Facing urban water challenges with integrative irrigation techniques in drought-prone areas.

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This study aids consumers with reducing outdoor water use by implementing an integrative irrigation technique and drought-tolerant plants in their landscape. This study analyzes the performance of 97 ornamental landscape species in Central Texas to provide consumers with an index to identify the highest performing plants using four ET-based irrigation treatments: 0.6, 0.4, 0.2 and 0.0 of Evapotranspiration. Results show that there is no significant difference between the overall appearances 0.6 ETo and 0.4 ETo treatments and some plants can survive a period of drought with no supplemental irrigation. Limiting factors to this technique are discussed for future policy making.

Introduction

Water is a major limiting factor for maintaining the aesthetic performance of ornamental landscape plants. The public uses various sources of information to determine the watering needs of plants, from use of peer-reviewed articles to qualitative assessments of plant performance. This interest is driven in Central Texas by variable weather, rainfall, and a history of prolonged periods of drought. In a period of drought, plant desiccation can be especially concerning, prompting over-watering and a higher peak demand for water. Typically, outdoor irrigation can range from 25% to 50% of total residential water use in Texas (Hermitte & Mace., 2012), and landscape irrigation tends to increase substantially during (1) dry periods of the year, such as during summer, and (2) dry years, such as the Texas drought of 2011 (Hermitte & Mace, 2012). This suggests that outdoor water use is a key area for potential water savings in household and commercial water use and can be realized through adjusted landscape practices.

Studies even show that high quality landscaping can result in 11% to 17% returns in sales price for residential homes and higher rents for office buildings (Henry, 1999; Laverne & Winson-Geideman, 2003; Behe et al., 2005; Stigarll & Elam, 2009). When designed properly, drought-tolerant landscapes can reduce declines in property values that result from drought or watering restriction-induced landscape mortality (Hilaire et al., 2008).

However, there is often still an over-application of irrigation water to native ornamentals and in most cases landscape plants receive an excessive amount of water in residential landscapes (Kjelgren, Rupp & Kilgren et al., 2000; White et al., 2004). In fact, ornamental appearances can remain at an acceptable level over a large range of ET-based irrigation levels (Montague et al., 2007; Smeal et al., 2010).

Evapotranspiration (ET) is a process that describes the water a plant loses through evaporation and transpiration. ET, along with potential evapotranspiration (ETo), are used to determine irrigation rates. Potential evapotranspiration (ETo) is an estimate of ET calculated using the Penman-Montieth equation and climatic data such as temperature, dew point, wind speed, and solar radiation (Romero & Dukes, 2010). In drought-related experiments, it is common to use ET-based irrigation treatments (Devitt, Morris & Neuman, 1994; Costello et al., 2000; Beeson, 2006) and to compare soil volumetric moisture content with plant appearance to establish water requirement or drought tolerance (Chai et al., 2010). Treatments have used the entire range of possible ET replacement irrigation strategies from zero percent (0.0 ETo) to full evapotranspiration replacement (1.0 ETo) (Beeson, 2006; Henson, Newman & Hartley et al., 2006). Because of continued horticultural experimentation, ornamental species can be categorized and used to model accurate irrigation recommendations (Costello et al., 2000; Beeson, 2005).

The study identified seven key measures that are important in conducting a plant demonstration. (1) Consumer interest in drought-resilient landscapes. (2) Recommended establishment periods. (3) Irrigation treatments that mimic both drought conditions and consumer management. (4) Establishing a visual assessment scale to document plant stress response to irrigation treatments. (5) Providing the significance of soil moisture as a determinant of irrigation treatment and soil moisture content. (6) Use of a plant performance index to convey results helpful to the consumer. (7) Consideration of drought tolerant plants and drip irrigation as an efficient water conservation mechanism.

