HORTSCIENCE 27(9):996-999. 1992.

Restricting Overhead Irrigation to Dawn Limits Growth in Container-grown Woody Ornamentals

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Additional index words. *Rhododendron* sp., *Ligustrum japonicum, Elaeagnus pungens, Photinia ×fraseri,* pulse irrigation, production

Abstract. ***Elaeagnus pungens* Thunb., *Ligustrum japonicum* Thunb., *Photinia ×fraseri* 'Red Top', and *Rhododendron* sp. 'Fashion' (azalea) growing in 10.4-liter containers were irrigated only at dawn with overhead impact sprinklers or pulse-irrigated three or four times each day with a drip system. Plant water potential was measured diurnally each week for 24 weeks, and growth was measured at the end of the growing season in December. Overhead irrigation resulted in less growth of all species than plants maintained near 100% container moisture with pulse irrigation. With the exception of photinia, more growth was associated with significantly lower daily accumulated water stress. Water stress of overhead-irrigated plants was generally not severe enough to cause stomata1 closure.**

Container-grown landscape ornamentals in the United States are commonly irrigated with an overhead system, normally with impact or off-center rotary sprinkler heads. This type of irrigation is especially common for production of the most common container sizes-15 liters and smaller. For these small containers, the cost and/or labor to install and maintain a drip system are often considered prohibitive. However, overhead irrigation is a very inefficient method to irrigate container-grown plants. The percentage of water actually reaching the container medium surface ranges from 12% to 50% (Beeson and Knox, 1991). Over the course of a production period, only 13% to 20% of the water applied overhead is retained for plant growth; the rest becomes runoff or evaporation (Weatherspoon and Harrell, 1980). These low efficiencies explain why Harrison (1976) reported container nurseries apply 1930 to 3810 mm·year^{-1} in Florida.

Most woody ornamental nurseries irrigate during the day, often starting near dawn on one block then continuing to successive blocks throughout the day until early evening. While this is the most convenient period, it occurs when evaporation is the highest, contributing to low efficiency. In Florida, drought conditions and growing demands on limited freshwater reserves led to the imposition in 1991 of an indefinite ban on overhead irrigation from 1000 to 1600 HR. In anticipation of more severe restrictions, the question arose as to how overhead irrigation confined to periods of low evaporation (i.e., early morning) would affect plant growth. The objective of this report was to determine whether daily overhead irrigation at dawn would result in reduced growth compared to maintaining optimum container moisture conditions and how this was related to diurnal water stress.

Four plant species, *Elaeagnus pungens, Ligustrum japonicum, Photinia ×fiaseri,* and *Rhododendron* sp. 'Fashion' (azalea), growing in 10.4-liter containers were borrowed from a local nursery in June 1990. All plants were uniform within a species and in the second and final year of their production cycle. Marketable size was obtained by Oct. for all species. Plants were grown in a 3 pine bark : 1 peat : 1 sand (by volume) mixture in full sun. Fifty plants of each species were randomly divided between two irrigation treatments consisting of daily overhead irrigation or pulse irrigation supplied by 15cm Dramm rings (Dramm International, Manitowoc, Wis.). Overhead irrigation was supplied only at dawn by impact sprinklers (Model 1374; Nelson Corp., Peoria, Ill.) at a rate of 10 mm·day^{-1}. Based on the container surface area and a 35% deflection rate, an estimated 330 ml of water was supplied daily to each container. Pulse irrigation was supplied four times daily to each plant until mid-October, when it was reduced to three times daily at a rate of 1500 ml each time. The first pulse irrigation occurred concurrently with the dawn overhead irrigation. The objective of the pulse irrigation treatment was to apply water frequently enough to maintain the container moisture level near 100%. Excess water was always observed draining from the containers after each pulse. All plants were fertilized with an 18.0N-2.6P-l0.0K slow-release fertilizer (Grace-Serra Chemical Co., Milpitas, Calif.) on 15 June at the recommended rate of 50 g/container. About the top 15 cm of the photinia shoots were pruned in mid-August to promote lateral shoot growth.

