Water use and response to water stress is measured in six woody landscape plants grown in lysimeters.

Evaluation of a Method for Classifying Landscape Plants by Relative Water Use

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This project represents an attempt to establish a simple method for making empirical ratings of landscape plant water requirements under normal and minimum irrigation. The conventional means of evaluating the irrigation requirements of plant species is to determine empirically a crop coefficient, which is used in conjunction with a published or measured reference evapotranspiration (ET) rate. This approach has been used successfully with turfgrasses and agronomic crops, where relatively large surface areas are devoted to cultivation of a single, well-irrigated species that achieves complete canopy cover; however, these conditions do not prevail in typical landscapes. Indeed, the numerous attempts to describe the irrigation requirements of plants in landscapes have either failed or achieved only limited success. Among the confounding factors are the presence of mixed plantings encompassing a range of water requirements, incomplete canopy covers, varying degrees of drought hardening, and effects of adjacent structures and surfaces. The difficulty of this means of determining irrigation requirements is so great that even researchers involved in determining landscape ET coefficients have sought a different tack, such as the WUCOLS Project. In that project, water requirements of landscape species were estimated by asking participants to classify each species as a high, moderate, low, or very low water consumer.

We have proposed a different approach. Rather than determining crop coefficients for individual species of landscape plants, we suggest that the plants be placed in broad categories based on water use. This would allow for some modification of irrigation in existing landscapes and better design of future landscapes. The main impediment has been the insufficient amount of information on water use by landscape plants. Our hypotheses are that well-irrigated plants of comparable leaf area in containers will have similar consumptive water use, that when subjected to water stress these plants will differ in water use, and that this difference in water use among plants grown in containers will be indicative of relative water use in the landscape.

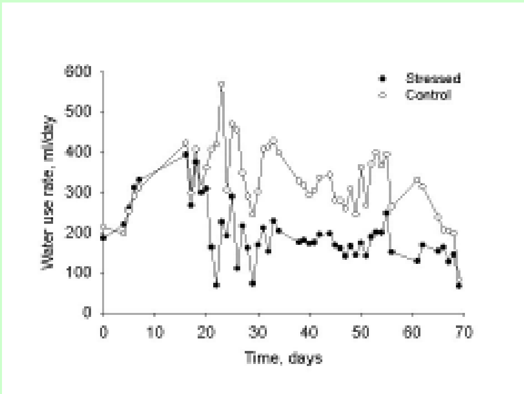
The primary objectives were to construct lysimeters, establish one-gallon landscape plants in them, and compare the water use of those plants to that of one-gallon plants at the end of commercial nursery production.

Materials and Methods

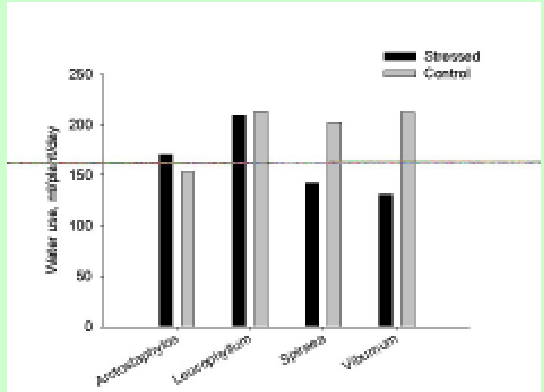
Plant material. Six species of woody landscape shrubs in one-gallon containers, purchased from a commercial nursery, were used as the experimental plants. Three of the species selected were expected to have high water consumption, the other three were expected to have low water consumption, based on published data on water use of woody plants in commercial nurseries (Burger et al. 1987):

High water consumption
Berberis thunbergii 'Atropurpurea'
Spiraea vanhouttei
Viburnum tinus
Low water consumption
Arctostaphylos densiflora 'Howard McMinn'
Leucophyllum frutescens
Mahonia aquifolium

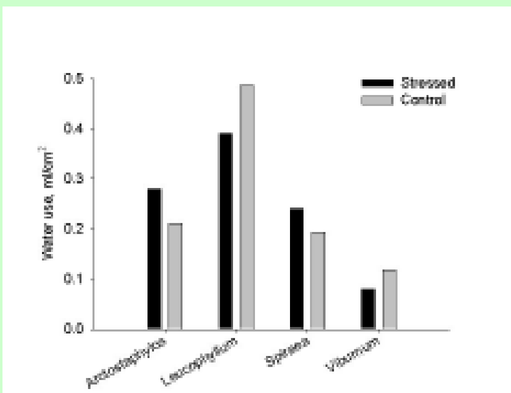
The commercial nursery from which the plants were ordered failed to complete the order (and in fact has gone out of business). As a result, there were enough plants to begin the establishment of plants in lysimeters, but not sufficient plants to complete the testing of all plant species in one-gallon containers. *Leucophyllum* was available in sufficient quantities to



