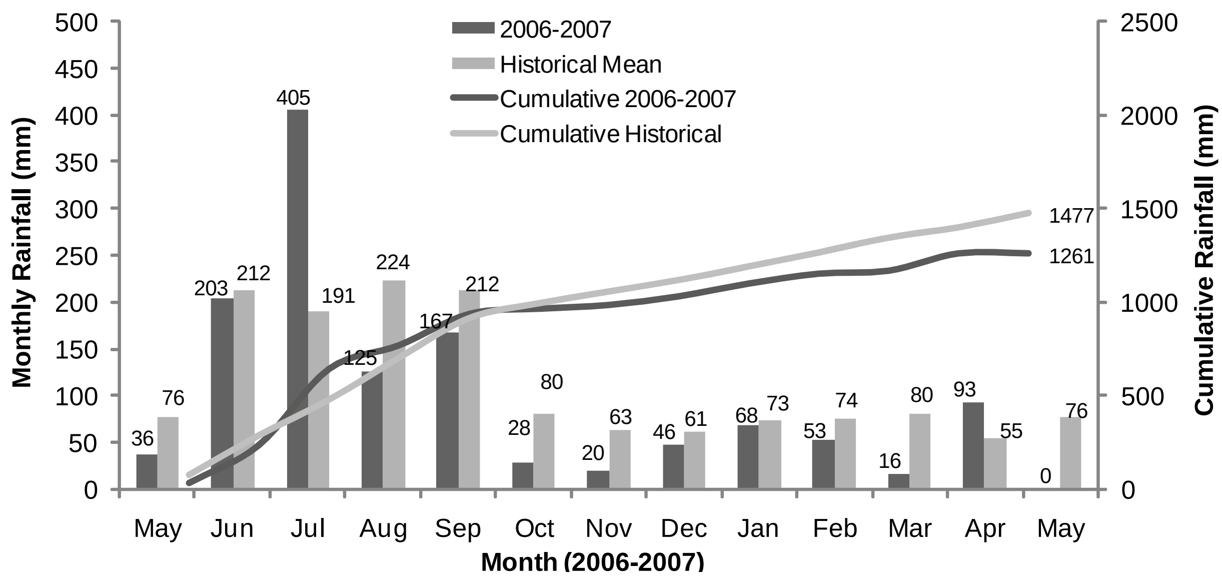

Fig. 1. Comparison of rainfall for the 2006–2007 study period and mean historical rainfall on a monthly and cumulative basis for Southwest Florida.

and time-based treatments were not statistically different in irrigation application during this time period, totaling 547 and 594 mm (21.5 and 23.4 in), respectively.

The treatment period between 27 and 52 WAT (November 23, 2006–May 8, 2007) was considerably drier than 0 to 26 WAT, totaling 278 mm (10.9 in) of rainfall and 81% dry days. During this dry period, the Weathermatic and time-based treatments applied significantly higher irrigation volumes, totaling 559 and 575 mm (22.0 and 22.6 in), respectively, compared to the Toro and reduced time-based treatments, applying 265 and 325 mm (10.4 and 12.8 in) (Table 3).

The maximum demand totaled 421 and 506 mm (16.6 and 19.9 in) for the 0 to 26 WAT and 27 to 52 WAT periods, respectively (Table 3). The reduced time-based treatment was the only treatment where the volume of irrigation applied was less than the maximum demand amount for both treatment periods, meeting 90% of the demand during the 0 to 26 WAT period and 64% of the demand during the 27–52 WAT period. The Toro treatment applied 48% less irrigation than the maximum demand and 18% less than the reduced time-based treatment during the dry period (27 to 52 WAT). This treatment would have applied less irrigation if the controller was installed at the time that the irrigation treatments commenced; prior to installation, these plots received irrigation using the time-based schedule (May 25–August 13, 2006). The remaining treatments applied more irrigation than the maximum demand.

Table 3. Mean cumulative volume of irrigation water applied (mm) to mixed ornamentals in landscape plots at 0, 26, and 52 weeks after treatment (WAT). Within columns, means followed by the same letter are not significantly different using the Tukey test with a significance level of α = 0.05.

Irrigation treatment	0–26 WAT	27–52 WAT	Total
	mm		
Weathermatic	768a	559a	1327a
Toro	547b	265c	812c
Time-based	594b	575a	1169b
Reduced-time	378c	325b	703d
Maximum demand[z]	421	506	927

[z]Maximum Demand is defined as the theoretical maximum amount of irrigation required to maintain the soil water at field capacity. Maximum demand is calculated using reference evapotranspiration and rainfall in a daily soil water balance model.

Results for the entire study period showed that the use of ET controllers did not result in large water savings compared to the time-based methods. The Toro treatment applied 12% less irrigation over the study period compared to the maximum demand, but applied 15% more than the reduced time-based treatment (Table 3). Irrigation application was highest by the Weathermatic controller, applying 43% more than the maximum demand, but would have applied much less if programmed with the correct application rate during 0 to 10 WAT. Irrigation savings for the ET controllers would have been higher if the controllers had been installed and programmed correctly during the entire study period. In a companion study evaluating these irrigation treatments on St. Augustinegrass turf, ET controllers averaged 43% in water savings compared to a time-based irrigation schedule without a rain sensor (7). Also, ET controllers were approximately twice as effective at reducing irrigation compared to a rain sensor alone (7). The time-based treatment and the reduced time-based treatment were both scheduled using the same time clock and the same rain sensor. Therefore, the reduced time-based treatment also did not respond to rainfall as well as it should have by irrigating when other treatments bypassed irrigation due to rainfall.

