Final Report
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Evaluating the Water Usage and Climate Zone Tolerances of Potential "UC Davis Arboretum All-Stars" Plant Introductions for Shade

Principal Investigator:

Lorence (Loren) R. Oki, Ph.D., CE Specialist, Landscape Horticulture
Department of Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616-8780
(530) 754-4135 office
(530) 754 4883 fax
lroki@ucdavis.edu

Cooperators:

David W. Fujino, Director, California Center for Urban Horticulture, UC Davis
S. Karrie Reid, Staff Research Associate, UC Davis, Dept. of Plant Sciences
Ellen Zagory, Director of Horticulture, UC Davis Arboretum

Introduction and Project Goals

California's unpredictable rainfall and snow-pack levels have led to frequently recurring reservoir shortfalls. Growing population pressures in the state, which lead to an increasing need for water in urban and suburban landscapes, place an additional strain on all sources of this precious resource. Most plants currently available for use in these areas require large amounts of water, fertilizers, and pesticides which end up in run-off from poorly managed irrigation systems (Hanak and Davis, 2006). This in turn adversely affects the waterways receiving this run-off (Bailey et al, 2000). One significant factor in reducing these negative environmental impacts is to use a larger number of "low-input" landscape plants (those with fewer input requirements of water and chemicals).

Over the course of the last several years the first state-wide, university-coordinated, low-input plant evaluation and introduction program has been launched with the support and directing leadership of the California Center for Urban Horticulture (CCUH, 2009). Through this effort, the UC Davis Arboretum has begun to realize its goal of reaching a broad California audience with its message and its plant choices for sustainable urban landscapes. The Department of Plant Sciences has been supporting these goals with trials designed to establish water use ranges and climate zone tolerances of the Arboretum's plant selections. This project is part of the ongoing research trials.

The need for attractive shade plants that also fit the description of low-input species is made necessary by the continued expansion of housing and commercial development into areas of native oaks. These trees, which provide shade and beauty to the landscape, invariably suffer disease and eventual death if under-planted with turf or other plants requiring summer water (Hagen, 1990, Johnson, 1989). Additionally, homeowners are encouraged by many public utilities and non-profit agencies to plant drought-tolerant trees to conserve energy and reduce water waste. As more individuals,

municipalities, and landscape companies comply with these recommendations, there will be a growing need for plants that can live in the shade without large inputs of summer water. In order for these plants to find a wide market, they must be attractive enough to be appealing to the public. Shade plants which are also water-conserving are a real and growing need in the California horticulture market.

The "UC Davis Arboretum All-Stars" plant selections are comprised of California natives with ornamental potential and plants from other Mediterranean-type regions of the world, many of which are currently under-represented in the landscape horticulture market (UCD Arboretum, 2009). Many plants in this category are not only beautiful, but are adapted to our summer-dry climate by having low water needs and few disease problems. They also often attract and foster beneficial insects and birds that are pollinators and play a role in an integrated system of pest management, reducing the need for chemical control. These characteristics are useful not just to homeowners and landscapers, but to growers as well, who face strict regulations on waste water management (CalEPA, 2007).

The goal of this research expands the on-going "Arboretum All-Stars" irrigation trials to include an open field area with shade structure to evaluate potential introductions for dry shade at four irrigation levels. These plants are also provided to the demonstration gardens for evaluation in those climate zones.

Evaluating these plants for low-water use and a wide range of climatic tolerances before introduction provides the information necessary to promote the use of the plants with confidence. Growing them in demonstration gardens throughout the state creates the additional opportunity to educate the public on the environmental benefits of buying and using them and, by exposing the public to their beauty, create market demand.

Methods

Deficit Irrigation Trials

The field site was located on the University of California campus in Davis, CA. The field was manually weeded between rows and herbicide (Round-up) was applied around the perimeter of the field as needed. Throughout the trial, no pesticide or fertilizer treatments were applied to the plants.

The plants were planted in the ground under a 10 ft tall shade house with 50% black shade cloth, which was constructed with funding provided by this grant. The structure had shade cloth walls on the south, east, and west sides to ensure shading of all the plants throughout the day. Planting beds were mulched one meter wide and 3-4 inches deep with a one meter space between rows. Each row had four 1-inch water lines corresponding to one of the four irrigation treatments. Two 2-gallon/hour drip emitters attached to one of the four lines were installed near the base of each plant to supply irrigation. The plants and treatments were randomized throughout the field in two complete blocks.

