Irrigation and Climate Zone Trials of Perennial Plants for Sustainable Landscapes

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Abstract:

Unstable water supplies in the Western U.S. have become more uncertain due to increasingly drier winters and rising urban populations, and chemical laden runoff from over-watered urban landscapes threatens the health of waters that receive the runoff. In California, this has led to regulations on landscape planning and installation that require knowledge of plant water requirements and the use of water-conserving plants to balance turf water needs. However, there is very little research-based data on the water use of landscape plant species.

To address these issues, 2-year irrigation and climate zone trials were begun in 2005, 2007, 2009, and 2011 on landscape perennials considered by the University of California Davis Arboretum to be water-conserving, pest tolerant, and disease resistant. In each trial, ten species were evaluated on 4 levels of irrigation based on reference evapotranspiration (ET_0), the estimated amount of water loss from a reference crop. Six replicates of each species and treatment were planted and established on regular irrigation (80% of ET_0) the first year. The following May through October they received an irrigation treatment at 20, 40, 60, or 80% of ET_0. Monthly measurements and qualitative evaluations were made to assess differences between treatments. Many of the same plants were also placed in demonstration gardens in different climate zones across California where UC Master Gardeners evaluated their performance. In many cases, there were no significant differences between irrigation treatments in either plant growth or quality, while a few species showed slight differences in one or both areas. The plant water use data being generated in these trials is helping support the necessary transition to sustainable gardens in summer-dry Mediterranean climates.

INTRODUCTION

Urban water quality and availability have become areas of major concern for the summer-dry Western U.S. where water supplies have always been put under severe pressure by cyclical drought and demands from rising populations. California in particular receives no significant precipitation from May to October, and so, on average, 50% of urban water use is by public and private landscapes (Hanak and Davis, 2006). Too often this water is poorly applied and creates runoff which flows into storm drains carrying a wide variety of garden fertilizers and pesticides to rivers, wetlands, lakes, and the ocean (Bailey et al., 2000; Weston, et al., 2005).

In response to these issues, the California government has now mandated that all newly permitted landscapes include features that prevent runoff and carefully calculated water budgets that require knowledge of plant water use as a percentage of reference evapotranspiration (ET_0) (DWR, 2009). Unfortunately, the most commonly used reference, *The Water Use Classification of Landscape Species*, uses anecdotal information, since little research has been done to determine ornamental plant water use (Costello et al., 2000). The development of a research method to examine ornamental plant water requirements in the landscape was begun in 2005 (Reid and Oki, 2008).

Continuing refinement and expansion of the method has taken place in subsequent years in an effort to build a catalog of plant water use data to be used in maximizing landscape water use efficiency. These trials have focused on water-conserving, pest tolerant, disease resistant plants recommended by the University of California Davis Arboretum as “All-Stars” in their sustainable gardening outreach and plant introduction program in cooperation with the California Center for Urban Horticulture.

MATERIALS AND METHODS

In the 2007-2009 trials, 8 species were used: *Acacia boormanii*, *Ceanothus* × *pallidus* ‘Marie Simon’, *Cercocarpus montanus* var. *blancheae*, *Iris* ‘Canyon Snow’, *Leucophyllum langmaniae* ‘Lynn’s Legacy’, *Muhlenbergia dubia*, *Penstemon heterophyllus* ‘Margarita BOP’, and *Saponaria* × *lempergii* ‘Max Frei’. These plants are included in the UC Davis Arboretum All-Stars program. Twenty-four plants of each species were planted 2 m apart in rows 2 m apart in 2 completely randomized blocks. This allowed for 6 reps on each of 4 levels of irrigation. Rows were covered with 7-8 cm of chipped wood mulch 1 m wide with 1 m of bare ground between rows.

Four levels of irrigation were supplied to each row and water was delivered to each plant through two 7.5 L/hr drip emitters. Irrigation treatments were based on reference evapotranspiration (ET_0), the estimated loss of water to the atmosphere by the combined processes of evaporation (from soil and plant surfaces) and transpiration (from plant tissues) from a reference crop: well watered and maintained tall fescue turf grass. The California Irrigation Management Information System (CIMIS) provides online current and historical ET_0 data that is calculated from parameters collected from weather stations at 120 locations around the state. A local CIMIS station was monitored daily, and for the first year, trial plants were given regular water (80% of ET_0, the amount recommended for cool season turf) to allow them to establish their root system. Using a soil water deficit irrigation budget, the following year the plants were irrigated at 1 of 4 levels: 80%, 60%, 40%, or 20% of ET_0 (CIMIS, 2009). All plants were given 50% of the soil’s water holding capacity in the root zone (80 L) at each irrigation, but how often they received it was determined by the treatment percentage of ET_0.

