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Effect of Seasons and Irrigation Regimes on Plant Growth and Water-Use of Container-Grown *Photinia* × *fraseri*[1]

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Abstract

Water-use and plant growth of Fraser photinia (*Photinia* × *fraseri* Dress) were studied under varying irrigation regimes during 2 different growing seasons, winter and summer. Rooted cuttings were transplanted into 7.57 l (2 gal) plastic containers containing Metro-mix 500 and greenhouse-grown under 2 irrigation frequencies (3.5 or 7-day intervals) and 3 replacement amounts (100%, 75% or 50% replacement of actual water-use).

Increased irrigation frequency significantly reduced plant growth parameters of winter-grown plants, including shoot growth, leaf number, leaf area and shot dry weight. Decreased irrigation amount significantly increased root dry weight. Significant differences were not detected in growth measurements of summer-grown plants suggesting differences between experiments are seasonal in nature. Frequent irrigation resulted in poor plant performance under winter growing conditions of lower evapotranspiration (ET); however under summer growing conditions, frequent irrigation did not significantly affect plant growth.

Decreased irrigation frequency significantly increased total water-use for winter-grown plants due to increased plant performance. No significant differences in water-use due to frequency in summer-grown plants was found.

Index word: Fraser photinia

Significance to the Nursery Industry

Plant growth data from these experiments indicate that maintaining high medium moisture levels through frequent irrigations does not always stimulate growth and quality, especially during winter growing conditions. The data suggest that poor aeration is enhanced by frequent irrigation and results in decreased plant growth of *Photinia* × *fraseri* grown in containers filled with Metro-mix 500. In this study, high water contents were maintained in the medium of each treatment; therefore, reduced plant performance due to water deficits and low water potential of the medium was not evident.

Variation in water holding capacities and porosity of growing media requires that nursery managers and research scientists monitor medium moisture levels and ET rates to optimize plant growth and irrigation water-use and/or validate research findings. For Metro-mix 500, a medium with high water-holding capacity, there seems to exist a fine line between optimum irrigation and excess irrigation. This is especially true under conditions of low ET rates combined with high medium moisture levels often experienced in greenhouse and nursery operations during winter months. Careful consideration should be given to irrigation scheduling during such periods to avoid plant damage by saturated medium environments and poor medium aeration. Fixed irrigation schedules for long-term convenience should be avoided due to variations in ET rates, media moisture capacities and plant development.

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Introduction

Fraser photinia (*Photinia* × *fraseri* Dress) production represents as much as 10% of annual production of woody landscape plants in container nurseries throughout the southern U.S. Despite the popularity of this landscape species, the optimum irrigation regime for Fraser photinia production is not known.

A standard irrigation practice for the nursery industry involves frequent watering schedules (ie., daily, twice daily) to maintain high moisture levels in the growing medium (7). This schedule is believed to avoid reduced plant quality and growth caused by lack of water; therefore, excess water is often applied.

Efficient irrigation schedules should be based on actual water needs of the plants, environmental conditions and moisture and aeration conditions of the growing medium (8). Research is limited on irrigation scheduling for woody landscape species during the production phase based on these factors.

The research reported here was conducted to investigate the effect of changing moisture and aeration levels in the growing medium on plant growth and water-use of Fraser photinia. The objective was to measure plant growth and water relations under varying irrigation regimes during different seasons, winter and summer.

Materials and Methods

Cultural Conditions. Rooted cuttings of Fraser photinia (3), averaging 20.1 cm (8.0 in) in length, were transplanted into 7.57 l (2 gal) plastic containers containing 4800 cm^2 (293 in^3) Metro-mix 500, a 1:1:2 (v/v/v) vermiculite:peat:bark mix. Plants were transplanted 4 days before initiating irrigation treatments and grown under greenhouse conditions.

The duration of the winter experiment was 63 days (mid October to late December, 1987). The average daylength for this period was 10.49 hr and global irradiance was 14.69 MJ/sq m/d. Average greenhouse temperatures were 23°C (70°F) day and 17°C (62°F) night.