Irrigation was based on reference evapotranspiration (ET_0). There were four treatment levels: 80%, 60%, 40%, and 20% ET_0. The plants were established during fall and winter of 2009 and spring and summer of 2011. The deficit irrigation treatments began in June, 2011 and continued through October, 2011. During the deficit irrigation treatments, the 80%, 60%, 40%, and 20% treatment levels received seven, five, four, and two irrigations, respectively.

Measurements of length (l), width (w), and height (h) were taken on a monthly basis. The plants were evaluated for growth using a plant growth index: $[(l + w)/2 + h]/2$. Qualitative ratings were also taken on a monthly basis. The plants were rated on a scale of 1-5 for foliage, flowering, vigor, and general appearance qualities; with 5 being perfect and 1 being extremely poor. The guidelines for rating are as follows:

- A "5" rating for foliage means the plant is in full leaf with no signs of leaf burn, disease or insect damage, and had an appealing appearance. A "1" would mean the plant was on its last legs and practically dead.
- A "5" for flowering would mean full, glorious bloom. A "1" would mean very poor, straggling bloom, damaged flowers, OR the plant is either just beginning to bloom with very few blooms open or finishing.
- A "5" for insect or disease resistance would mean no visible damage. A "1" would mean badly damaged and probably dying.
- A "5" for overall vigor would mean the plant is thriving, a "3" would mean it is surviving (not its best, but perhaps on its way back from transplant shock, animal browsing, mechanical damage or frost bite), and "1" would mean it is on its way out.

Five species are currently being trialed in the shade field. These species are: *Heuchera maxima, Woodwardia fimbriata, Osmanthus heterophyllus* 'Purpureus', *Helleborus* 'Lady' series, and *Ribes viburnifolium*.

Climate Zone Trials

Plants were distributed to 12 demonstration gardens in cities representing 11 UC Cooperative Extension county offices: Redding (Shasta), Grass Valley (Nevada/Placer), Palo Alto (Santa Clara), Livermore (Alameda), Stockton (San Joaquin), Mariposa (Mariposa), Fresno (Fresno), Sun Valley (Los Angeles), Riverside (Riverside), Irvine (Orange), and El Cajon and Point Loma (San Diego). Two of the gardens (Mariposa and Sun Valley) are devoted to California native plants and only received the three California native species (Table 1). UC Master Gardeners measure the plants quarterly and monthly report on general appearance, flowering, foliage characteristics and any pest or disease problems in their garden. At the end of each year, they make recommendations on the plants' suitability to their area.

Table 1. Number of trial plants in each of the participating Master Gardener programs

	Helleborus	*Heuchera*	*Osmanthus*	*Ribes*	*Woodwardia*
Alameda		3		1	
Fresno		3		3	3
Los Angeles		3		3	2
Mariposa		6		3	3
Nevada/Placer	6	3	3		6
Orange	3	3	3	1	3
Riverside	3	3	3	3	3
San Diego 4	5	5		3	3
San Diego 3			3		
San Joaquin				1	
Santa Clara	3	3	3	1	
Shasta	3	1		5	3

Results

Heuchera maxima

The *Heuchera* did not differ in growth between the treatments (figure 1). Although the 40% and 20% treatments were smaller than the 60% and 80% treatments, the difference is not great. The lack of difference in growth between treatments was also reflected in the performance ratings (table 2). As seen in table 2, all the ratings for the *Heuchera* were above three. Figure 2 shows the *Heuchera* in bloom in May. The 80% treatment did experience some mortality. Out of the six plants in the treatment, one died in June and a second in July, resulting in a 33% mortality rate for the 80% treatments; no plants were lost in the other three treatments.

Table 3 shows the average ratings for each plant by county. As seen, the Heuchera was rated high, above 4, in all the counties except Riverside. In October, the growth of the *Heuchera* plants in the Alameda and Nevada County gardens was significantly greater than those in the Orange, Fresno, and Mariposa gardens (figure 3). Based upon first year results, Riverside did not recommend this plant due to the level of heat at that location; this could explain the low rating the plant received in Riverside. Santa Clara County did not recommend this plant stating that the flowering was very subdued. As seen in figure 2, the blooms on this species of Heuchera are not as showy as some other species. This plant could be suitable to dry-shade landscapes where a brightly colored flower show is not necessary.