Each plant was measured monthly to determine an average plant growth index (PGI) for each treatment using the formula $((l + w)/2 + h)/2$, where l, w, and h represent length, width, and height of the plant (Irmak, Suet et al., 2004). Length and width measurements were taken at right angles along and across the rows respectively. Relative indexes were calculated by dividing the monthly PGI by the pre-treatment PGI for each plant. Means and standard errors were calculated and ANOVA performed to determine statistical significance of any apparent differences between treatments. Plants were also rated in 5 quality categories: foliage appearance, flowering, pest tolerance, disease resistance, and vigor. One “overall appearance” rating was also given to reflect the combination of the previous factors. All ratings were on a scale of 1 to 5, with 1 being the lowest and 5 the highest quality.

Selections of these plants were also placed in demonstration gardens with conservative watering practices in 9 California counties representing 10 Sunset climate zones (Brenzel, 2007). UC Master Gardeners evaluated the plants in their climate zones by taking quarterly growth measurements and monthly quality ratings according to the same criteria as the irrigation trials. These data were compiled and compared across sites to help determine the effective growing range of the plants (Only quality ratings shown).

RESULTS AND DISCUSSION

Four of the 8 species evaluated showed the highest quality ratings on the lowest irrigation treatment (20% of ET_0): *Acacia boormanii*, *Ceanothus* × *pallidus* ‘Marie Simon’, *Cercocarpus montanus* var. *blancheae*, and *Penstemon heterophyllus* ‘Margarita BOP’. *Muhlenbergia dubia* was completely indifferent to irrigation treatment with respect to quality. Only *Iris* ‘Canyon Snow’ showed a preference for the highest water levels, though the lowest irrigation level also produced good quality plants. The remaining two species, *Leucophyllum langmaniae* 'Lynn's Legacy' and *Saponaria* × *lempergii* 'Max Frei', were best at 40% of ET_0, though either would also do well planted next to a lawn receiving 80% of ET_0 (Table 1). The quality ratings varied by county, and these data will be used to inform landscape professionals, retail distribution, and plant labels (Table 2).

Relative plant growth indexes are best combined with the quality ratings to get the complete picture of the recommended irrigation rate for a particular species (Table 1). *A. boormanii* showed no significant difference in growth between treatments, but the overall quality improved as the irrigation decreased (Fig. 1). The lowest irrigation rate would therefore be recommended. *C.* × *pallidus* 'Marie Simon' showed better growth on the 3 lowest treatments, with the 20% treatment significantly better than 80% of ET_0 (Fig. 2). However, it had a repeat fall bloom at 40% of ET_0, making either 20 or 40% of ET_0 reasonable irrigation recommendations. Two of the California native plants, *C. montanus* var. *blancheae* and *P. heterophyllus* 'Margarita BOP', showed no significant difference in growth between irrigation treatments, but the highest quality at the lowest water level (Figs. 3 and 7). Because there were no significant differences between treatments in either quality or plant growth for *M. dubia*, the lowest level of irrigation can be used, though no detrimental effects would be expected at higher levels (Fig. 6). The better growth at 60% of ET_0 for *Iris* 'Canyon Snow', though not statistically significant, when combined with the high quality ratings, make this the recommended irrigation level for this highly ornamental California native (Fig. 4). Both *L. langmaniae* 'Lynn's Legacy' and *S.* × *lempergii* 'Max Frei' showed insignificant differences in relative plant growth between treatments, but had the highest quality ratings at 40% of ET_0 (Figs. 5 and 8).

CONCLUSIONS

Most commercial and private landscapes in the Western U.S. are irrigated during the summer months at rates that are much higher than is sustainable (Hanak and Davis, 2006). To reduce water use, significant portions of these landscapes must be converted to plants that can maintain a high level of aesthetic quality on low levels of irrigation. The results of these studies demonstrate that there are landscape ornamentals available that will fill this need using significantly less water than the 80% of ET_0 required by most lawns. Additionally, most of them can be grown with fairly high quality ratings in a wide variety of Western climatic regions.