Methodology

The study tested the drought survivability of 97 ornamental landscape plants (Table 1). Plants were selected based on popular landscape guides in Central Texas to represent consumer interest. A roundtable was conducted with horticulturists to finalize the plant list, and then the final plant list was subject to nursery availability. The Drought Survivability Study (DSS) was conducted in an outdoor demonstration site in San Antonio, TX.

Table 1. List of species included in the Drought Survivability Study.

1. Agarita (*Mahonia trifoliolata*)
2. American Beautyberry (*Callicarpa Americana*)
3. Anacacho Orchid (*Bauhinia lunaroides*)
4. Asiatic Jasmine (*Trachelospermum asiaticum*)
5. Bat-Faced Cuphea (*Cuphea llavea*)
6. Belinda's Dream Rose (*Rosa Belinda's Dream'*)
7. Bicolor Iris (*Dietes bicolor*)
8. Blackfoot Daisy (*Melampodium leucantum*)
9. Blue Grama Grass (*Bouteloua gracilis*)
10. Blue Liriope (*Liriope muscari 'Big Blue'*)
11. Blue Princess Verbena (*Verbena X hybrida 'Blue Princess'*)
12. Boxwood (*Buxus*)
13. Buford Holly (*Ilex cornuta 'Bufordii'*)
14. Bulbine (*Bulbine frutescens*)
15. Butterfly Vine (*Mascagnia macroptera*)
16. Carolina Jessamine Vine (*Gelsemium sempervirens*)
17. Cemetary Iris (*Iris albicans*)
18. Cenizo (*Leucophyllum frutescens*)
19. Chile Pequin (*Capsicum annuum*)
20. Compact Nandina (*Nandina domestica 'Compacta'*)
21. Confetti Lantana (*Lantana camara*)
22. Coral Honeysuckle (*Lonicera sempervirens*)
23. Cotoneaster (*Cotoneaster frigidus*)
24. Creeping Juniper (*Juniperus horizontalis*)
25. Crepe Myrtle (*Lagerstroemia x. hybrid*)
26. Cross Vine (*Bignonia capreolata*)
27. Daylily (*Hemerocallis sp.*)
28. Dutch Iris (*Iris hollandica*)
29. Dwarf Chinese Holly (*Ilex cornuta 'Rotunda'*)
30. Dwarf Nandina (*Nandina domestica 'Firepower'*)
31. Esperanza (*Tecoma stans*)
32. Evergreen Sumac (*Rhus virens*)
33. Fall Aster (*Symphyotrichum oblongifolium*)
34. Fall Obedient Plant (*Physostegia virginiana*)
35. Firebush (*Hamelia patens*)
36. Flowering Senna (*Senna corymbosa*)
37. Four-nerve Daisy (*Tetraneuris scaposa*)
38. Garden Phlox (*Phlox paniculata*)
39. Gaura (*Gaura lindheimeri*)
40. Glossy Abelia (*Abelia x grandiflora*)
41. Grandma's Yellow Rose (*Rosa 'Nacogdoches'*)
42. Gregg Salvia (*Salvia greggii*)
43. Gulf Muhly-5gal (*Muhlenbergia Capillaris*)
44. Gulf Muhly-1 gal (*Muhlenbergia Capillaris*)
45. Henry Duelberg Salvia (*Salvia farinacea 'Henry Duelberg'*)
46. Indian Grass (*Sorghastrum nutans*)
47. Jerusalem Sage (*Phlomis fruticosa*)
48. Knock Out Rose (*Rosa Knock Out*)
49. Large Daylily (*Hemerocallis sp.*)
50. Lindheimer Muhly-5gal (*Muhlenbergia lindheimeri*)
51. Lindheimer Muhly-1 gal (*Muhlenbergia lindheimeri*)
52. Little Bluestem (*Schizachyrium scoparium*)
53. Martha Gonzales Rose (*Rosa 'Martha Gonzalez'*)
54. Mexican Bush Sage (*Salvia leucantha*)
55. Mexican Dwarf Petunia (*Ruellia brittoniana*)
56. Mexican Feathergrass (*Nassella tenuissima*)
57. Mexican Honeysuckle (*Justicia spicigera*)
58. Mexican Mint Marigold (*Tagetes lucida*)
59. Mexican Oregano (*Lippia graveolens*)
60. Milkweed (*Asclepias curassavica*)
61. Mistflower (*Conoclinium greggii*)
62. Monkey Grass (*Liriope sp.*)
63. Moy Grande Hibiscus (*Hibiscus 'Moy Grande'*)
64. Mutabilis Rose (*Rosa 'Mutabilis'*)
65. Mystic Spires Salvia (*Salvia Longispicata x farinacea*)
66. New Gold Lantana (*Lantana x hybrida 'New Gold'*)
67. Nolina (*Nolina sp.*)
68. Oleander (*Nerium oleander*)
69. Photina (*Photinia sp.*)
70. Pittosporum (*Pittosporum sp.*)