The duration of the summer experiment was 49 days (mid May to early July, 1988), with an average of 32% longer daylengths (13.80 hr) and 113% greater global irradiance (31.29 MJ/sq m/d) compared to winter conditions. Average greenhouse temperatures were 26°C (70°F) day and 20°C (68°F) night.

Irrigation treatments maintained various levels of aeration and moisture in the growing medium without entering into water deficit or flooded conditions. Irrigation frequencies of 3.5 and 7-day intervals were included to investigate the effect of increased intervals between irrigations on plant growth. By varying the percent replacement of actual water-use (100%, 75% and 50%), the effect of air-filled porosity in the growing medium on plant growth was investigated.

Actual water-loss was determined gravimetrically (2). The medium surface was covered with white polyethylene plastic to eliminate evaporation (1); therefore, actual water-use was equivalent to transpiration. Each potted plant was weighed at 3.5 or 7-day intervals and the amount of water-use was determined. The amount of irrigation water applied was calculated by multiplying actual water use by percent replacement for that treatment.

Irrigation water was applied by hand using reverse osmosis-treated water. Fertilizer was applied twice during both experiments through irrigation water at 100 ppm of N (15N-6.8P-14.1K).

Growing medium physical characteristics included: bulk density of 0.21 g/cu cm; container water capacity of 2950 ml (3 qt), 61.5% by vol; calculated total porosity of 76% by vol; medium air porosity at container capacity of 14.5% by vol; medium water content at permanent wilting (−1500 kPa) of 682 ml per container (0.72 qt), 14.2% by vol; and plant available moisture of 2268 ml (2.39 qt), 47.3% by vol per container. Metro-mix 500 releases 77% of its plant available moisture between container capacity and −33 kPa, which is within the normal range of container growing media (9).

Measurements. Growth measurements (including shoot extension and leaf number) were made weekly. Leaf area and 2-dimensional root area were measured with an area meter (Delta-T Devices LTD, Cambridge, England) at the beginning and termination of each experiment. Final measurements included shoot dry weight and root dry weight of each plant. Relative growth for both experiments was calculated by dividing the mean growth rate (shoot extension per day) of each irrigation treatment by the highest mean growth rate.

Whole plant water-use (transpiration) and irrigation water applied were totaled for both experiments. Medium moisture depletion was determined at termination for each treatment in both experiments. For 100% replacement treatments, depletion values represent the total depletion between each irrigation, where as 75% and 50% replacement resulted in an increasing depletion throughout the experiments. Also medium aeration was estimated for the 100% replacement treatments in both irrigation frequencies for each experiment. The values for air-filled porosity represent the mean porosity immediately before irrigation.

Statistics. A split plot design was utilized, with irrigation frequency as the whole plot and irrigation amount as the sub-plot. Four replications per irrigation treatment were used in the winter experiment and six in summer. An analysis of variance procedure was performed on all data and mean separations were determined by Duncan's multiple range test for frequency and amount, and Fisher's Protected LSD test for interactions.

Results and Discussion

Plant Water-Use and Growth. Throughout both experiments, values for total water-use and cumulative depletion of plant available moisture in the medium were calculated (Table 1). Due to the high water-holding capacity of the growing medium, the water potential of the medium for all treatments never decreased below −33 kPa or 57% of plant available moisture (1303 ml available moisture remaining). Under these medium conditions, reduction of plant growth because of limited available moisture would not be expected.

In the winter experiment, irrigation frequency significantly effected plant water-use with 3.5-day frequency plants using significantly less water than those irrigated every 7 days. No significant differences were observed in the summer experiment.

At termination of each experiment, comparisons of water-use and medium moisture depletion between experiments were not made due to the variation in duration of seasonal treatments. However for comparison, on day 42 of the experiments the winter experiment averaged significantly less plant water-use (945 ml) and depletion of medium moisture (335 ml) than summer water-use (1383 ml) and depletion (511 ml).