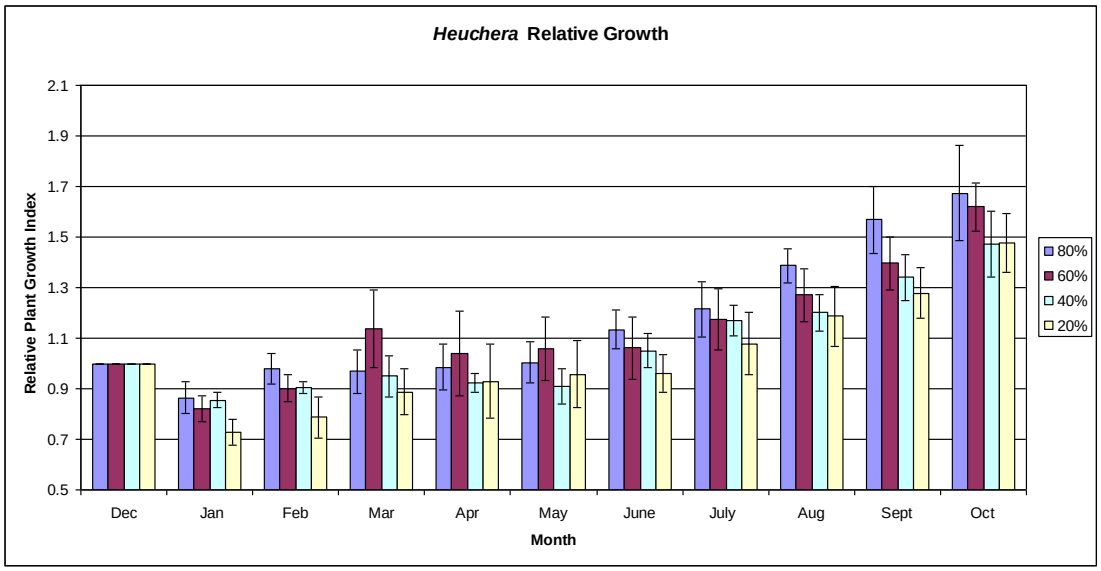

Figure 1. *Heuchera* relative growth across treatments based upon individual planting size. Error bars indicate ± standard error.

Table 2. *Heuchera* average performance and flower ratings across treatments for each month during the deficit irrigation period.

	May		**June**		**July**		**Aug**		**Sept**		**Oct**	
	flower	avg	flower	avg	flower	avg	flower	avg	flower	avg	flower	avg
80%	3.6	3.8		3.5		4.4		4.6		3.9		3.7
60%	4.0	3.8		3.9		4.1		4.6		4.4		4.7
40%	2.0	3.2		3.9		4.1		4.3		4.4		4.6
20%	3.3	3.4		4.2		4.3		4.5		4.5		4.8

Figure 2. *Heuchera maxima* plant in bloom in May.

Table 3. The average ratings of each species by county.

Average Rating by County											
	Alameda	Fresno	Mariposa	Nevada	Orange	Riverside	San Joaquin	Santa Clara	San Diego 3	San Diego 4	Shasta
Hellebore				4.4	3.8	2.9		4.1		4.1	3.1
Heuchera	4.3	4.7	4.1	4.4	4.5	3.4		4.3		4.5	3.8
Osmanthus				4.5	4.3	4.2		4.8	4.9		
Ribes	4.5	4.6	4.4		4.6	3.4	4.6	4.2		4.5	4.1
Woodwardia		3.9	3.9	4.4	4.5	2.1		4.3		3.6	3.8

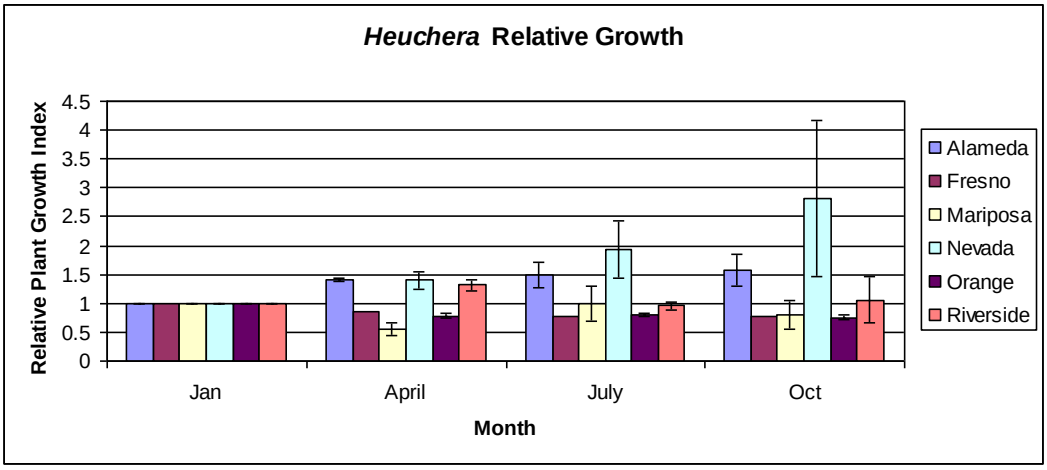

Figure 3. Relative growth of *Heuchera* in each county. Error bars indicate ± standard error.