Table 1 continued. List of species included in the Drought Survivability Study.

71. Plumbago (*Plumbago auriculata*)
72. Pomegranate (*Punica granatum*)
73. Possumhaw Holly (*Ilex decidua*)
74. Pride of Barbados (*Caesalpinia pulcherrima*)
75. Primrose Jasmine (*Jasminum mesnyi*)
76. Prostrate Rosemary (*Rosmarinus officinalis 'Prostratus'*)
77. Purple Coneflower (*Echinacea purpurea*)
78. Purple Fountaingrass (*Pennisetum setaceum 'Rubrum'*)
79. Purple Heart (*Tradescantia pallida*)
80. Red Yucca (*Hesperaloe parviflora*)
81. Rock Rose (*Pavonia lasiopetala*)
82. Rosemary (*Rosmarinus officinalis*)
83. Sabal Minor Palm (*Sabal minor*)
84. Sago Palm (*Cycas revoluta*)
85. Sandankwa Viburnum (*Viburnum suspensum*)
86. Santolina (*Santolina chamaecyparissus*)
87. Skullcap (*Scutellaria suffrutescens*)
88. Society Garlic (*Tulbaghia violacea*)
89. Texas Mountain Laurel (*Sophora secundiflora*)
90. Texas Sotol (*Dasylirion texanum*)
91. Thyrallis (*Galphimia glauca*)
92. Turk's Cap (*Malvaviscus arboreus*)
93. Variegated Liriope (*Liriope muscari 'Variegata'*)
94. Viburnum Tinus (*Vibarnum tinus*)
95. Yaupon Holly (*Ilex vomitoria*)

96 Yellow Columbine (*Aquilegia chrysantha*)

97. Zexmania (*Wedelia texana*)

The experiment was conducted in Lewisville silty clay (fine-silty, mixed, thermic Udic Calciustolls). The experimental area was a 5,000-square-foot demonstration site, divided into four even plots and equipped with a drought simulator (i.e. moveable roof) to cover treatments 0.0 ETo and 0.2 ETo if rainfall was detected. The soil in all four plots was lightly tilled to reduce compaction and minimize root growth restrictions. Irrigation was applied using drip irrigation with 2-gallon emitters and species were planted at ground level without any restrictions to soil depth. Plants were spaced to mimic crowded residential landscape conditions, with typical root competition.

Research Plot Management

After a plant is moved to a new environment, an establishment period is used to avoid moisture stress and promote plant growth after planting (Watson, 2000). In this study, the establishment period began in February 2015 and continued until July 2015. During the establishment period, glyphosate was applied to control unwanted vegetation along with routine mowing, chemical treatments, hand weeding and two to three inches of mulch. Based on a soil test result, nitrogen soil treatment was applied to normalize soils.

