Factors Affecting the Irrigation Requirement of Container-Grown Ornamentals©

Jeff B. Million and Tom H. Yeager
Dept. Environmental Horticulture, Univ. Florida, IFAS, Gainesville, Florida 32611, USA
Email: jmillion@ufl.edu

INTRODUCTION

The irrigation requirement of a container-grown ornamental plant is the amount of irrigation water needed to resupply water lost from the container substrate via evapotranspiration (ET) processes. Besides ET water loss, one also needs to consider the irrigation system's ability to deliver water to the container substrate. For sprinkler irrigation, two additional factors must be considered: (1) the plant canopy's capacity to channel water into the container that would otherwise fall between containers (described by irrigation capture factor), and (2) the irrigation system's ability to supply water uniformly within the irrigation zone. Knowledge of factors affecting irrigation requirement is critical if water is to be applied efficiently in the nursery. This is particularly important for container production as container substrates have limited water storage capacity so that, compared to field production, there is little buffer between under- and over-watering. We will discuss some important factors affecting irrigation requirement and how managers can use this information to more efficiently irrigate container-grown crops.

EVAPOTRANSPIRATION

Container versus In-Ground

Evapotranspiration (ET) is water evaporated from leaf and substrate surfaces and is typically measured for a 24-h period. The potential rate of ET for a dense, actively-growing plant canopy is primarily affected by weather (solar radiation, temperature, humidity, wind) and fluctuates daily. Weather stations and weather services typically provide a daily potential (or reference) ET value given in depth of water (e.g. inches); similar to how rain is described. We describe how the ET value relates to a container production system where containers occupy only a fraction of the production surface. Two identical crops are compared with one crop (top) planted in the ground and the second in containers (bottom) (Fig. 1). Let's also assume both crops are essentially providing a full canopy of leaves over the production area and therefore actual ET is essentially equivalent to potential ET, in this example 0.51 cm (0.2 in.). For in-ground plants, roots are able to exploit water from the total area allotted each plant 0.1 m^2 (1 ft^2), so that 0.51 cm (0.2 in.) of irrigation water (or rain) would be needed to resupply ET water loss. For the same plants grown in containers, the ET rate is also 0.51 cm (0.2 in.), however, all the ET water lost from 0.1 m^2 (1 ft^2) of production area has to come out of the container with a 0.02 m^2 (0.2 ft^2) top area (one-fifth allotted production area). Thus, when ET = 0.51 cm (0.2 in.), container ET (ET_c) = 2.5 cm (1 in.). This means that 5 times [2.5 cm (1 in.)] more irrigation water (or rain) would need to be applied to the container than it would to the same plants in the ground. From this example one can see that container size and spacing play an important role in estimating irrigation requirement based on ET.