Woodwardia fimbriata

This was the species with the most variation between treatments. The *Woodwardia* growth was not significantly different between the 80%, 60%, and 40% treatments. There was, however, greatly reduced growth in the plants under the 20% irrigation treatment (figure 4). By October, all of the plants in the 20% treatment appeared dead or had only one frond. This difference in treatments was also reflected in the *Woodwardia* monthly average ratings (table 4). Figure 5 shows a plant on the 80% treatment. The only time the 20% treatment had a rating of greater than three, was in August. At this time, all the ratings increased from those previously recorded; this could be due to slightly cooler weather than June and July. In July, there was a 17% and a 33% mortality rate for the 20% and 40% treatments, respectively.

All of the plants in each county were given an average rating above 3, with one exception (table 3). In Riverside, the *Woodwardia* received and average rating of 2.1. On average, the *Woodwardia* received the lowest ratings in each county. Orange County had the *Woodwardia* plants with the largest growth, which could be due to the fact that this is the county with the mildest summers (figure 6). The *Woodwardia* was not

recommended for Shasta County due to the extreme winter cold. It was also not recommended in the San Diego 4 garden (located in Encinitas), or the Riverside garden. This is a plant that does not seem to do well under conditions of low-water and heat. It is possible that the plant would perform well in a medium-water, deeply shaded area of the landscape.

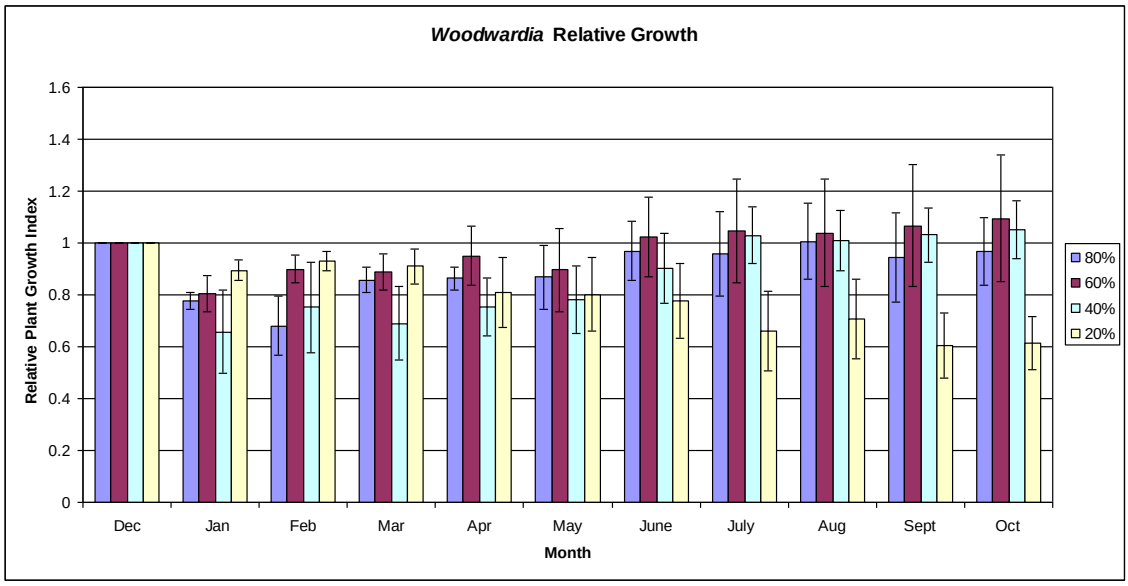

Figure 4. *Woodwardia* relative growth by treatment. Error bars indicate ± standard error.

Table 4. *Woodwardia* average performance ratings across treatments for each month during the deficit irrigation period.

	May		**June**		**July**		**Aug**		**Sept**		**Oct**	
	flower[1]	avg	flower	avg	flower	avg	flower	avg	flower	avg	flower	avg
80%		3.1		3.4		3.3		4.2		4.2		4.7
60%		3.1		3.4		3.4		3.7		3.7		4.0
40%		2.4		2.9		3.4		4.0		3.5		3.1
20%		2.7		2.3		2.6		3.1		2.7		2.6

[1]Non-flowering plant, no data collected

Figure 5. *Woodwardia fimbriata* on 80% treatment.