Irrigation

Climatological data was obtained from the San Antonio North weather station from the Texas ET Network for ETo estimates using the Penman-Montieth equation (Montieth, 1965). Irrigation was applied at 0.6, 0.4, 0.2, and 0.0 of historical monthly ETo then adjusted to account for monthly rainfall or higher ETo. Except for the 0.0 ETo plot, all plots were irrigated twice a week. Rainfall was also added to the total water received in treatments 0.4 and 0.6 ETo since the roof did not cover these plots during rain events. Actual percent ETo irrigated was calculated using total inches irrigated in each plot based on runtimes over total ETo for the treatment period.

Data Collection

For the drought treatment period, appearance and soil moisture data were collected weekly by the DSS team and volunteers across San Antonio including the Bexar County Master Gardeners, landscaping professionals, and San Antonio residents all with some horticultural experience. The study used plant stress as it can be commonly gauged using physiological or appearance measures (Chaves et al., 2002; Chalmers et al., 2008; Domenghini et al., 2013). Studies typically use a 1-9 scale or a 1-5 scale from low to high aesthetic quality to assess appearances of plants (Pittenger et al., 2001, 2009; Henson, Newman & Hartley, 2006; Scheiber et al., 2007, 2008; Domenghini et al., 2013). In this study, appearance ratings were assessed based on a scale of 0-5 where (0) dead, (1) defoliated, (2) leaf drop, (3) wilt, (4) stable, and (5) lush.

Soil moisture data is an accepted physiological water stress measurement (Jones, 2004, 2007; Chai et al., 2010). Thus, volumetric soil moisture content was measured using a FieldScout TDR (time-domain measurement technology) 100 Soil Moisture Meter with 3-inch probes for 11 indicator-plants every week during the duration of the project. The indicator plants were randomized within each plot and used to assess the effects of each irrigation treatment.

After the drought treatment period, the recovery period began in December 2015 and continued until March 2016. Irrigation was turned off for all plots, and the roof remained in a neutral position so that plants only received natural rainfall to recover following the drought treatment period. The same appearance guidelines were used to record plant appearances and soil moisture in all plots during the unirrigated period.

Results

Soil Moisture

Average soil moisture content was measured using soil moisture data collected in each plot every week from 10 July 2015 to 25 September 2015 (Figure 1).

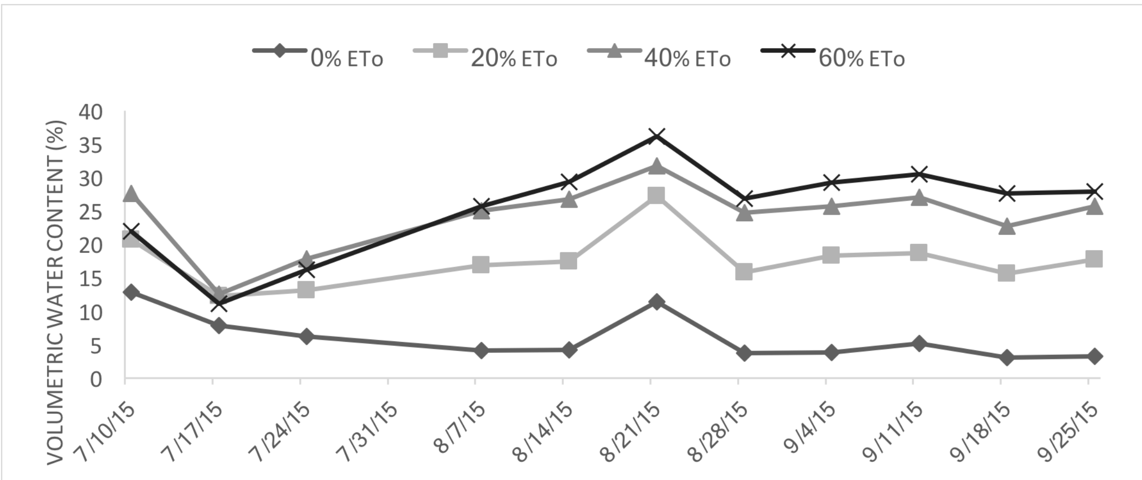

Figure 1. Soil moisture levels by irrigation treatments from 10 July 2015 to 25 September 2015.