Shoot water potential (Ψ_T) was measured weekly on four plants of each species in each treatment beginning in mid-June 1990. Different plants were sampled each week on a rotating basis so that each plant was sampled only once every 6 weeks. Diurnal measurements were made about every 2 h from 0800 to 1630 HR. Shoot water potential was determined with a pressure chamber (Model 3000; Soil Moisture Equipment Corp., Santa

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Received for publication 25 Oct. 1991. Accepted for publication 4 May 1992. Florida Agricultural Experiment Station Journal Series no. R-01957. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

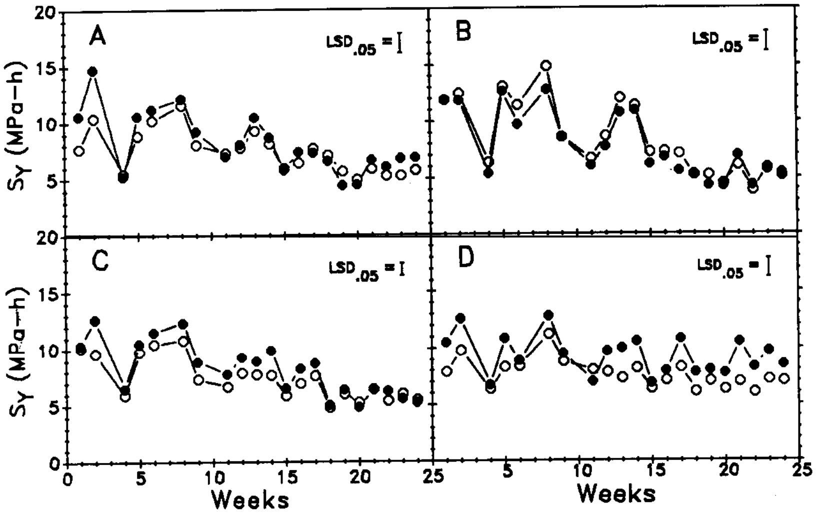

Fig. 1. Mean daily accumulated water stress (S_Y) for **(A)** ligustrum, **(B)** photinia, **(C)** azalea, and **(D)** elaeagnus during the last 24 weeks of production. Plants were pulsed-irrigated(○) or irrigated by overhead only at dawn (●). Measurements were started 12 June and ended 20 Nov. Each point is the mean of four plants.

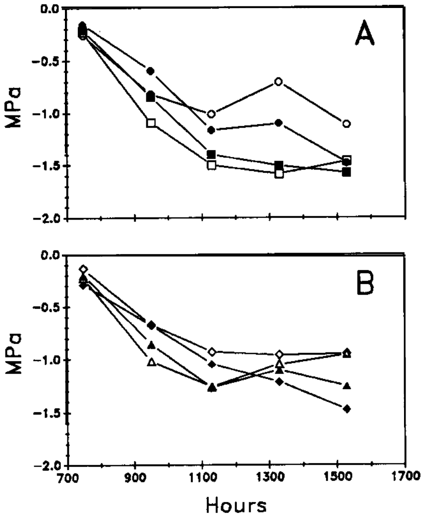

Fig. 2. Diurnal changes in total water potential for **(A)** photinia (□, ■) and ligustrum (○, ●) and **(B)** azalea (△, ▲) and elaeagnus (◇, ◆) for week 5. Plants were pulse-irrigated (open symbols) or irrigated by overhead only at dawn (filled symbols). Each point is the mean of four plants.

Barbara, Calif.) using compressed N, with pressure increasing at a rate of 2.5 $kPa\cdot s^{-1}$. Measurements were made on individual leaves for the photinia and on twigs (≈ 5 cm long) for the other species. Daily accumulated water stress (S,) was determined for each species at each measurement date by integrating the area over the water potential curve and taking the absolute value. Curves were extrapolated to -0.15 MPa at sunset to achieve a complete diurnal record. In preliminary experiments and from previous experience, such increases to -0.15 MPa always occurred, except in stressed plants (Beeson, unpublished data).