Despite the significant differences in the volume of water applied, there was no irrigation treatment effect on growth index (Table 4), height (data not shown), quality or density (data not shown) of *P. auriculata*, *L. indica* 'Natchez', or *L. muscari* 'Big Blue' over the course of the study. It is possible that there was no effect of irrigation on growth or quality because all irrigation treatments supplied irrigation in excess of plant requirements. Both the Weathermatic and time-based treatments applied more irrigation than the estimated theoretical maximum demand (Table 2). In addition, the

Table 4. Mean growth index of plumbago, liriope and crepe myrtle planted in the landscape under two ET-controller and two time-based irrigation treatments at 0, 26, and 52 weeks after treatment (WAT). Within columns, means followed by the same letter are not significantly different using the Tukey test with a significance level of α = 0.05.

	Growth index (m^3)		
Irrigation treatment	**0 WAT**	**26 WAT**	**52 WAT**
		Plumbago	
Weathermatic ET	0.07a	0.50a	0.62a
Toro ET	0.07a	0.42a	0.67a
Time-based	0.08a	0.31a	0.55a
Reduced-time	0.07a	0.49a	0.62a
		Liriope	
Weathermatic ET	0.03a	0.05a	0.05a
Toro ET	0.04a	0.05a	0.06a
Time-based	0.03a	0.05a	0.04a
Reduced-time	0.04a	0.05a	0.06a
		Crepe Myrtle	
Weathermatic ET	0.57a	2.05a	2.11a
Toro ET	0.67a	1.72a	2.65a
Time-based	0.73a	1.83a	2.08a
Reduced-time	0.53a	1.91a	2.31a

amount of irrigation applied in the Toro and reduced-time treatments was lower than the maximum demand, but still exceeded 75% of the maximum demand (Table 2). It is also possible that the three species would have performed acceptably had they been irrigated with less water than was applied. Previous studies suggested that many ornamental plants will exhibit acceptable growth and quality when irrigation is significantly reduced. For example, Staats and Klett (22) found that some species of groundcovers (*Cerastium tomentosum* and *Poentilla tabernaemontani*) maintained 'optimum visual quality' when irrigated at 50 and 75% estimated ET, respectively in an semi-arid environment. They also found that once established, irrigation at 25% estimated ET was optimum for *C. tomentosum* and *Sedum acre*. Pittenger et al. (18) also reported that *Baccharis pilularis* 'Twin Peaks', *Drosanthemum hispidum*, and *Hedera helix* all maintained at least 'minimally acceptable visual quality' when irrigated at 20% ET_O, and *Vinca major* required irrigation at a minimum of 30% ET_O in southern California. Montague et al. (16) reported that transplants of *Lagerstroemia indica* 'Victor', *Forsythia* × *intermedia* 'Lynwood', *Spiraea* × *vanhouttei*, and *Photina* × *fraseri* were 'aesthetically pleasing and had growth acceptable for landscape situations' when they received irrigation at 50% ET_O in west Texas. In Arizona, Feldman and Niemiera (11) reported that *Myoporum parvifolium* performed best when irrigated at 25% of pan evaporation, while *Dalea greggi* required irrigation at 75% of evaporation. Montague et al. (15) calculated the water loss coefficient (K_C) for several tree species in a semi-arid environment (*Acer platanoides* 'Emerald Queen' — 0.19; *Platanus* × *acerifolia* 'Bloodgood' — 0.52; *Fraxinus pennsylvanica* 'Patmore' — 0.54; *Tilia cordata* 'Greenspire' — 0.83; *Salix matsudana* 'Tortuosa' — 1.05); their results suggest that some of these species can be irrigated at levels significantly lower than ET_O (i.e. maximum demand in the present study).

The results of our study indicate that these (and potentially other) commonly grown woody ornamental and herbaceous perennial plant species will grow well in Florida landscapes when irrigated using simple ET-based scheduling methods to reduce the total volume of water applied — as was done with the reduced time-based treatment in this study. Supplying only 76% of the estimated maximum demand did not reduce growth, density, or quality. These results indicate that a fraction of the maximum demand was enough to maintain these plants at quality levels associated with much higher irrigation levels provided by other treatments. However, the physiological characteristics of plants are variable and will ultimately affect the relative irrigation requirements of individual ornamental plant species (14).

The plant species selected for our study, *P. auriculata*, *L. indica* 'Natchez', and *L. muscari* 'Big Blue' are anecdotally categorized as having medium, high, and medium drought tolerance, respectively (24). This may suggest that these species would perform acceptably with less irrigation than supplied by the lowest treatment in the study. If species with a higher maximum water requirement were selected, then we may have shown growth differences between irrigation treatments. Therefore, these results suggest that further research should be conducted to determine the effects of irrigation using ET controllers or other irrigation controllers that reduce irrigation inputs on plant species with higher water demands.

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