Water use in California's ornamental nurseries

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Little is known about how much water container-grown plants require for maximum growth and value. This study answered some fundamental questions on the subject.

The cost and availability of high-quality irrigation water are important production considerations for California nursery growers. Irrigation water is expensive and now accounts for 4 to 7 percent of the total production cost of 1-gallon, ornamental plants. A great deal has been published on water use in agronomic and field crops, but little research has been conducted in California to answer fundamental questions regarding water use by container-grown, ornamental plants. It is largely unknown how much water a plant growing in a container requires for maximum growth and aesthetic value.

Stringent requirements are placed on the production of ornamental plants, because they are grown in containers with a limited soil volume and thus a limited supply of water. It is not enough to grow the plants at their maximum growth rate if the quality of that growth is reduced. Many of the marketing and pricing strategies for nursery products are closely tied to quality. The challenge is to grow the finest quality plants in the shortest period of time with a minimum use of raw materials.

In this report, we describe findings from research conducted over the past two years in Davis and other California locations. Our objectives were to determine the water-use characteristics (crop coefficients, effects of spacing) of some of the most important, container-grown ornamentals in California, to rank these container crops in terms of their water use, and to develop a system for including CIMIS (California Irrigation Management and Information System) weather data into nursery irrigation management.

Water use, as measured by weight changes of plants in containers, was determined with a digital balance attached directly to a portable microcomputer.

Water-use characteristics

Water use by container-grown plants is measured in milliliters (or cubic centimeters) of water transpired by the plant and evaporated from a container over a given period. Changes in weight of an irrigated plant can be used to determine milliliters of water used, since 1 milliliter of water essentially weighs 1 gram.

In all of the experiments conducted, we approximated the physical layout of a production nursery by spacing container plants at known densities. Once the experimental design was set, all of the plants were watered thoroughly, allowed to drain for one hour (time period to attain container capacity), and weighed. After 24 hours, the plant was weighed again. The difference between the beginning and ending weights was the water used, in cubic centimeters (cm^3) or milliliters (ml), over the 24 hours. Evapotranspiration of the container crop (ET$_{crop}$) can be determined from this information by using the following equation:

$$\mathrm{ET_{crop}\ (cm)} = \frac{\text{Volume of water used (cm}^3\text{)}}{\text{Container surface area (cm}^2\text{)}}$$

The designation of surface area in the equation is slightly different from those in similar equations used for field crops. In container-grown plants, the canopy-covered, surface area and the surface area representing the water reservoir are not the same. The sole source of water for the plants is the container; the plant's canopy, however, can extend beyond the container surface area. It is therefore difficult to make direct comparisons between the ET$_{crop}$ for container-grown plants and that for field crops. The surface area of the container (188 square centimeters for a 1-gallon container) as the "cover-crop" area has been used in all of the calculations presented here.

If the ET$_0$ (the reference crop evapotranspiration, which is the ET rate of healthy grass, completely covering the ground to a uniform height of 3 to 6 inches) is known for the time period when the ET$_{crop}$ was determined, crop coefficients (K$_c$) can be calculated by the equation:

$$K_c = \frac{\mathrm{ET_{crop}}}{\mathrm{ET_0}}$$

Crop coefficients (K$_c$) can then be used to determine when to irrigate and how much water to apply to a particular crop.

We performed experiments at Davis during the summer of 1985 to determine evapotranspiration and crop coefficients for different container-grown ornamentals arranged in two container spacings. During these experiments, three leaf readings of three different plants spaced at 20 containers per square meter were made using a Licor autoporometer to determine transpiration rates. Three plants from each species were used to determine fresh and dry weights (to confirm that the plants were relatively similar in biomass) and to determine the total leaf area. Leaf areas were determined with a Licor leaf area meter.

During the summer of 1986, we conducted similar experiments to determine whether crop coefficients remain constant in different climates. Three frequently planted species in the California landscape, oleander *(Nerium oleander)*, bottlebrush *(Callistemon citrinus)*, and sweet mock orange *(Pittosporum tobira)*, were used.

TABLE 1. Crop coefficients (K_c) at two container spacings, 16/m² (pot-width spacing) and 36/m² (pot-to-pot spacing), of ornamental plants growing in 1-gallon containers