Knowing how often to irrigate a landscape and how much water to apply is an issue complicated by site specific conditions such as: water delivery method, soil type, species mix, and microclimate. Using ET_0 percentages as an indicator of a plant's water needs in conjunction with the knowledge of the soil's water holding capacity should provide a method for standardizing water application across climates, where the ET_0 information is locally available. Since the ET_0 will vary by region and the recommended irrigation rate is species dependent, the resultant application will vary based only on weather. However, it would be useful to evaluate this by replicating this trial method on the same species simultaneously at sites that vary significantly in climatic conditions. Currently, the trials field has been doubled in size to allow for alternate year planting and deficit irrigation so more species can be evaluated. We are also performing evaluations on species that prefer shade using the same method under 50% shade cloth. These data will be useful for landscape designers and managers, as well as homeowners who are looking to improve landscape water use efficiency.

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Tables

Table 1. Average quality ratings on a scale of 1-5[1] for 8 landscape species under 4 levels of deficit irrigation based on percentages of ET_0, with recommended irrigation level.

Plant species	Irrigation percentage of ET_0				Recommended rate
	80	60	40	20	(% of ET_0)
Acacia boormanii	3.4	4.5	4.7	4.9	20
Ceanothus × *pallidus* 'Marie Simon'	3.4	4.1	4.3	4.4	20-40
Cercocarpus montanus var. *blancheae*[2]	4.0	3.5	4.1	4.4	20
Iris 'Canyon Snow'[2]	3.9	3.9	3.4	3.8	60
Leucophyllum langmaniae 'Lynn's Legacy'	4.6	4.4	4.8	4.2	40
Muhlenbergia dubia	4.3	4.3	4.3	4.3	20
Penstemon heterophyllus 'Margarita BOP'[2]	4.2	4.2	4.1	4.8	20
Saponaria × *lempergii* 'Max Frei'	3.9	3.2	3.9	3.5	40

[1] On the rating scale, 1 is the lowest and 5 is the highest quality rating.
[2] California native.

Table 2. Average quality ratings on a scale of 1-5[1] for 7 landscape plant species at the end of the first year in demonstration gardens in 9 California counties.

Plant	County and Sunset Climate Zone											
	Alameda	Fresno	Mariposa	Nevada	Orange	Riverside	San Diego - coastal	San Diego - inland 1	San Diego - inland 2	San Joaquin	Santa Clara	Shasta
	14	8	7	7	22	18/19	23	24	21	14	15	9
Acacia boormanii	3.6				4.0	4.1		3.8	4.7	4.2	4.3	3.9
Ceanothus × *pallidus* 'Marie Simon'	4.0		4.8	4.1	3.6	3.9	4.3		3.9	4.0	3.6	4.3
Iris 'Canyon Snow'	4.1	5.0	4.6	4.7	3.6	4.0	4.3		4.6	3.7	4.4	3.7
Leucophyllum langmaniae 'Lynn's Legacy'	4.0			4.0	3.9	4.4	4.5	4.0	4.3			3.9
Muhlenbergia dubia	4.6	4.7		4.8	4.4	4.7	4.3		4.6	4.5	4.4	4.9
Penstemon heterophyllus 'Margarita BOP'	4.1	4.9	4.9	4.7	4.5	4.8	4.3	3.9		4.1	4.5	4.4
Saponaria × *lempergii* 'Max Frei'	4.0	4.5		4.5	3.3	3.8	4.4	3.8	4.2	4.1	4.1	3.6

[1]On the rating scale 1 is the lowest and 5 is the highest quality rating.

Figures

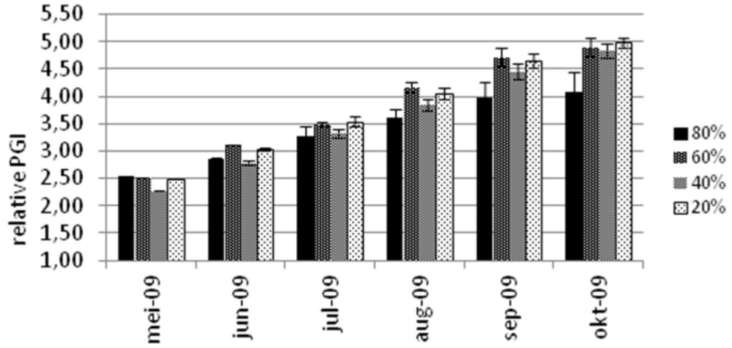

Fig. 1. *Acacia boormanii* relative plant growth index under 4 irrigation regimes based on percentages of ET_0 1 year after establishment. Error bars represent ±1 SE. ($p>.05$).