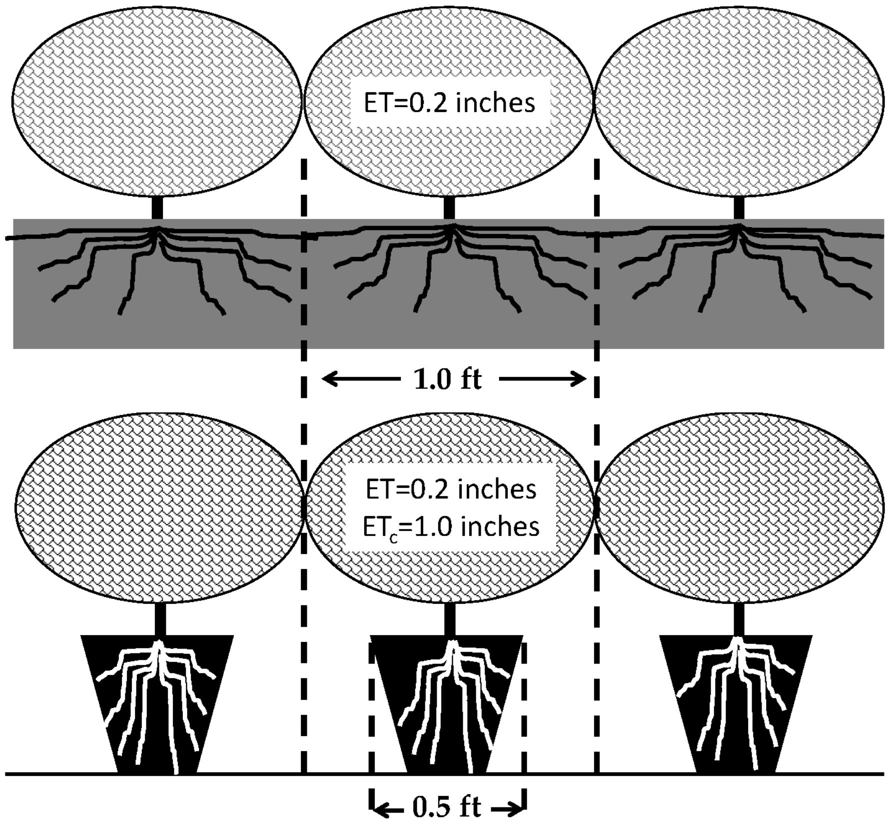

Fig. 1. Evapotranspiration is compared between two identical crops, one planted in-ground (above) the other in containers. In both cases, ET is 0.51 cm (0.2 in). For containers, the ratio of production area to container area is 5 [.09 m^2 (1.0 ft^2) ÷ .02 m^2 (0.2 ft^2)] so that the equivalent depth of water out of the container (ET_c) is 2.5 cm (1 in.).

Container Spacing

The previous discussion showed that ratio of area allotted the plant to the top area of container plays an important role in relating ET to ET_c. When containers are placed in close-spacings, the situation approximates an in-ground situation. However, as plants grow and canopies become shaded by neighboring plants, growers are likely to space containers to increase light levels around plant canopy sides. How does container spacing affect ET?

We investigated the effect of container spacing on ET_c and ET at the University of Florida by randomly dividing mid-season *Viburnum odoratissimum* (sweet viburnum) grown in trade #3 containers [28 cm (11 in.); top area 610 cm^2) into four groups placed at four equidistant spacings: [0, 14, 28, and 42 cm (0, 5.5, 11, and 16.5 in.)] between containers. We weighed seven interior plants of each group after irrigation early in the morning and again at the end of the day and repeated this for five separate days re-randomizing plants for each day. Daily weight loss in grams was used to calculate ET_c knowing that 1 g = 1 cm^3 of water (Formula 1):

$$ET_c\ (cm) = weight\ loss\ (cm^3) \div container\ area\ (cm^2);\ ET_c\ (cm) \div 2.54 = ET_c\ (inches) \qquad (1)$$

Percent canopy cover for each spacing was estimated by taking digital photos above the canopy and using image analysis software (GIMP V. 2.6; www.gimp.org) to determine percent of photo in dense foliage.

Increasing the container spacing from 0 to 14, 28 and 42 cm (0 to 5.5 and 11 and 16.5 in.) increased ET_c 30, 45, and 50%, respectively (Table 1). The observed increase in water loss per container is attributed to increased light interception per plant and increased temperatures that result from solar radiation being absorbed by black container and production surface materials (Fig. 2). While ET_c increased as spacing increased, ET decreased, which is directly related to the decrease in percent canopy cover in the production area.

Table 1. Effect of spacing on daily evapotranspiration (ET)[z] of *Viburnum odoratissimum* in trade #3 (11-in. diameter) containers. Means are the average of seven plants and 5 days. Mean separation by Tukey's HSD at 5% confidence level.

Spacing (in. between containers)	Area ratio[y]	Plant canopy cover (%)	ET_c (in.)	ET (in.)
0	1.1	95	0.254	0.231
5.5	2.5	52	0.330	0.134
11	4.4	35	0.364	0.083
16.5	6.9	24	0.389	0.055
$HSD_{0.05}$			0.023	

[z]ET=vertical inches over production area; ET_c=vertical inches over container top area.
[y]Production area allotted each plant ÷ container top area.

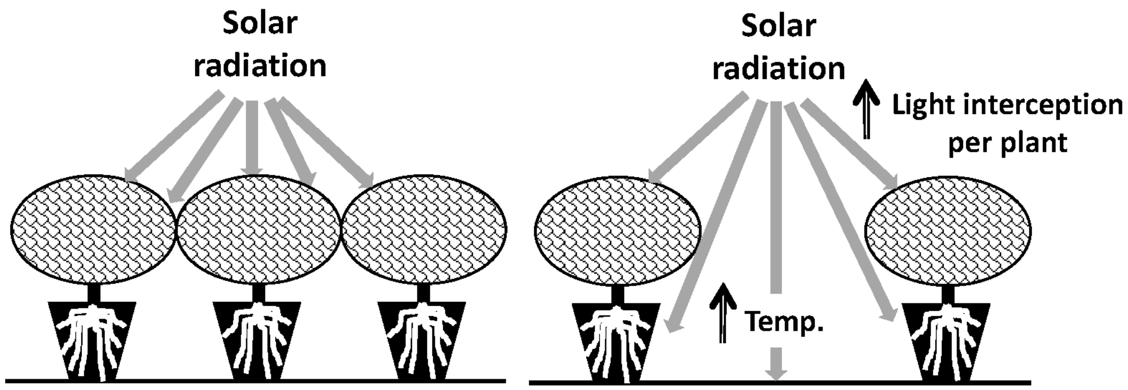

Fig. 2. Illustration showing the effect of plant spacing on temperature and light interception and how that can affect evapotranspiration of individual containers having same-sized plants.

