Effects of Irrigation Volume and Frequency on Shrub Establishment in Florida[1]

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Abstract

Irrigation frequency and volume effects were evaluated on recently installed #3 container grown shrubs of three taxa, *Ilex cornuta* Lindl. & Paxt. 'Burfordii Nana', *Pittosporum tobira* Thunb. 'Variegata', and *Viburnum odorotissimum* Ker Gawl. Irrigation frequency and volume had no effect on *Pittosporum* at any time for any measured root or shoot parameter. Irrigation frequency and volume had no effect on *Ilex* and *Viburnum* canopy biomass, root biomass, root dry weight:canopy dry weight ratio, and stem water potential at any time after planting. Canopy growth was affected by irrigation treatment only for *Viburnum* plants installed in May 2004, and growth response to more frequent irrigation only occurred while plants were irrigated, with no lasting impact on growth once irrigation ceased. Root spread and root spread:canopy spread ratio for only one species, *Ilex*, were influenced by irrigation treatment. Applying excessive irrigation volume (in this case 9L) reduced root dry weight:shoot dry weight ratio for *Ilex* and could increase the time needed for plants to grow enough roots to survive without irrigation. Our study found only slight influences on shrub growth from the tested values of irrigation frequency and volume regardless of the time of year when data was collected. This indicates that these shrubs can be established with 3 liters irrigation applied every 4 days until roots reach the edge of the canopy under the mostly above normal rainfall conditions of this study. Applying more volume or irrigating more frequently did not increase survival or growth. Canopy growth and plant quality data combined with past research suggest that establishment of these shrub species may be more influenced by environmental conditions such as rainfall than by the irrigation frequency and volume used in this test.

Index words: root growth, root spread, root:shoot ratio, xylem potential, drought tolerance.

Species used in this study: dwarf Burford holly (*Ilex cornuta* Lindl. & Paxt. 'Burfordii Nana'); variegated Japanese pittosporum (*Pittosporum tobira* Thunb. 'Variegata'); and sweet viburnum (*Viburnum odorotissimum* Ker Gawl.).

Significance to the Nursery Industry

The different volumes and frequencies of irrigation applied to the root ball and to the small area around the root ball had little influence on canopy growth or health of #3 container grown shrubs planted into sandy landscape soil under average or above average rainfall conditions. Irrigating every 4 days with 3 liters appears to be an efficient method of establishing shrubs of this size in north Florida when average rainfall occurs after planting. Applying more volume or irrigating more frequently did not increase survival or growth. Irrigating every 2 days may provide for a slightly more attractive shrub in the first year after planting.

Introduction

Too little water hampers establishment and growth of newly installed woody plants in the landscape by restricting root growth (2, 20) and results in a corresponding reduction in vegetative and reproductive growth (15). Several studies note increased growth in response to increased frequency of irrigation during establishment. However, Barnett (3) notes that optimal frequency and volume of irrigation vary with soil type. Barnett (3) reported greater canopy growth (4.9 ft^3 plant volume) of #1 (1 gal) sized *Ligustrum vulgare* with more frequent irrigation and sparser foliage (1.0 ft^3) with less frequent applications. Gilman et al. (7) found that increased irrigation frequency in warm, moist, temperate Florida resulted in significantly greater new shoot growth, and shifted new root growth from the bottom of the root ball to the top for *Ilex cornuta* 'Bufordii Nana'.

Red maple responded to increased irrigation frequency in temperate eastern United States with an increase in trunk diameter (5.8 vs. 4.7 cm), height (3.4 vs. 2.7 m), and new root mass (102.9 vs. 52.5 g) (10). Stabler and Martin (16) in the drier climate of Arizona found that growth of *Caesalpinia pulcherrima* and *Cercidium floridum* increased as irrigation frequency increased; however, trees in all treatments grew during the study and none exhibited signs of water stress. Growth, mortality, and visual appearance of *Ceanothus griseus*, *Rhamnus californica*, and *Photinia* × *fraseri* in the dry climate of southern California were not affected by irrigation frequency (daily or every 3, 5, or 7 days) following planting; mortality was affected by species rather than irrigation (11).

Irrigation frequency appears to be more important to tree establishment than volume applied. Gilman et al. (6) found that irrigation volume greater than 6 liters (1.5 gal) did not significantly affect plant growth or stem water potential of 5 cm (2 in) caliper *Quercus virginiana* in warm temperate Florida; irrigation frequency was most important. Renquist (12) found that peach trees were also more influenced by irrigation frequency than by volume during establishment. Similarly, changes in irrigation volume were not reflected in significant changes in growth of *Photinia* × *fraseri* (19).