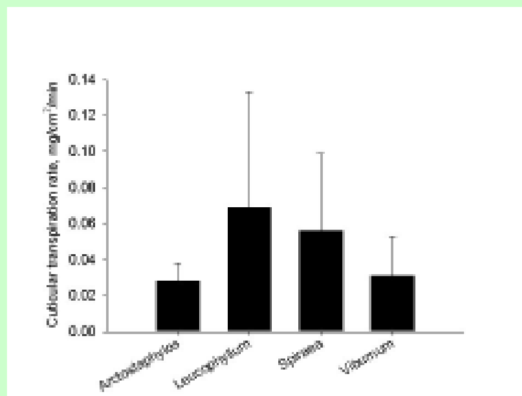
Water use rate of water-stressed and control *Leucophyllum* plants grown in one-gallon containers. Water stress treatment was begun on Day 0. (Fig. 1)



Water use rate of water-stressed and control plants grown in one-gallon containers. Data are average of daily water use during the third week after imposition of water stress. (Fig. 2)



Water use rate of water-stressed and control plants grown in one-gallon containers, based on leaf area of plants. Data are average of daily water use during the third week after imposition of water stress. (Fig. 3)



Cuticular transpiration rate of water-stressed plants grown in one-gallon containers. Data are from the third week after imposition of water stress. (Fig. 4)

conduct testing of water use; for other species, some data on physiological and morphological responses to water stress were collected as described below (these plants were overly mature for the containers and were not used for measurement of water use). *Berberis* plants that remained in one-gallon containers could not tolerate even the mild water stress of control plants, and most of the *Mahonia* plants that remained in one-gallon containers died.

Testing of plants in containers. *Leucophyllum* plants were arranged in two 4 X 4 blocks in the Environmental Horticulture nursery. In each block, the outer two rows of plants on all sides served as a buffer, and the inner four plants served as a treatment. Initially, all plants received irrigation as needed to maintain moisture at a level comparable to that in a normal commercial nursery. Daily water use of the four replicates of each species was determined gravimetrically.

After two weeks, a water stress treatment was applied to one block of plants by withholding irrigation until plants have removed nearly all available water from the container, then rewatering the plants to container capacity. Daily water use was determined gravimetrically. The cycle was repeated through the summer

Species	Irrigation	Leaf count (Δ number)		Stem diameter (Δ mm)		Plant height (Δ cm)		Stem length (Δ cm)
		Time interval (days)						
		0-18	19-38	0-18	19-38	0-18	19-38	0-38
Spiraea	Control	1.0	-4.3	-1.9	0.0	1.2	1.6	0.1
	Stressed	-11.4	-3.3	-1.5	0.4	3.9	-2.7	-0.1
Viburnum	Control	11.9	1.3	2.2	0.6	6.6	12.9	0.4
	Stressed	-1.9	-5.0	5.56	1.1	-3.1	1.9	-1.9
Arctostaphylos	Control	–	0.4	–	2.9	–	-0.3	-1.2
	Stressed	–	2.4	–	4.3	–	1.4	-3.9
Leucophyllum	Control	-12.3	-23.2	3.1	0.3	5.3	2.1	-1.5
	Stressed	-1.2	-4.9	2.6	2.2	5.0	2.2	-2.2

Relative changes in growth of plants in one-gallon containers. Changes are differences in natural logarithm of actual values over time. Time intervals are expressed in days after first imposition of water stress treatment. (Table 1)

to allow for water stress acclimation. The relative water use of plants in the two treatments was compared before and after imposition of water stress.

In addition, several characteristics of plant response to water stress were assessed periodically on one-gallon plants of all six species in both irrigation treatments. Plant height was measured from the soil line; stem length, diameter, and leaf number were measured on randomly selected shoots from each irrigation treatment, and leaf chlorophyll content of randomly selected fully expanded leaves was determined using a Minolta SPAD meter. Randomly selected shoots were detached and used for determination of volumetric elastic modulus and water potential at full and zero turgor. These values were obtained by allowing the shoots to wilt on a lab bench while periodically taking measurements of fresh weight and water potential, then constructing a pressure-volume curve. Cuticular transpiration rate of leaves was determined gravimetrically on leaves after determination of leaf area. Relative water content was also determined on random samples from each species.

Testing of plants in lysimeters. Sixty drainage lysimeters (60-cm diameter and 85-cm depth) were constructed and filled with a loamy sand soil. The lysimeters were moved from their initial location because the ground beneath them was unstable when wet. The current site is a concrete pad with plumbing to catch leachate from the lysimeters. Plants in one-gallon nursery containers, representing the same species used in the nursery container study, were transplanted into the lysimeters in winter 1997 and irrigated as needed during the summer and fall. Irrigation treatments were not imposed during 1997 because the root systems of the plants were not sufficiently extensive yet. Nevertheless, some of the physiological and morphological measurements were made according to the procedures outlined above.