The roof malfunctioned during a rain event on 14 August 2015 and caused an increase in volumetric moisture content (Figure 1). Precipitation from this event was added equally across irrigation treatments to limit the impact on irrigation treatment effectiveness since volumetric moisture differences continued to be observed after 14 August 2015.

Average Plant Appearance

An overall analysis of the average appearances ratings for each treatment showed that all plants began with (5) lush or (4) stable appearances. For the 0.0 ETo treatment, plants steadily declined to levels of (2) defoliated or (1) leaf drop. Both overall average appearances for the 0.4 ETo and 0.6 ETo treatments stayed between (4) stable or (5) lush and performed almost identically (Figure 2).

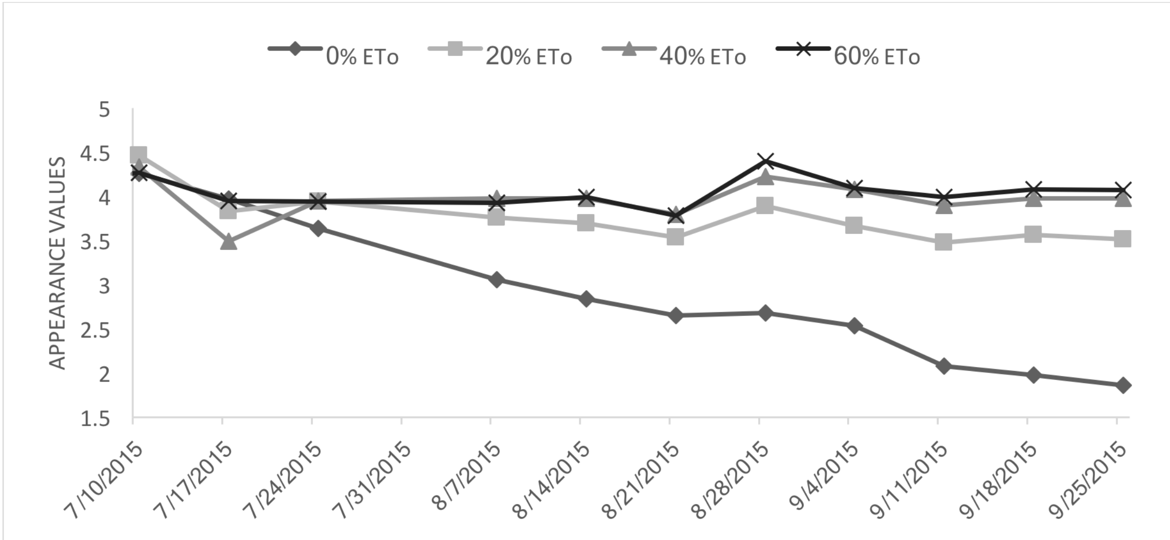

Figure 2. Average appearance rating for all plants within irrigation treatments from 10 July 2015 to 25 September 2015.

The study used log-transformed, (Log (x+1)), appearance values due to unequal variances. Overall performance of all species as measured by appearance differed significantly between all treatments except between 0.6 ETo and 0.4 ETo ($p < 0.05$), as shown in Table 2. Within the 0.2 ETo treatment, the plants consistently performed between appearance values 3 (wilt) and 4 (stable). Plants in 0.0 ETo treatment, or no irrigation, declined at a rate of 59% during the drought treatment period. Significant differences among treatment means were made using Tukey's HSD test at α=0.05.

Table 2. Mean appearance values for all plants in four irrigation treatments.

Treatment				Mean
0.6 ETo	A			4.064
0.4 ETo	A			4.030
0.2 ETo		B		3.784
0.0 ETo			C	2.916

*Treatments not connected by the same letter are significantly different ($p<0.05$).