Similar increases in ET_c when containers were spaced apart compared to closely spaced were observed for several different plant species grown in trade #3 containers at Saunders Brothers Nursery in Piney River, Virginia during the summer of 2012 (Table 2).

Plant Species

When daily ET rates of different plant species are compared on the same day and with containers arranged so that percent canopy cover approaches 100%, we have found that differences in ET are not great. For example, we observed *Ilex vomitoria* (dwarf yaupon) in trade #1 containers [16 cm (6.3 in.) diameter] to exhibit similar ET rates as *V. odoratissimum* in trade #3 containers when measured on the same five days and with full canopy coverage [0.58 vs. 0.61 cm (0.23 vs. 0.24 in.); unpublished data]. Making similar plant species comparisons at Saunders Brothers Nursery in the summer of 2012, we observed little difference in ET among plant species and between different varieties of the same species. Based on ET measurements made on more than twenty different plant species at varying plant sizes and container spacings at Saunders Brothers Nursery during the summers of 2011 and 2012, ET_c values estimated by considering only weather (potential ET), percent plant canopy cover and container spacing agreed fairly well with observed ET_c values indicating that the effect of plant species may be minor relative to these other factors.

Table 2. Effect of two different spacings on daily evapotranspiration (ET)[z] of several ornamental plant species in trade #3 (11-in. diameter) containers measured at Saunders Brothers Nursery, VA. Means are the average of seven plants and two days.

Plant species	Spacing (in. between containers)	Plant canopy cover (%)	ET_c (in.)	ET (in.)
Berberis thunbergii	0	95	0.41	0.37
	17	40	0.56	0.08
Thuja occidentalis	1	95	0.35	0.25
	17	67	0.43	0.16
Juniperus rigida subsp. *conferta*	0	95	0.31	0.28
	18	63	0.41	0.14
Nandina domestica	3	95	0.28	0.25
	17	36	0.45	0.06
Pinus mugo	1	95	0.32	0.25
	8	55	0.49	0.16

[z]ET=vertical inches over production area; ET_c=vertical inches over container top area.

IRRIGATION CAPTURE FACTOR

Plants growing in containers can channel sprinkler irrigation water into the container that would otherwise fall un-intercepted between containers. The capture factor (CF) can be used to describe the water-capturing ability of container-grown plants (Formula 2):

$$CF = \textit{water captured with a plant} \div \textit{water captured without a plant} \qquad (2)$$

A CF=1 indicates that the canopy has no effect on irrigation capture while CF values >1 indicate that the canopy is augmenting irrigation capture and CF value <1 indicating the canopy is negatively affecting irrigation capture. Capture factor has significant implications for adjusting irrigation rates to accurately deliver desired amounts of water to containers. For example, if the container water deficit was determined to be 1.3 cm (0.5 in.) a grower NOT considering CF would apply 1.3 cm (0.5 in.) of irrigation water. However, if it was determined that CF=2, the grower would know that 1.3 cm (0.5 in.) of irrigation would supply 2.5 cm (1 in.) or twice the desired irrigation amount to containers. Knowing CF, the grower could irrigate with only 0.63 cm (0.25 in.) to deliver 1.3 cm (0.5 in.) of water to containers. The general equation for adjusting irrigation is (Formula 3):

$$\textit{Irrigation (inch)} = \textit{Container water deficit (inch)} \div CF. \qquad (3)$$

Using this formula to schedule irrigation throughout production of *V. odoratissimum* in trade #1 containers reduced total irrigation 39% compared to a fixed irrigation rate (Million et al., 2010).

Capture factor is affected by several factors including plant species, plant size, container size, and container spacing. Plant species exhibiting upright, branching habit (e.g., *V. odoratissimum*, *Ligustrum japonicum*) can exhibit CF values >3 when containers are spaced and plants are large (unpublished data). Maximum CF values of plant species with broad- and semi-broad spreading habit (e.g., *Juniperus parsonii*, *Ilex vomitoria*) are typically smaller (CF <3). A plant with a CF=1 (no effect) when small can exhibit larger CF values when more fully grown in the same container (Fig. 3; Million et al., 2010). Actual CF values are limited physically by the ratio of production area allotted each plant to the top area of the container (area ratio). The dynamic nature of CF presents challenges for CF monitoring/prediction in container nurseries that irrigate a wide range of plant species at various stages of production. Functions are available to estimate CF based on plant size and container spacing (Million et al., 2011).