Results and Discussion

Beginning three weeks after the imposition of water stress, the water use of stressed one-gallon *Leucophyllum* plants was consistently lower than that of control plants (Fig. 1). On most days, water use of stressed plants was approximately half that of control plants. After 10 weeks, precipitation made water use comparisons inconsistent. Although these results are limited to one species, they are consistent with the hypothesis that plants in one-gallon containers at the conclusion of nursery production can acclimate fairly rapidly to the imposition of water stress.

The advanced maturity of most of the species in one-gallon containers precluded thorough comparison of drought responses—the control plants were also somewhat stressed because of limited water-holding capacity of the containers. In addition, the limited number of samples available made resolution of likely

Species	Irrigation	Ψ_{100} (MPa)	Ψ_0 (MPa)	ε (MPa)	RWC (%)
Spiraea	Control	1.09	1.78	2.69	82.6
	Stressed	0.92	1.60	1.56	79.2
Viburnum	Control	1.17	1.55	6.11	93.4
	Stressed	1.19	1.57	17.91	94.8
Leucophyllum	Control	0.93	1.60	1.10	73.0
	Stressed	1.25	2.04	2.78	71.4

Water potential, volumetric modulus of elasticity, and relative water content at zero turgor of plants in one-gallon containers (Table 2)

Y_{100} is water potential at full turgor, Y_0 is water potential at zero turgor, e is volumetric modulus of elasticity, and RWC is the relative water content.

differences impossible in some instances. There were differences in some of the plant responses to water stress (Table 1). *Leucophyllum* lost significantly more leaves than other plants in the control irrigation during the later time interval, a response that is opposite that of all other species studied. A similar response is commonly observed in field-grown *Leucophyllum*. The relative change in stem diameter during the initial time interval was significantly different; that of *Viburnum* and *Leucophyllum* was significantly greater than that of *Spiraea*. There was no significant difference during the second time interval. *Viburnum* plants in the control group had a greater relative increase in height than the other species, but there were no significant differences among species in the stressed irrigation treatment. There were no significant differences in the relative change in stem length. These results are not easily interpreted, perhaps because of the unclear distinction between control and water-stressed plants. The relative responses of *Leucophyllum* and *Viburnum* are not clearly consistent with observations of fresh weight gain of these species in field plantings, where growth of water-stressed *Leucophyllum* was significantly greater than that of *Viburnum*. Nevertheless, relative growth of *Viburnum* was severely checked by water stress, whereas *Leucophyllum* grew equally well or better when exposed to water stress.

Preliminary results on water use among four species of plants in one-gallon containers were obtained three weeks after imposition of the water stress treatment. Water use was not significantly different among control plants, but was significantly different in the water-stressed plants (Fig. 2). Water use of *Spiraea* and *Viburnum* was significantly lower when plants were stressed. This response was partially due to a decrease in leaf area, because water use expressed on the basis of leaf area was similar in both control and stressed plants of these species (Fig. 3). On the basis of leaf area, *Viburnum* had the lowest water use, and water use by *Leucophyllum* was higher than that of all other species. It is interesting, however, that *Leucophyllum* was the only species that had a significant reduction in water use per unit leaf area after imposition of water stress.

Cuticular water loss was not significantly different among the species tested, but again the lack of discrimination because of insufficient numbers of plants may have masked a significant difference (Fig. 4).

The pressure-volume determination revealed some significant differences among the species tested, but no differences due to irrigation treatment (Table 2). The volumetric elastic modulus was greater in *Viburnum* than in either *Leucophyllum* or *Spiraea*. This is a measure of cell wall rigidity: High values indicate that a higher turgor pressure is required to obtain an increase in cell volume. Thus, *Viburnum* cell walls appear to be more rigid than those of either *Spiraea* or *Leucophyllum*, which again seems to be consistent with observations of growth of field-planted shrubs.

The relative water content at zero turgor was lowest in *Leucophyllum* and highest in *Viburnum*. *Leucophyllum* could lose considerably more water before losing turgor than the other species could. This may explain the ability of this species to continue growing in minimum irrigation regimes.

Water potential at full turgor and at zero turgor were not significantly different. A more complete study of water relations in these species would be required before drawing conclusions about how plant water potential is affected by imposition of water stress.

Conclusions from this study must remain tentative until water use and response to water stress can be compared in plants grown in one-gallon containers and lysimeters, which is anticipated in Summer, 1998. Results to date are promising because they are consistent with our previous observations of field-grown *Leucophyllum* and *Viburnum*. It is apparent that plant responses to water stress will be varied. For example, *Leucophyllum* appears to have physiological traits, such as a low volumetric elastic modulus, that allow it to grow well under minimum irrigation. *Spiraea* loses leaves when exposed to water stress, which conserves water at the expense of ornamental value. *Viburnum* has a sharply curtailed growth rate when water stress is imposed, which is another avenue toward limiting leaf area. It is encouraging that these traits, which appear to be consistent with what has been observed in landscapes, can be induced in plants in containers immediately after commecial poduction, because it indicataes that this method of assessing plant water requirements may be useful.

Literature Cited

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