Plant Performance Index (PPI)

A plant performance index was created to readily convey plant performance in terms of water use. A performance index is a useful measure in counting the number of times an entry occurred in the top statistical group across all parameters (Wherley et al., 2011;

Zhang et al., 2016). The Plant Performance Index (PPI) compared the highest and lowest performing species for each treatment.

For the study, appearance values stable (4) and lush (5) represent the highest performing plants. The appearance values dead (0), defoliated (1), leaf drop (2), and wilt (3) were assumed to represent plant performance that would be undesirable in a typical landscape. The four treatment columns in the PPI (Figure 3) represent plant performances in each respective treatment over the entire 12-week period. Figure 3 is a shortened version of the Plant Performance Index, see the report for the full list (Truong et al., 2016).

0.0 ETo		0.2 ETo		0.4 ETo		0.6 ETo	
Cenizo	125	Esperanza	144	Boxwood	144	Boxwood	144
Chile Pequin	114	Flowering Senna	144	Gaura	144	Confetti Lantana	144
Mistflower	102	Knock Out Rose	137	Esperanza	140	Red Yucca	141
Indian Grass	99	Oleander	137	Indian Grass	140	Santolina	141
Mexican Honeysuckle	48	Moy Grande Hibiscus	115	Blue Grama Grass	127	Asiatic Jasmine	130
Society Garlic	43	Anacacho Orchid	108	Rosemary	126	Gulf Muhly	129
Thyrallis	42	Bulbine	106	Zexmania	126	Indian Grass	129
Blue Liriope	28	Blue Liriope	72	Gregg Salvia	98	Texas Mountain Laurel	105
Asiatic Jasmine	26	Primrose Jasmine	70	Texas Mountain Laurel	95	Jerusalem Sage	102
Coral Honeysuckle	25	Milkweed	69	Fall Obedient Plant	92	Viburnum Tinus	101
American Beautyberry	24	Dutch Iris	66	Agarita	89	Cemetary Iris	91
Glossy Abelia	24	Sago Palm	64	Possumhaw Holly	84	Gregg Salvia	91
Yaupon Holly	22	Mexican Mint Marigold	49	Monkey Grass	71	Glossy Abelia	75
Buford Holly	20	Monkey Grass	42	Mexican Mint Marigold	69	Moy Grande Hibiscus	74
Nolina	12	Viburnum Tinus	38	Mexican Oregano	58	Nolina	58
Purple Coneflower	12	Bat Faced Cuphea	34	Dwarf Chinese Holly	49	Dwarf Nandina	56
Dwarf Chinese Holly	7	Purple Coneflower	24	Blue Princess Verbena	35	Blue Liriope	43
Carolina Jessamine Vine	6	Yellow Columbine	24	Dwarf Nandina	33	Pittosporum	33
Cemetary Iris	3	Mexican Oregano	20	Pittosporum	33	Purple Coneflower	30

Figure 3. Shortened Plant Performance Index with only 55 species.

In the 0.0 ETo treatment, 21% of plants performed in the top quartile. Plants that performed in the top 25% quartile in the 0.0 ETo treatment can be expected to withstand a 12-week drought period with no supplemental irrigation. These plants are especially valuable during drought periods and can potentially reduce peak water demands for water purveyors

As percentage ETo irrigation increased, the percentage of plants in the top quartile increased while the percentage of plants in the last quartile decreased. As more irrigation was applied, most plants such as Bat-faced Cuphea (*Cuphea llavea*) responded with increased performance Fall Aster (*Symphyotrichum oblongifolium*) remained in the top 25% quartile in all treatments and responded with increased blooms as more irrigation was applied. These performances indicate some plants can thrive in water-limiting environments whereas some may show signs of wilt and/or have decreased aesthetic appeal such as a reduction in flower production.