Frequency of irrigation significantly effected plant growth in the winter experiment. Shoot growth, leaf number, leaf area and shoot dry weight were significantly less under 3.5-day frequency than 7-day frequency (Table 2).

In the winter experiment, significant differences in root dry weight and root area were due to irrigation amounts (Table 3). Irrigation at 50% replacement of water-use pro-

Table 1. **Effect of irrigation interval and percent replacement of transpired water on cumulative water-use, water applied and depletion of medium moisture (total plant available moisture is 2268 ml) at termination of the winter and summer experiments in Fraser photinia.**

Irrigation interval (days)	% Water replacement	Water-use (ml)	Water applied (ml)	Depletion (ml)
			Winter Experiment	
3.5		1458 b[z]	1114 a	364 b
7.0		1702 a	1243 a	528 a
	100	1471 a	1471 a	131 c
	75	1593 a	1264 b	414 b
	50	1677 a	800 c	793 a
			Summer Experiment	
3.5		1362 a	1362 a	395 a
7.0		1401 a	1402 a	432 a
	100	1437 a	1437 a	247 b
	75	1431 a	1075 b	357 b
	50	1279 a	642 c	637 a

[z]In each experiment, interval and replacement means within columns followed by the same letter are not significantly different as determined by Duncan's multiple range test, P = 0.05.

duced the highest root dry weight and root area, followed by 75% and 100%.

Data from the summer experiment indicated no statistical differences in shoot extension, shoot dry weight, leaf number, leaf area and root area (Table 2 and 3). However, results showed similar trends to winter data with more frequent, higher amounts of irrigation producing less shoot length.

Amount of irrigation significantly effected root to shoot (R/S) ratios of summer-grown plants, with 100% replacement of water-use resulting in lower ratios (Table 3). The winter experiment R/S ratio showed similar trends of increased irrigation amounts producing lower ratios (Table 3).

In the winter experiment, decreased plant water-use between irrigation treatments seems to be a direct response to decreases in plant growth (Table 2), since plants watered on a 3.5-day interval had significantly less growth than those watered on a 7-day interval. This evidence suggests that the 3.5-day interval between irrigations, regardless of replacement amount, is detrimental to plant growth under reduced transpirational demands of winter.

The results suggest that the presence of shorter days and less global irradiance in winter directly effected plant growth, water-use and moisture depletion. The results indicate that frequent irrigation under winter conditions is responsible for poor growing medium aeration and plant growth (Figure 1). It is suggested that as irrigation frequency increased, depletion of the medium moisture is greater between irrigations. This increased moisture depletion results is increased aeration compared to frequent irrigation. In the winter experiment, irrigation treatment of 50% replacement and 7-day frequency resulted in greater plant growth due to increased air-filled porosity. In the summer experiment, plants did not significantly differ in total water-use or plant growth. Under high transpirational demands of summer, acceptable air-filled porosity of the medium was perhaps maintained by increased water-use.

Seasonal Conditions and Medium Aeration. Under the winter growing conditions of decreased transpirational demand, more frequent irrigation may have caused near saturated conditions in the growing medium. Near saturated conditions for this medium would be at container capacity (14.5% air-filled porosity). These medium conditions may result in less medium pore space filled with air, perhaps

Table 2. **Effect of irrigation interval on shoot extension, shoot dry weight, leaf number and leaf area in Fraser photinia at termination of the winter and summer experiments.**

Irrigation interval (days)	Shoot extension (cm)	Shoot dry weight (g)	Leaf number	Leaf area (cm^2)
		Winter Experiment		
3.5	16.46 b[z]	4.35 b	19.6 b	227 b
7.0	27.21 a	5.71 a	27.2 a	361 b
		Summer Experiment		
3.5	26.33 a	5.51 a	25.7 a	325 a
7.0	28.81 a	6.13 a	26.0 a	350 a

[z]In each experiment, interval means within columns followed by the same letters are not significantly different as determined by Duncan's multiple range test, P = 0.05.