In early June, four extra plants of each species were well-watered by hand, then water was withheld for the following 6 days. During this time, stomatal conductance was measured on a leaf of each plant in full sun every 2 h when photosynthetically active radiation was >800 $mol\cdot m^{-2}\cdot s^{-1}$. Stomatal conductance was measured with a steady-state porometer (Model 1600; LI-COR, Lincoln, Neb.). Immediately after each measurement, the twig with the leaf was cut from the plant and Ψ_T determined. Stomatal conductance was then plotted vs. Ψ_T. From these plots, the Ψ_T threshold for stomatal closure for each species was estimated.

In Dec. 1990 plant height and width were measured for each plant. A growth index was calculated as: growth index (m^3) = width 1 × width 2 × (height/2), where width 1 was the widest canopy width and width 2 was the width perpendicular to width 1. Height was divided by two to reduce its contribution to the growth index. Canopies of five plants selected at random from each species and treatment were removed at the medium surface, cut into ≈ 20-cm pieces, and dried at 50C for a minimum of 5 days. Samples were further dried at 70C for an additional 48 h and separated into leaves and stems before being weighed.

Growth data were analyzed as a randomized design for each species. The water stress integrals were analyzed separately for each species as repeated measures, using a split-plot analysis, with irrigation treatment as the main plot and time as the subplot, as recommended by Snedecor and Cochran (1980). When appropriate, integral means were separated by protected LSD (Snedecor and Cochran, 1976).

Maintaining the container moisture near 100% (pulse) significantly (α = 0.05) increased maximum height over those plants irrigated by overhead sprinklers at dawn (Table 1). Increases in height ranged from 8% for azaleas to 15% for the ligustrum. Growth indexes were also larger (α = 0.05) for pulse-irrigated azaleas (65%) and elaeagnus (30%) but not for ligustrum (17%) or photinia (10%; Table 1).

Dry weights of leaves increased with pulse irrigation for photinia and elaeagnus but not for azaleas or ligustrum (Table 1). Pulse irrigation resulted in increased (α = 0.05) stem dry weight only for photinia and ligustrum (Table 1). Total canopy dry weight was larger for all species with pulse irrigation except azalea, although the mean dry weight for pulse-irrigated azaleas was 33% higher than overhead-irrigated plants (Table 1).

For S,, there was an interaction between irrigation treatment and time (α = 0.01) for all species except photinia (Fig. 1). With the latter exception, plants maintained near 100% container moisture (pulsed) generally had lower S_Y than those watered by overhead only at dawn. Differences in S_Y between irrigation treatments for azaleas were significant for weeks 8 through 17 but not thereafter. By early October (week 18) shorter daylengths and the seasonal return to lower daytime temperatures resulted in marked declines in daily water stress. This seasonal effect was also seen in ligustrum and photinia. Significant differences among treatments in S_Y for ligustrum occurred only during weeks 1 through 5. After mid-July (week 5), there were no significant differences in S_Y between pulse- and overhead-irrigated ligustrum, although through mid-September (week 15), pulse-irrigated plants tended to accumulate less daily water stress. Pulse-irrigated photinia accumulated more daily water stress than overhead-irrigated plants, with both treatments decreasing with time. Elaeagnus maintained near 100% container moisture usually accumulated less diurnal water stress (α = 0.05) than plants overhead-irrigated at dawn. Unlike the other species, these differences continued into late fall (week 24). Diurnal water stress in elaeagnus decreased little during the experiment.

Most of the differences in S_Y between treatments can be traced to differences in Ψ_T that occurred in mid- to late afternoon. Generally, there were no differences in Ψ_T between treatments during the morning to midday hours, as exemplified by week 5 (Fig. 2). However, by 1300 HR plants irrigated by overhead had lower Ψ_T, except photinia, with the difference becoming more pronounced by 1600 HR.