As referenced in Table 2, overall plant performance assessments among treatments 0.4 ETo and 0.6 ETo are not significantly different ($p<0.05$). The mean appearance ratings for all plants over the 12-week drought treatment period are similar (0.4 ETo = 4.030 and 0.6 ETo = 4.064). These performances indicate that similar overall plant performances could be achieved with a lower ETo treatment and result in substantial water savings. A 0.4 ETo irrigation regime represented a savings of 8 gallons or 3.2 inches of irrigated water per plant when compared to the 0.6 ETo plot over the 12-week period of this study (Table 3). This was observed with species such as Henry Duelberg Salvia (*Salvia farinacea 'Henry Duelberg'*) and Jerusalem Sage (*Phlomis fruticose*), which maintained similar performances in treatments 0.4 ETo and 0.6 ETo.

More significantly, plants that performed well across all treatments such as Oleander (*Nerium oleander*) can perform well with no irrigation compared to a 0.6 ETo based irrigation, which provides 25 gallons or 10.4 inches of water savings over a 12-week period of drought (Table 3).

Table 3. Total irrigation and ETo irrigated in each plot over treatment period.

	0.6 ETo	0.4 ETo	0.2 ETo	0.0 ETo
Total Irrigation and precipitation (inches)	10.4	7.2	3.9	0
Total Irrigation and precipitation (gallons/per plant)	25	17	9	0
Actual ETo received	0.55	0.38	0.20	0
Irrigation received twice a week (minutes)	37-40	23-25	10-13	0

The recovery period began in December 2015 and continued until March 2016 with normal amounts of rain. The purpose of this period was to see if any plants from 0.0 ETo and 0.2 ETo plots could make a recovery with only rainfall after a drought period. Table 4 lists plants with declined appearances and plants that recovered at the end of the recovery period.

Table 4. List of plants with declined appearances and a list of recovered plants in 0.0 ETo at the end of the recovery period.

Declined Appearance	Recovered Plants
Butterfly vine	Agarita
Chile Pequin	Belindas Dream Rose
Confetti Lantana	Boxwood
Esperanza	Bulbine
Fall Aster	Cemetary Iris
Firebush	Compact Nandina
Gaura	Crepe Myrtle
Mexican Bush Sage	Cross Vine
Pride of Barbados	Daylily
Turks Cap	Dutch Iris
	Evergreen Sumac
	Four Nerve Daisy
	Jerusalem Sage
	Knock Out Rose
	Martha Gonzales Rose
	Mexican Mint Marigold
	Mutabilis Rose
	Mystic Spires Salvia
	Photina
	Possumhaw Holly
	Primrose Jasmine
	Rosemary
	Sandankwa Viburnum
	Texas Mountain Laurel
	Thyrallis

Water Conservation with Drip Irrigation

Drip irrigation is encouraged in central Texas with benefits, which include water and energy savings as well as healthier plants (Texas Water Development Board, 1993). In drought-prone areas, drip irrigation is encouraged to minimize evaporative losses and reduce energy consumption compared to traditional rotary spray based irrigation (Jobbins et al., 2015). However, these savings are not always realized with drip-irrigation due to over-watering (Ophradt, 2007). This perception of inefficiency can slow investment in drip irrigation.

Water does not have an even distribution for time and space during a period of drought. Peak demand is normally recorded during summer periods where ET levels are noticeably higher due to dryer and warmer conditions. In a period of drought, these demands are heightened and can cause supply shortages. The Texas Commission on

Environmental Quality (TCEQ) requires all public water suppliers to submit and implement a drought contingency plan when applying for or amending a water right (30 TAC §288.20). These plans include twice-a-week or once-a-week irrigation restrictions depending on water levels.

While these drought contingency plans restrict water use, an approach to reduce conflict with landscape managers is the use of ET-based irrigation with drought tolerant plants. However, a lack of demonstrated results have hindered investment in drip irrigation and use of drought tolerant plants. Water purveyors and landscape managers can benefit if material existed on plant performance at varying conditions of water limitations.