Table 3. **Effect of percent replacement of transpired water on root dry weight, root area and root to shoot ratio in Fraser photinia at termination of the winter and summer experiments.**

% Water replacement	Root dry weight (g)	Root area (mm^2)	Root:shoot ratio
	Winter Experiment		
100	0.718 b[z]	244.9 b	0.176 a
75	1.018 ab	334.9 a	0.196 a
50	1.135 a	370.1 a	0.224 a
	Summer Experiment		
100	0.635 b	199.9 a	0.108 b
75	0.878 a	235.4 a	0.141 a
50	0.816 ab	212.6 a	0.150 a

[z]In each experiment, percent replacement means within columns followed by the same letter are not significantly different as determined by Duncan's multiple range test, P = 0.05.

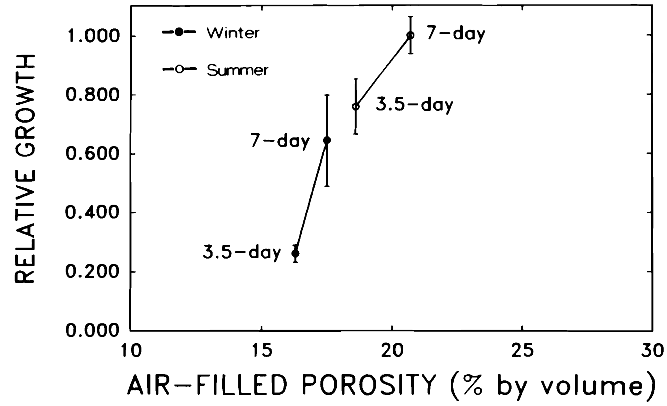

Fig. 1. **Effect of air-filled porosity just before irrigation on relative growth of Fraser photinia produced under varying irrigation intervals (day) and 100% replacement of transpired water. Bars are standard errors of the means.**

reducing medium gas exchange and adversely affecting growth (7). Increased irrigation frequency and decreased percent replacement seemed to enhance plant growth in the winter experiment, which may be attributed to an increase in aeration of the medium.

Plant Growth and Medium Aeration. For Fraser photinia, this data suggests that medium air-filled porosity of 16.3% by volume may result in decreased plant growth as indicated by winter-grown plants under 3.5-day irrigation interval and 100% water replacement (Figure 1). Within each experiment, plant relative growth was increased under an irrigation interval of 7 days. This increased interval corresponds to an increase in air-filled porosity of the growing medium. The air-filled porosity estimated for the summer experiment 7-day irrigation interval and 100% water replacement was 20.7%.

Comparison of plant growth under each experiment indicated superior performance by summer experiment plants. With summer conditions having 32% longer days, 113% greater global irradiance and summer-grown plants having up to 78% higher water-use, medium moisture depletion between irrigations of the 100% replacement treatments was increased almost 2-fold compared to the winter experiment (Table 1).

Early investigations concerning the concept of optimum aeration in container growing media were conducted by Flocker et al. in 1959 (5). They reported that air-filled porosities greater than 20%, and sometimes greater than 30%, were needed for optimum establishment and growth of container-grown tomatoes. Their conclusion was that each growing medium has an optimum air porosity and greater or less than this optimum results in reduced plant growth. Grable, in further studies, concluded that plant species vary greatly as to medium aeration requirements for optimum growth (6).

Within this experiment, medium aeration seems to be limited primarily by increased water content resulting in a reduced number of large diameter pores in the medium. These 'transmission pores' serve simultaneously as the major pathway for water drainage, the exchange of gases between atmosphere and soil and the unrestricted penetration of roots (4). Near saturated conditions and limited aeration may reduce root and shoot growth, decrease medium fertility and reduce root respiration. In the winter experiment, those plants exhibiting reduced plant performance may be suffering from these mechanisms of injury.

The irrigation treatments in this study helped define acceptable levels of medium aeration, available medium moisture and irrigation for Fraser photinia. The experiment also identified excess levels of these parameters.

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