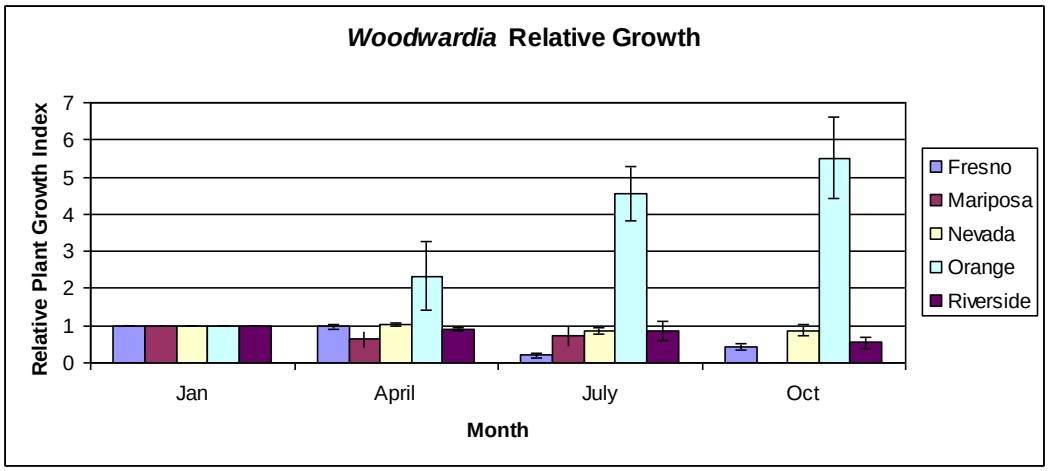

Figure 6. Relative growth of *Woodwardia* in each county. Error bars indicate ± standard error.

***Osmanthus heterophyllus* 'Purpureus'**

The *Osmanthus* treatments did not differ in growth until October (figure 7). From September to October, the 80% treatment did not increase in growth as the other three treatments did. This smaller size is significant between the 80% and the 60% treatments, but not the 40% or 20% treatments. Although there was a difference in growth at the end of the season, with the 80% treatment having a lower PGI than the 60% treatment, there was no difference in regards to ratings, with all the treatments having an average rating of greater than 4 (table 5). Figure 8 shows one of the *Osmanthus* plants with new growth. There was 0% mortality in the *Osmanthus* treatments; however, this species was occasionally eaten by rabbits and/or ground squirrels.

In October, the *Osmanthus* plants with the smallest growth were located in the Orange County garden (figure 9). The *Osmanthus* was not recommended for the Nevada/Placer County and the Orange County areas as it was found to be susceptible to sunburn and frost damage. This species was, also, not recommended by the Riverside garden due to heat. There was no evidence of sunburn under the 50% shade of the irrigation trials. It is possible that this plant could have performed in Orange County if it was planted in denser shade. This species could be suitable to dry-shade landscapes with a shade density of at least 50%.

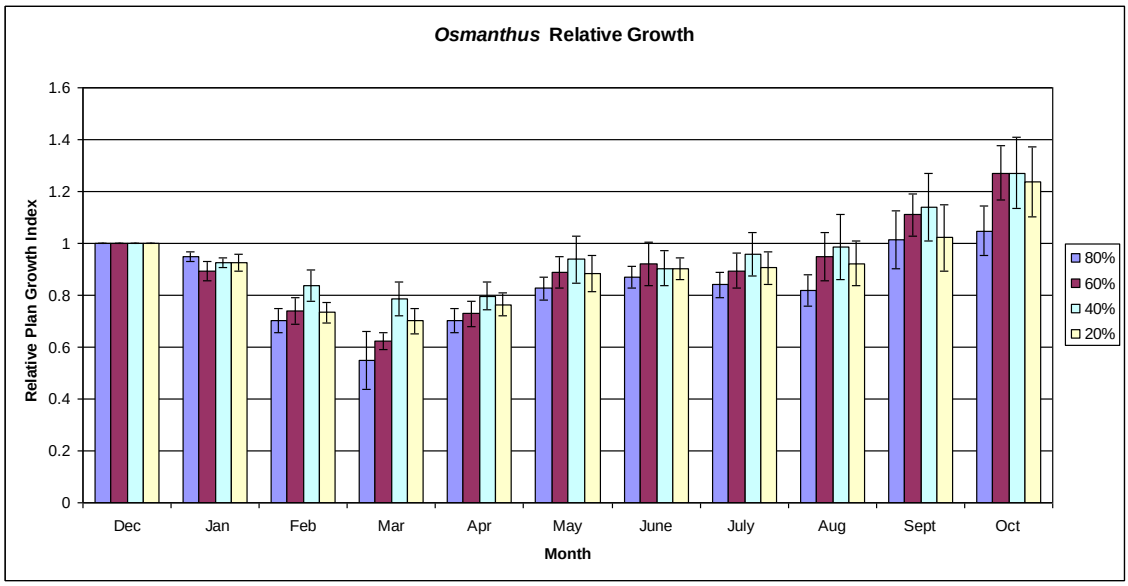

Figure 7. *Osmanthus* relative growth by treatment. Error bars indicate ± standard error.