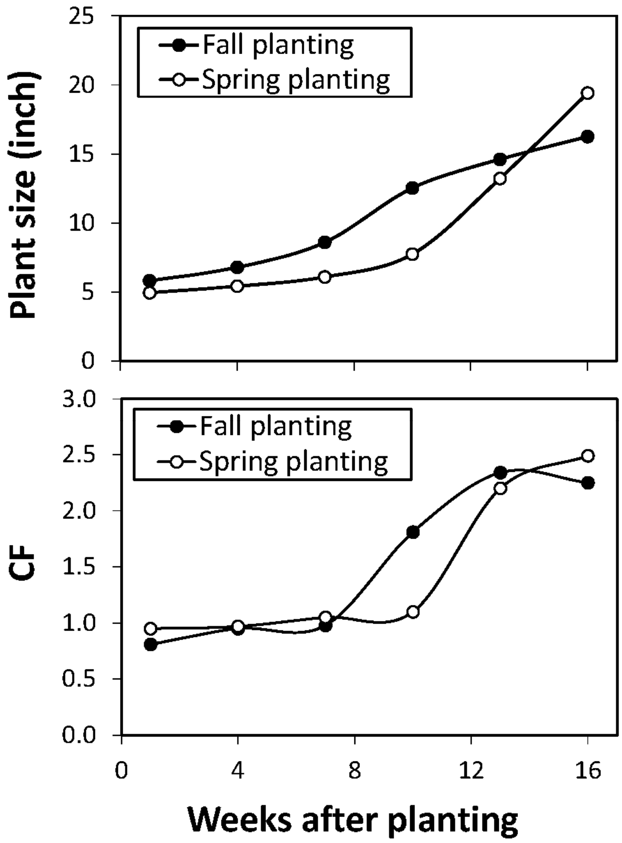

Fig. 3. The irrigation capture factor (CF) increases during the season as plants grow in size (avg. of plant height and width) and containers are spaced. CF was monitored during two seasons of *Viburnum odoratissimum* production in trade #1 containers (Million et al., 2010).

IRRIGATION UNIFORMITY

Distribution of sprinkler irrigation water within the production area should also be considered when adjusting irrigation rates to supply desired amounts of water to container-grown plants. The distribution uniformity (DU) is a measure of irrigation uniformity and is determined by collecting irrigation water in cups spaced throughout the irrigated area and calculating the average amount of water caught in the lowest 25% of all cups relative to the overall mean amount of water caught in all cups. If containers in the 'low' areas are to receive a certain desired amount of irrigation, irrigation rates would need to be increased according to the DU (Formula 4):

$$\textit{Irrigation (inches)} \div DU = \textit{Adjusted irrigation (inches)} \quad (4)$$

For example, if DU = 0.75 (75%) and desired irrigation is 0.76 cm (0.3 in.), then irrigation would need to be increased to 1 cm (0.4 inches) [0.76 cm (0.3 in.) ÷ 0.75) to supply 0.76 cm (0.3 in.), to containers in the "low" area of the production area. It follows that a portion of the production area would receive more than the desired 0.76 cm (0.3 in.) irrigation water.

CONCLUSIONS

The daily irrigation requirement of container-grown ornamentals is a dynamic amount that depends in large part on the past day's daily evapotranspiration rate, irrigation capturing ability of the plant and distribution uniformity of the irrigation system. We discussed how plant species, plant size, percent canopy cover, and container size and spacing can affect ET and CF. A general understanding of these concepts will help growers and grower-advisers to better understand, communicate and manage irrigation in container nurseries. Growers can measure ET, CF and DU (http://edis.ifas.ufl.edu/EP458) to obtain detailed information relative to important crops in their nursery. The effectiveness of irrigation amounts applied can be monitored periodically by performing leachate fraction tests and adjusting irrigation to maintain small leaching fractions (volume of leachate/volume of water captured). Applying irrigation in amounts that meet plant demand with minimal leaching requires detailed management, particularly in container nurseries with diverse plantings. Fortunately, the positive effects of increased irrigation efficiency on plant quality, water conservation, and agrichemical effectiveness will reward those who work toward this goal.

Literature Cited

Million, J.B., Ritchie, J.T., Yeager, T.H., Larsen, C.A., Warner, C.D. and Albano, J.P. 2011. CCROP - simulation model for container-grown nursery plant production. Sci. Hort. 130:874-886.

Million, J.B., Yeager, T.H. and Albano, J.P. 2010. Evapotranspiration-based irrigation scheduling for reducing runoff during production of *Viburnum odoratissimum* (L.) Ker Gawl. HortScience 45:1741-1746.