Despite declines in Ψ_T of overhead-irrigated plants during the afternoon, Ψ_T seldom declined to the estimated threshold for stomatal closure. For azaleas, the threshold for stomatal closure was assessed to be -1.3 MPa (Fig. 3A). Plants maintained near 100% container moisture reached this point once by 1600 HR during the experiment. Water potentials of overhead-irrigated plants declined to this level six times, generally between weeks 6 through 12. Elaeagnus appears to have a threshold of -1.8 MPa (Fig. 3B). This Ψ_T was reached only twice in the overhead-irrigated plants. Pulse-irrigated plants were never measured at this level. Ligustrum behaved similarly, only the dawn-overhead-irrigated plants reached the threshold of -1.6 MPa (Fig. 3C), and then only four times. The threshold value for photinia was estimated to be -1.5 MPa (Fig. 3D). Water potentials more negative than -1.5 MPa were

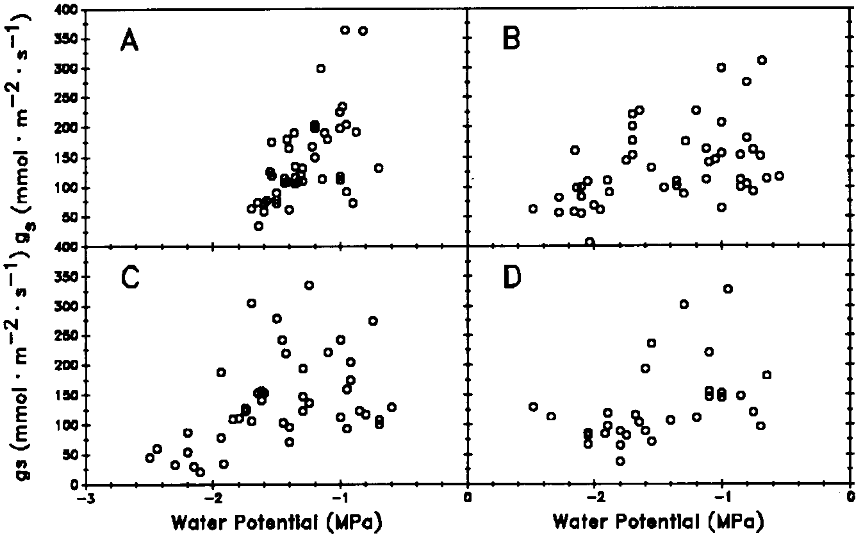

Fig. 3. Scatter plots of twig water potential vs. leaf stomatal conductance (g_s) measured over 6 days in which plants were irrigated only at the beginning. Plots are composites of data from four plants of each species for **(A)** azalea, **(B)** elaeagnus, **(C)** ligustrum, and **(D)** photinia. Measurements were made only on leaves in full sun when photosynthetically active radiation ranged between 800 to 2250 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

Table 1. Growth characteristics of four ornamentals measured after 24 weeks of irrigation treatments. Pulse-irrigated plants were irrigated three or four times per day to maintain near 100% container moisture. Overhead-irrigated plants were irrigated daily with impact sprinklers only at dawn. Data were analyzed separately for each species.

Species	Shoot ht^z (m)	Growth index^y	Dry wt^x (g) Leaf	Stem	Total
Rhododendron					
Pulse	0.54	0.142	117	132	252
Overhead	0.50	0.086	83	100	184
	**	**	NS	NS	NS
Elaeagnus					
Pulse	1.10	0.352	164	187	351
Overhead	0.98	0.271	132	157	289
	*	*	*	NS	1
Ligustrum					
Pulse	1.41	0.628	257	199	456
Overhead	1.22	0.538	184	158	342
	**	NS^w	NS	**	*
Photinia					
Pulse	1.29	0.469	133	260	394
Overhead	1.15	0.427	107	160	267
	**	NS	*	**	1*

^{y}Height of tallest shoot (m) based on 25 plants/treatment.
^{y}Growth index (m^3) calculated as width 1 × width 2 × (height/2). Means were calculated from measurements of 25 plants/treatment.
^{x}Means based on five plants/treatment.
^{w}Probability of significant F = 0.0507.
^{NS,*,**}Nonsignificant or significant at α = 0.05 and 0.01, respectively.

measured five times over the 24 weeks for both treatments. Most of these Ψ_T less than -1.5 MPa occurred within the first 2 months.