Table 5. *Osmanthus* average performance ratings across treatments for each month during the deficit irrigation period.

	May		**June**		**July**		**Aug**		**Sept**		**Oct**	
	flower[1]	avg	flower	avg	flower	avg	flower	avg	flower	avg	flower	avg
80%		4.2		3.8		4.2		4.5		4.7		5.0
60%		4.5		4.0		4.3		4.7		5.0		5.0
40%		4.1		4.1		4.3		4.7		5.0		5.0
20%		4.6		4.1		4.2		4.7		4.5		5.0

[1]Did not flower during this year, no data collected

Figure 8. *Osmanthus heterophyllus* 'Purpureus' with new growth.

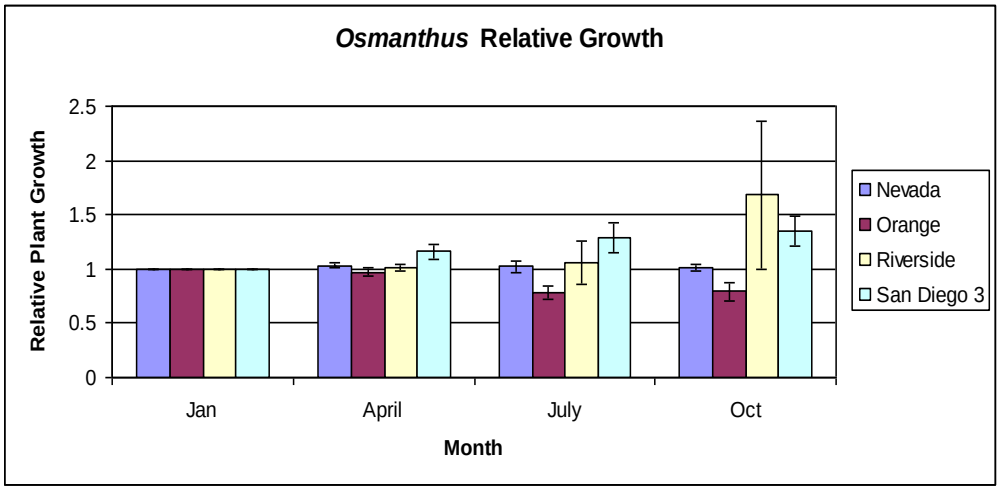

Figure 9. Relative growth of *Osmanthus* in each county. Error bars indicate ± standard error.

***Helleborus* "Lady Series"**

The *Helleborus* did not differ in growth between the treatments; however, in October the 80% treatments did have the lowest PGI, although not significantly different (figure 10). The lack of significant difference in growth of was also reflected in the performance ratings (table 6). As *Helleborus* is a winter flowering plant, there are no ratings while this plant was in full bloom. Figure 11 shows the plant in bloom in January. The flower ratings seen in table 6 represent the appearance of the old blooms that remained on the plant after flowering. In June, the old flower stalks were removed. As the weather cooled during the end of the growing season, the plants started growing new leaves and improving in both foliage quality and overall appearance. The *Helleborus* suffered from slight insect damage all season and aphids were observed on the old flower stalks before removal in June. There was no mortality under any treatment for this species.

In Riverside, the *Helleborus* received and average rating of 2.9 (table 3). In October, the *Helleborus* plants with the smallest growth were located in the Orange County garden (figure 12). This species was recommended by all the gardens, except for Riverside. Riverside did not recommend this species due to heat.