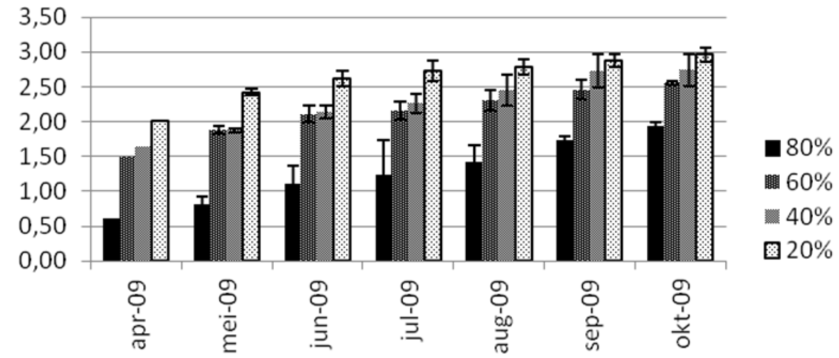

Fig. 2. *Ceanothus* × *pallidus* 'Marie Simon' relative plant growth index under 4 irrigation regimes based on percentages of ET_0 1 year after establishment. Error bars represent ±1 SE. ($p<.05$ between 20 and 80%).

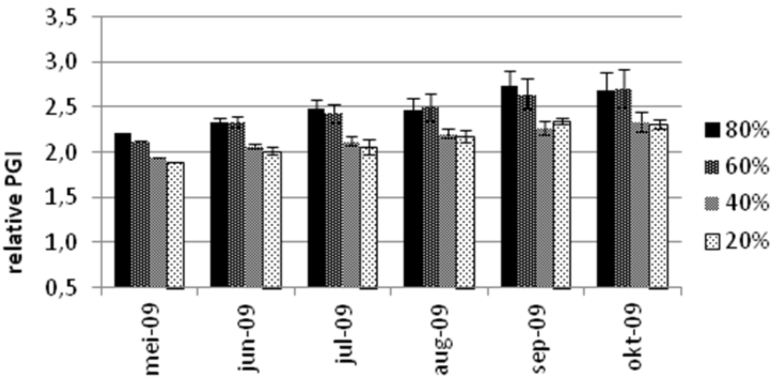

Fig. 3. *Cercocarpus montanus* var. *blancheae* relative plant growth index under 4 irrigation regimes based on percentages of ET_0 1 year after establishment. Error bars represent ±1 SE. ($p>.05$).

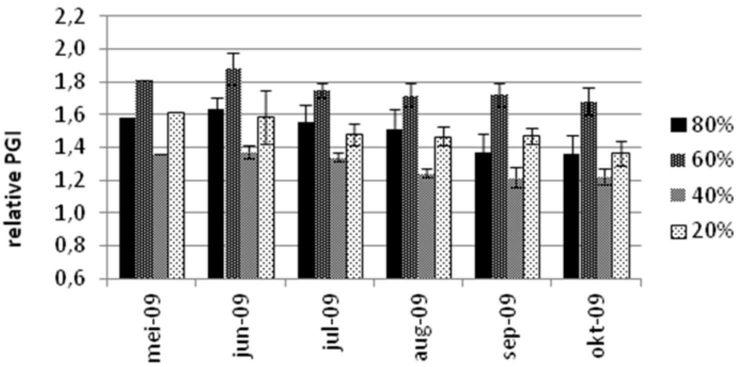

Fig. 4. *Iris* 'Canyon Snow' relative plant growth index under 4 irrigation regimes based on percentages of ET_0 1 year after establishment. Error bars represent ±1 SE. ($p>.05$).