Most work on irrigation during establishment has been performed on trees. The objective of this study was to evaluate impact of irrigation frequency and volume on shrub

[1]Received for publication February 3, 2009; in revised form March 29, 2009.

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establishment of *Viburnum odoratissimum*, *Ilex cornuta* 'Burfordii Nana', and *Pittosporum tobira* 'Variegata'.

Materials and Methods

Ilex cornuta Lindl. & Paxt. 'Burfordii Nana', *Pittosporum tobira* Thunb. 'Variegata', and *Viburnum odorotissimum* Ker Gawl. obtained from a local commercial nursery in 11.4 liter (#3) containers were planted May 27, 2004, into fine sand (Arredondo sand series) at the University of Florida's Plant Science Research and Education Unit in Citra, FL (USDA hardiness zone 8b). These three shrubs are commonly planted in the southern part of the United States. All shrubs were planted on 1.8 m (6 ft) centers with tops of root balls positioned even with surrounding landscape soil. Circling roots at the edge of containers were not cut at planting in accordance with landscape industry practices. One plant of each species was randomly planted in each of the five blocks (15 plants total) October 2003 (seven months before test plants were installed) in the same manner as test plants. These more established plants (called indicator plants) were irrigated with 9 liters every 2 days for 9 months to encourage rapid establishment. Indicator plants were used to compare against root to shoot ratios and stem water potential of test plants. The entire plot was mulched with 7.5–10 cm (3–4 in) long pine bark nuggets to a depth of 8 cm (3 in) (Florida Potting Soil, Orlando, FL) immediately after planting. A second (replicate) plot was planted November 16, 2004, in the same manner and adjacent to the first plot.

Two irrigation frequencies (every 2 or 4 days) and three irrigation volumes (3, 6 or 9 liters per plant per irrigation event) were evaluated in 5 blocks, for a total of 30 plants per species for each planting date in a split plot design. The two irrigation frequencies were the main plot randomized within each block; species and irrigation volumes were randomized within each frequency main plot. Each plant was irrigated with three bubbler emitters (Model Shrubbler® 360°, Antelco®, Longwood, FL) calibrated to deliver the desired volume. Each emitter was mounted 10.2 cm (4 in) above ground level with one emitter located on the east and west side of each plant, 15 cm (6 in) from the outside of the rootball, and the third emitter positioned on the rootball. Irrigation was switched on and off using a battery operated valve controller (Model SVC, Hunter® Industries Inc., San Marcos, CA). Irrigation began at 0500 HR and was completed by 0600 HR. Flow meters (Model C700TP, ABS, Ocala, FL) were installed for each frequency × block combination to record irrigation volume applied. Irrigation was discontinued 11 weeks after planting (WAP). Supplemental irrigation was supplied when signs of water stress (severe wilting or beginning of leaf drop) were apparent. After 33 days with no rainfall (26 WAP) supplemental irrigation was applied once in November 2004 to all May 2004 planted shrubs. The supplemental irrigation applied to each shrub was consistent with the irrigation volume that shrub had received the first 11 WAP. Supplemental irrigation after 11 WAP was never applied to the November 2004 planted shrubs.

Controlled-released fertilizer was applied every 3 months beginning 30 days after transplanting at a standard rate of 0.45 kg N·100 m^{-2} (1 lb N·1000 ft^{-2}) of 12N–0.9P–11.6K Southern Landscape Fertilizer (LESCO, Inc., Sebring, FL) uniformly broadcast to a 0.84 m^2 (9 ft^2) area around each plant. Weeds were controlled with periodic hand-pulling and *N*-(phosphonomethyl) glycine (glyphosate). Shrubs were not pruned during the study. Rainfall data were collected with a weather station on site.

To evaluate shrub establishment and growth, canopy height, greatest canopy width (width 1), and width perpendicular to the greatest canopy width (width 2) were measured at planting, and at 26, 34, and 52 WAP. Measurements of canopy height, width 1, and width 2 were used to calculate canopy growth index (CGI (m^3) = height × width 1 × width 2). Slight differences in initial shrub size at planting were accounted for by evaluating canopy growth. Canopy growth was calculated as follows: CGI (m^3) – initial CGI (m^3). Plant canopy density and dieback was visually evaluated 52 WAP on a scale of 1 (dead) to 9 (dense plant, no dieback similar to the indicator plants).