Species	Months in 1-gallon container	K_c 36/m²	K_c 16/m²
Heavy water users			
Pyracantha augustifolia 'Gnome'	15	4.5	5.1
Buddleia davidii 'Dubonnet'	15	4.4	4.5
Moderate water users			
Chaenomeles × *Clarkiana* 'Minerva'	15	2.4	3.8
Oleander, *Nerium oleander*	—	2.3	—
Spiraea vanhouttei	16	2.2	3.4
Creeping juniper *Juniperus horizontalis* 'Youngstown Compacta'	8	2.0	2.5
Forsythia intermedia 'Spring Glory'	8	2.0	3.2
Arborvitae, *Platycladus* (*Thuja*) *orientalis* 'Aureus Nana'	12	1.9	3.1
Japanese barberry, *Berberis thunbergii* 'Atropurpurea'	15	1.9	2.5
Chinese juniper, *Juniperus chinensis* 'Spearmint'	5	1.9	3.1
Savin juniper, *Juniperus sabina*, 'Buffalo'	15	1.7	3.5
Japanese privet, *Ligustrum japonicum*	11	1.7	3.1
Bottlebrush, *Callistemon citrinus*	—	1.6	—
Cotoneaster congestus 'Likiang'	16	1.5	2.6
Juniperus horizontalis 'Prince of Wales'	10	1.5	2.6
Juniperus chinensis procumbens 'Green Mound'	8	1.4	2.5
Sweet mock orange, *Pittosporum tobira*	—	—	2.4
Light water users			
Creeping manzanita, *Arctostaphylos uva-ursi*	11	1.2	1.7
Euonymus kiautschovica 'Manhattan'	15	1.2	2.8
Photinia fraseri	12	1.2	1.8
Scotch broom, *Cystisus scoparius* 'Moonlight'	12	1.1	1.8
Japanese barberry, *Mahonia repens*	11	1.1	1.7

NOTE: Values are averages of 10 to 12 plants.

Randomly selected plants from each species were sent to four California locations: Davis, Watsonville, San Bernardino, and Irvine (UC South Coast Field Station). The plants were arranged in identical experimental designs at the four locations. Thirty plants (six rows, five columns) of oleander and bottlebrush were set at a spacing of 36 containers per square meter (pot-to-pot), and 30 plants of sweet mock orange were set at a spacing of 16 containers per square meter. The outside border plants were not used in data collection. This left the inside 12 plants as the experimental units.

The plants were watered and weighed as described so that their evapotranspiration could be calculated. All of the data were sent to Davis for collating. On-line CIMIS computers were used to obtain the reference-crop evapotranspiration for each location while the experiment was in progress so that crop coefficients could be determined. Since there was no CIMIS weather station near the South Coast Field Station, we used the reference-crop data gathered there.

Results

Compared to published coefficients for other crops, those for container-grown plants are high, ranging from 1.1 to 5.1 depending on the species and the container spacing (table 1). Based on the coefficients, these plants can be grouped into heavy, moderate, and light water users. The heavy water users (pyracantha, buddleia) have coefficients greater than 4.0. Moderate water users (flowering quince, oleander, spiraea, juniper, forsythia, arborvitae, privet, bottlebrush, cotoneaster, sweet mock orange) have coefficients between 2.0 and 3.9. The light water users (manzanita, euonymus, photinia, Scotch broom, and Japanese barberry) have coefficients less than 2.0.

Container spacing has a significant effect on the K_c and ET_{crop}. This effect is to be expected, since as the container spacing increases, sunlight on the black container increases, raising the soil temperature and thus the evaporation rate. Transpiration rates of individual leaves of the test plants varied between 3 and 144 micrograms per square centimeter per second. Plants with the largest crop coefficients did not always have the largest transpiration rates (data not shown). The predictive quality of the autoporometer measurements was improved when the total leaf area of the plant was used, but the values were not accurate enough to be useful in predicting overall water use.

TABLE 2. Crop coefficients for three, ornamental species in four California locations

	Crop coefficient			
Species*	Davis	Watsonville	SCFS† Irvine	San Bernardino
Nerium oleander	2.3	2.1	1.8	2.1
Pittosporum tobira	2.4	2.2	2.3	2.6
Callistemon citrinus	1.6	1.8	1.7	1.7

* *Nerium* and *Callistemon* spaced at 36 containers and *Pittosporum* at 16 containers per square meter.
† SCFS = South Coast Field Station

The crop coefficients at the four different locations remained fairly constant (table 2). Although the coefficients for oleander were variable, these values would suffice for estimations and calculations necessary for irrigation scheduling.

Conclusions

The data presented here add to the growing collection of ET_{crop} and K_c data for California crops and are among the first water use data specifically for the ornamental industry. Care must be taken when using these data. Many interactive factors can alter the water use of container-grown plants. These include differences among cultivars of a given species (see the differences among the juniper species in table 1), developmental stage of the plant, nutritional status, shading, and other spacing layouts.

Crop evapotranspiration (ET_{crop}) and coefficients (K_c) are easily calculated, and a nursery manager can simply determine them for the crops being produced. Confidence in the accuracy of these coefficients will lead to the use of reference crop (ET_0) data, whether gathered from CIMIS or from pan evaporation rates calculated on-site, to predict how much water has been used and when to irrigate. For example, if the ET_0 for a given period were 2 cm and the K_c for a crop were 2.0, the equation

$$K_c \times ET_0 = ET_{crop}$$

would give an ET_{crop} of 4 cm. The nursery manager would therefore know to apply 4 cm of water on the crop.

This exercise assumes that the manager knows the application rate and distribution characteristics of the irrigation system used to apply the water. Also, plants with similar coefficients can be grouped together in the nursery and irrigated simultaneously. The importance of the diminishing supply of high-quality water and increased water costs will necessitate these kinds of improved water management techniques.

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