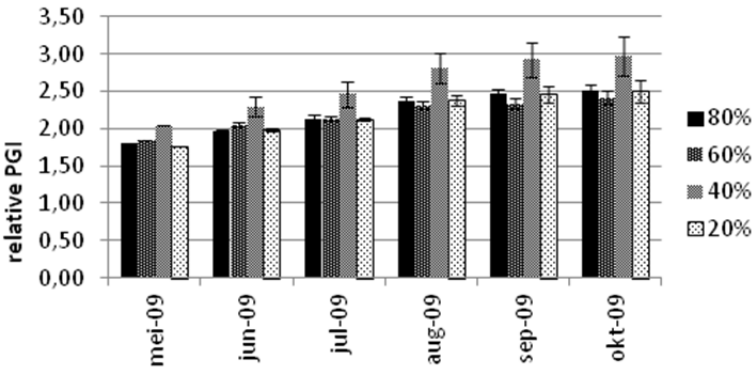

Fig. 5. *Leucophyllum langmaniae* 'Lynn's Legacy' relative plant growth index under 4 irrigation regimes based on percentages of ET_0 1 year after establishment. Error bars represent ±1 SE. ($p>.05$).

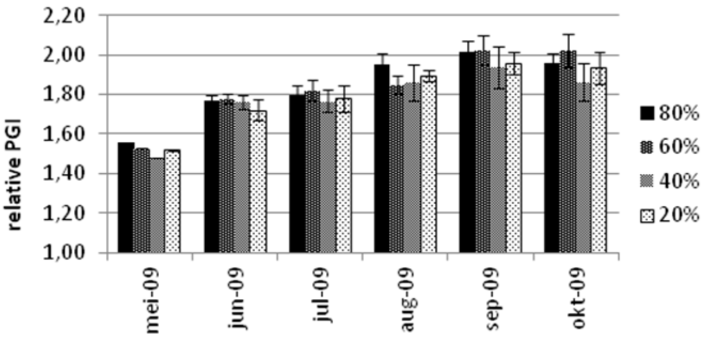

Fig. 6. *Muhlenbergia dubia* relative plant growth index under 4 irrigation regimes based on percentages of ET_0 1 year after establishment. Error bars represent ±1 SE. ($p>.05$).

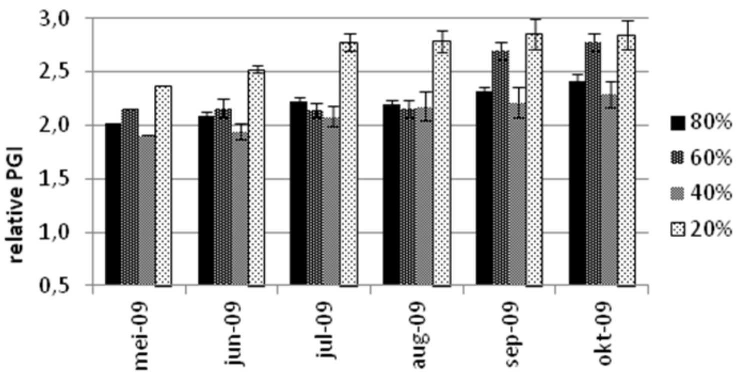

Fig. 7. *Penstemon heterophyllus* 'Margarita BOP' relative plant growth index under 4 irrigation regimes based on percentages of ET_0 1 year after establishment. Error bars represent ±1 SE. ($p>.05$).

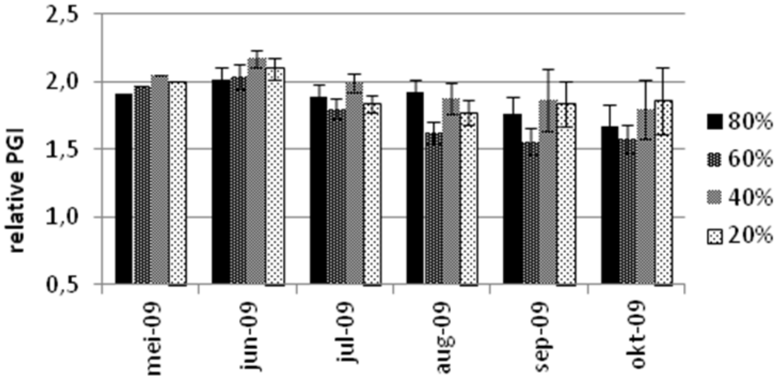

Fig. 8. *Saponaria × lempergii* 'Max Frei' relative plant growth index under 4 irrigation regimes based on percentages of ET_0 1 year after establishment. Error bars represent ±1 SE. ($p>.05$).