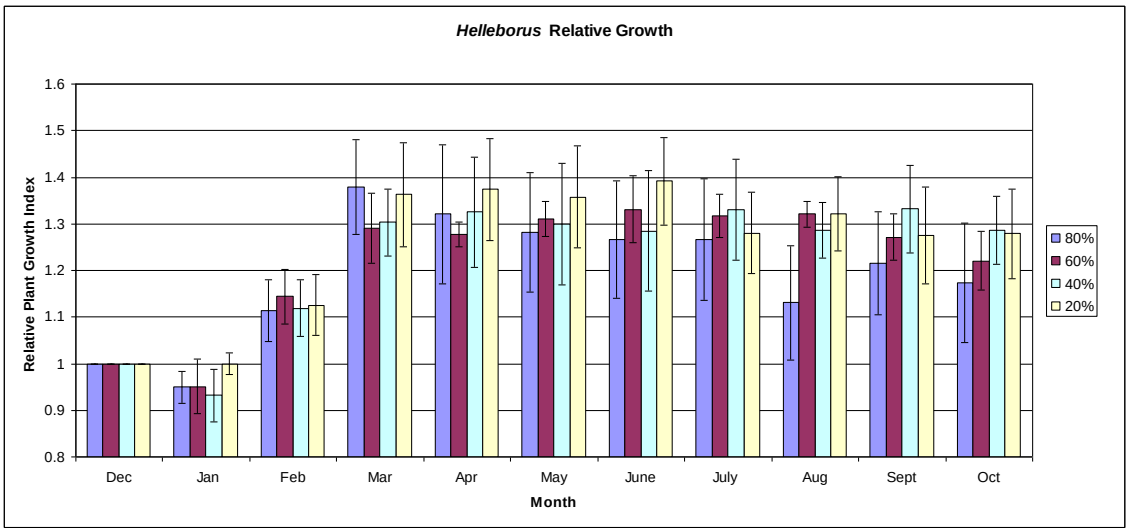

Figure 10. *Helleborus* relative growth by treatment. Error bars indicate ± standard error.

Table 6. *Helleborus* average performance and flower ratings across treatments for each month during the deficit irrigation period.

	May		**June**		**July**		**Aug**		**Sept**		**Oct**	
	flower	avg	flower	avg	flower	avg	flower	avg	flower	avg	flower	avg
80%	1.7	3.7	1.0	3.6		3.4		3.1		3.0		3.5
60%	2.2	4.1	1.0	3.6		3.5		3.5		3.4		3.6
40%	2.4	3.8	1.3	4.3		4.1		4.2		3.8		3.6
20%	3.0	3.9	1.0	3.9		3.8		4.1		3.6		3.8

Figure 11. *Helleborus* 'Lady' series in bloom in January.

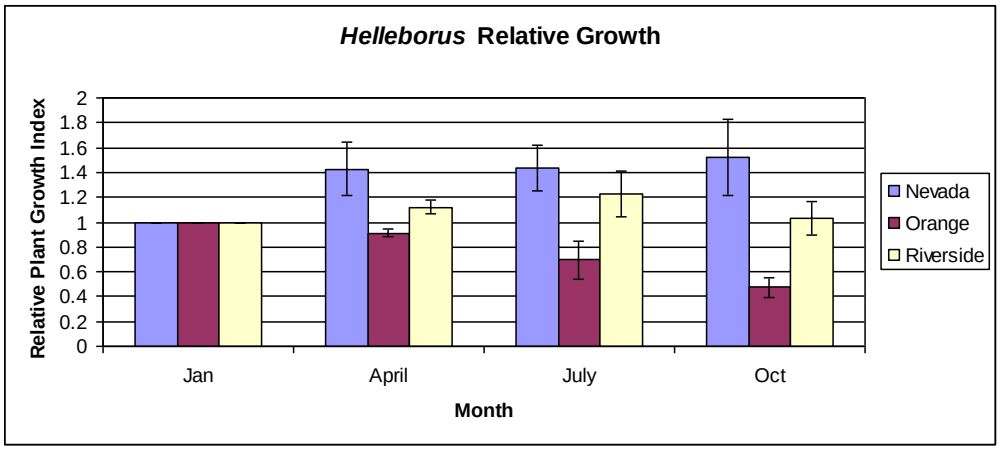

Figure 12. Relative growth of *Helleborus* in each county. Error bars indicate ± standard error.

Ribes viburnifolium

The *Ribes* had less growth in the 60% irrigation treatment than the 80%, 40%, and 20% irrigation treatments (figure 13). Although, the 60% treatment did differ in size from the other three treatments, there was no difference in the average ratings for each treatment (table 7). Almost all the ratings were above four, with the exception of the ratings in July which were between 3.7 and 4.1. Figure 14 shows and example of the appearance of the *Ribes* in the irrigation trial.

The *Ribes* located in Fresno had the greatest growth by the end of the season (figure 15). The *Ribes* was not recommended in any of the gardens as it was found to grow slowly and have a very "leggy" appearance.