Calculating accumulated daily water stress from diurnal Ψ_T measurements provides a way to quantify differences in water stress between treatments and statistically analyze the results. Predawn measurements of Ψ_T during growth were integrated over time to relate short-term water stress to long-term growth in pine (Linder et al., 1987; Myers, 1988) and to distinguish differences in growth between irrigation treatments for eucalyptus *(Eucalyptus maculata* Hook and *E. brockwayi* C.A. Garth.) (Myers and Landsberg, 1989). Accumulated predawn Ψ_T was also negatively correlated with decreases in maximum photosynthetic rates and net C gain (Schulze et al., 1980a, 1980b). The current experiment extends the use of accumulated water stress to diurnal Ψ_T measurements to account for differences in growth between two irrigation treatments. Because plants were irrigated daily, differences in predawn Ψ_T did not occur even though diurnal differences between treatments were apparent.

During the last 6 months of production, with the exception of photinia, small reductions in the S_Y resulted in significant increases in one or more of the growth variables measured. This increase in growth was not associated with maintaining Ψ_T above estimated thresholds for stomatal closure. Thus, it is highly unlikely that the reduced growth of the overhead-irrigated plants was due to stomatal-limited reductions in photosynthesis. At low to moderate levels of water stress, most reductions in CO_2 assimilation are due to stomatal closure (Chaves, 1991). For azaleas, an 11% reduction in the mean S_Y over 6 months resulted in a 65% increase in the growth index. Maintaining the container medium near 100% moisture lowered the mean S_Y by 18% for elaeagnus and increased the growth index by 30% and total dry weight by 21%. A 10% reduction in mean S_Y of ligustrum increased plant dry weight by 33%. A similar growth reduction was found for red pine *(Pinus resinosa* Ait.) seedlings irrigated at 73% container moisture content compared to 92% (Timmer and Armstrong, 1989).

The unusual response of photinia was probably due to infection and spread of photinia leaf spot *[Fabraea maculatum* Lev. (Atk.)] with overhead irrigation. Infection was absent in the pulse-irrigated treatment. Photinia leaf spot has been suggested to be systemic and shown to reduce growth (Strandberg, 1989). Once infected, fungicide treatments kept the disease in check but may not have controlled the systemic effects. Photinia has been shown to be an efficient water user (Knox, 1989) and, thus, may not have responded to container moisture levels near 100%.

The greater growth of azalea maintained near 100% container moisture is not surprising. Azaleas are known to require copious amounts of water compared to other species (Knox, 1989). The response of elaeagnus, however, was unexpected. Elaeagnus is considered to be a very drought-tolerant species and is often used in dry landscapes where irrigation is seldom applied. These results indicated that while this species may be drought-tolerant, it readily responds to abundant water with reduced water stress and significant increases in growth.

This study revealed that if presumably sufficient daily irrigation is restricted to near dawn, growth will be significantly decreased compared to plants grown in medium maintained near 100% container moisture. Plant quality and dry weight (30%) were increased when *Euonymus japonica* was irrigated twice daily compared to only at 0600 HR (Newman and Follett, 1988). Mid-morning and mid-afternoon overhead irrigation also increased the seasonal growth of ‘Hershey’s Red’ azalea compared to irrigation at 2100 HR (Keever and Cobb, 1985). The split irrigation for ‘Hershey’s Red’ reduced media and canopy temperatures 4C and was cited as the reason for the greater growth. The split irrigation would have also reduced the S_Y of these plants. In maple *(Acer rubrum* L.) seedlings, elevated root temperatures resulted in lower Ψ_T (Graves et al., 1989). The drip system used in this experiment may have also lowered medium temperatures. It is doubtful, however, due to the spacing of the containers and size of the canopies, that medium temperatures were excessive in this study. Based on the current study and previous research, it is impossible to determine whether the reduction in medium temperature or the increase in available water reduced the S_Y of container plants. In either case, decreases in canopy growth with dawn-only irrigation appear to be due to incremental increases in daily diurnal water stress over the course of a growing season. Similarly, moderate water stress over long periods was more detrimental to dry matter accumulation than severe stress for short periods in eucalyptus (Myers and Landsberg, 1989). If overhead irrigation is prohibited during the daylight hours to improve irrigation efficiency, slower growth of landscape ornamentals appears inevitable with the overhead irrigation systems currently used by most southeastern nurseries.

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