Other limiting factors to integrative irrigation adoption are lack of data on the watering requirements for water-reducing of “drought tolerant” plants, homeowner associations (HOAs) requirements for traditional turf landscapes, and programs that offer incentives to cap irrigation zones without the assurance plant survival in drought conditions.

This study generated watering data on drought tolerant plants and evaluated plant performance at varying water levels, thus addressing factors that have historically hindered adoption of drip irrigation or use of drought tolerant plants. By addressing this lack of data, economic losses to the landscaping industry can be avoided during a period of drought.

Discussion and Implications

This ambitious study is one of the first to attempt to quantify the performance of many Central Texas landscape plants at various volumetric soil moisture levels created by irrigation water supplied at various fractions of estimated evapotranspiration (ETo). The data generated by the DSS provides a basis for a water-conserving plant selection approach without sacrificing landscape aesthetics.

As part of the process for long-term water conservation and plant health, an appropriate establishment period to ensure root health and stability is required. A three- to four-month establishment period is suggested before exposing plants to water-limited conditions based on a review of published literature. Immediate exposure of plants to limitations in soil plant available water, while contributing to water savings, will not contribute to landscape plant establishment success.

Consumers can determine an ETo irrigation level that fits their needs and populate their landscapes with similar plants to achieve the same aesthetic performance over time. When planted together, plants that performed within the same PPI quartile should perform similarly in landscapes. Plants that fall in the top quartile can be planted together under the same irrigation treatment and expected to remain either “stable” or “lush.” Thus, water efficiency can be achieved because groupings of plants are not being overwatered or underwatered. This would allow more efficient irrigation management, particularly if ETo is used as a basis of plant irrigation. For ETo-based irrigation to be effective, however, a more robust network of weather stations is needed to support efficient irrigation efforts in Central Texas.

Treatments 0.6 ETo and 0.4 ETo were not significantly different for mean appearance values. In general, a maximum coefficient of 0.4 ETo for landscape plant irrigation would result in substantial water savings in landscapes with drought resilient plants. Additionally, a landscape with no irrigation or 0.2 ETo irrigation with a selection of robust plants can be expected to withstand a period of drought while maintaining aesthetic appearances. Recovery of drought-stressed plants also occurred within the recovery period of this study.

Additional evaluation of plants included in this study as well as others would strengthen the results demonstrated and may provide additional choices for use in water-conserving landscapes in Central Texas. The DSS assessed plant appearance but did not account for other plant performance indexes such as plant height or overall biomass. Thus, plants in other plots may have performed similarly but with stunted growth, or reduced biomass. A considerable amount of research remains, such as a standardized method to assess the water needs of landscape species and a discussion on experimental design and methods with proper randomization. The study included 97 species common to a Central Texas landscape; however, research can be extended to include species in other environments or Ecoregions.

Drought management restrictions reduce irrigation to twice-a-week or once-a-week in Texas and are largely considered aesthetically harmful to residential and commercial landscapes. This study concludes that water restrictions may not necessarily reduce plant appearances if consumers are able to irrigate at 0.4 ETo. Additionally, proper marketing for drought tolerant plants and drip irrigation can influence watering decisions without restricting consumer interest or harming the landscaping industry.

The study relied heavily on volunteer participation and benefitted from partnerships with local nurseries. Citizen science could be considered highly effective and readily translated into scientifically sound quantitative data. Additionally, public participation increased the feasibility of public adoption of the promoted irrigation management. It was sponsored by the utilities of the cities involved and included media coverage and communication outreach. Different levels of governance were a part of the “Drought Survivability Study” which aimed to reduce conflict and encourage collaboration during a period of drought. Urban communities facing water scarcity issues could target outdoor water use from a community-wide approach. Involving key stakeholders such as urban water managers, landscaping industries and practitioners who can employ these strategies can create synergies while avoiding conflict.

(Count: 5,065 words)

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