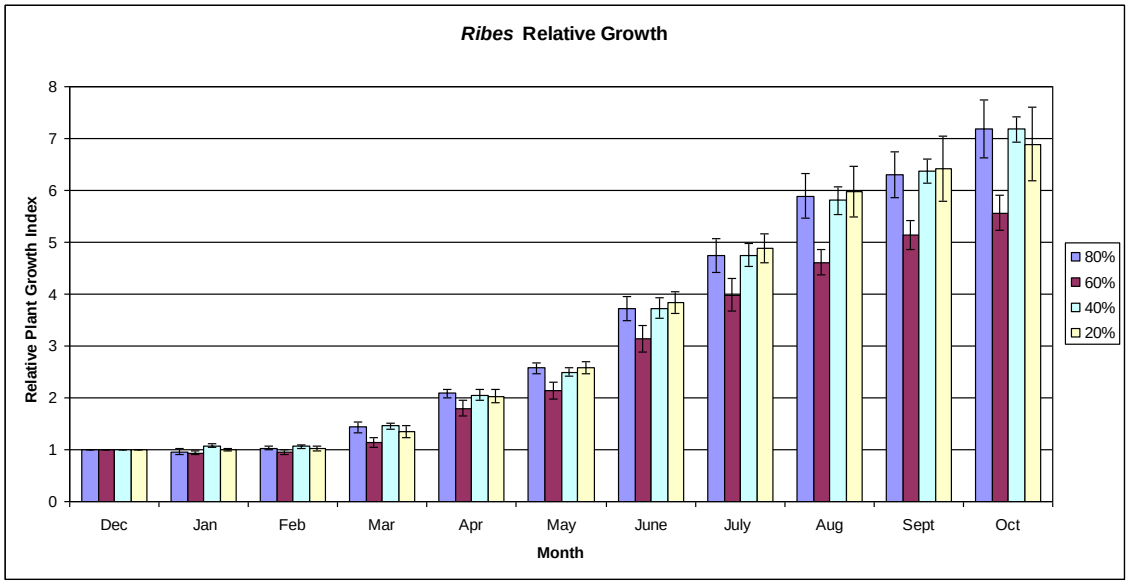

Figure 13. *Ribes* relative growth by treatment. Error bars indicate ± standard error.

Table 7. *Ribes* average performance ratings across treatments for each month during the deficit irrigation period.

	May		June		July		Aug		Sept		Oct	
	flower[1]	avg	flower	avg	flower	avg	flower	avg	flower	avg	flower	avg
80%		4.7		4.0		3.7		4.3		4.8		4.5
60%		4.9		4.1		3.8		4.9		4.8		4.8
40%		4.5		3.9		3.7		4.2		4.7		4.6
20%		4.8		4.3		4.1		4.6		4.7		4.7

[1]Did not flower this year, no data collected

Figure 14. *Ribes viburnifolium*.

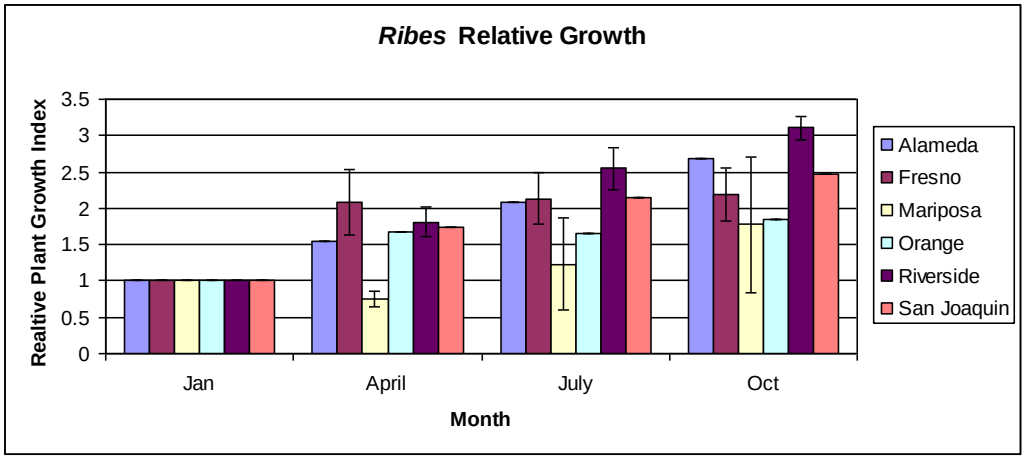

Figure 15. Relative growth of *Ribes* in each county. Error bars indicate ± standard error.

Conclusions

The results presented above are only for the first year of growth on these plants. It is possible that results might change after the second year of growth as the plants continue to mature. These plants were planted in November and allowed to establish through the winter with irrigation treatments beginning the summer after they were planted. This allowed us to conduct the deficit irrigation trial in one calendar year. We plan to conduct a second year of deficit irrigation treatments to monitor the plants' performance during two consecutive years of treatments. The plants will also remain under evaluation in the climate zone trials for an additional year.

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