Root spread radius measurements on all plants were made at 26, 34, and 52 WAP. Root spread was measured by gently removing the mulch layer from a section of soil approximately 30 cm (12 in) wide just beyond the estimated edge of the root system on two opposite sides (east and west) of the shrubs from each treatment combination. Soil was carefully removed by gently digging toward the plant until the outermost roots (those farthest from the trunk) were identified. Distance between the trunk and the farthest root was recorded as root spread radius. Mulch was carefully spread back into place. Root spread radius to canopy radius ratio was calculated by dividing root spread radius by the canopy radius. Canopy radius was calculated by dividing average diameter of the canopy by two.

Canopy dry weight and root system dry weight were measured at 64 WAP. The entire above ground canopy was harvested by severing the trunk at ground level. Two 1/8th wedge-shaped sections (for a total of 1/4) of the root system in the landscape soil were harvested starting at the trunk. Substrate and soil were washed from the roots. Shoot and root mass were dried at 65C (149F) until constant dry weight was obtained. Total root system dry weight was calculated by multiplying the harvested weight by four. Root to shoot biomass ratio was calculated by dividing total calculated root system dry weight by canopy dry weight.

Midday shoot water potential (Ψ_w) was measured on two replicates of each treatment combination for all species including the established indicator plants. Shoot water potential was determined with a pressure chamber (Model 3000; Soil Moisture Equipment Corp., Santa Barbara, CA) using compressed N, with pressure increasing at a rate of 2.5 kPa·s^{-2}. Measurements were made on individual stem sections (≈ 10 cm long) at 19 WAP which was two months after irrigation was discontinued.

Canopy growth, root spread radius, root spread to canopy ratio, shoot dry weight, root dry weight, root dry weight to canopy dry weight ratio, and stem water potential were analyzed separately for each species using the MIXED procedure of SAS (Version 9.1, SAS Institute, Cary, NC) ($P < 0.05$). Frequency and volume were the fixed effects. Mean separation was by Tukey's Test. Plant density and canopy die-back were analyzed using the RANK and the MIXED procedures of SAS for nonparametric analysis (Version 9.1, SAS Institute, Cary, NC) ($P < 0.05$). Mean separation was by Tukey's Test. Each planting date was analyzed separately.

Results and Discussion

Irrigation frequency and volume had no effect on *Pittosporum* at any time for any measured root or shoot parameter

Table 1. Canopy and root measurements 52 weeks after May 2004 planting of *Viburnum* with 2 irrigation frequencies and 3 irrigation volumes.

Irrigation frequency	Irrigation volume	Canopy growth (m^3)	Canopy density[z]	Canopy dieback[z]	Canopy dry weight[y] (g)	Root spread radius (cm)	Root dry weight[y] (g)	Root spread radius to canopy radius ratio	Root dry weight to canopy dry weight ratio[y]
Every 2 days	3 L	.66	97.00	143.50	1142.50	87.67	591.73	1.77	.53
Every 2 days	6 L	.72	159.00	105.33	1156.57	93.17	477.87	1.81	.42
Every 2 days	9 L	.62	97.00	105.33	1399.00	97.67	734.67	2.00	.53
Every 4 days	3 L	.63	97.00	143.50	1151.47	97.00	488.67	2.01	.41
Every 4 days	6 L	.67	128.00	105.33	1099.00	96.83	514.27	1.88	.47
Every 4 days	9 L	.53	74.33	143.50	1127.97	88.50	446.30	1.86	.37
Irrigation frequency		.58	.30	.56	.38	.89	.16	.73	.32
Irrigation volume		.38	.01*[x]	.37	.49	.74	.42	.69	.91
2 vs 4 days with 3 L		.85	0.00	0.00	.96	.31	.51	.21	.40
2 vs 4 days with 6 L		.74	.48	1.00	.77	.69	.61	.52	.60
2 vs 4 days with 9 L		.37	.32	.32	.24	.51	.23	.64	.15

[z]Density and dieback means were generated by the Proc RANK procedure in SAS.

[y]Biomass measurements were recorded 64 weeks after planting.

[x]Significance of treatment effects and interactions *($P < 0.05$).

during the study (data not shown). This indicates that these shrubs can be established with 3 liters irrigation applied every 4 days under the conditions of this study. Applying more volume or irrigating more frequently did not increase survival or growth. Irrigation frequency and volume did not affect *Ilex* and *Viburnum* canopy dry weight, root dry weight, root dry weight to canopy dry weight ratio (May planting: Tables 1 and 2; November planting: data not shown), and stem water potential after planting (data not shown). Growth of a drought tolerant tree (*Quercus virginiana* Mill.) planted from either containers or a field nursery also did not respond to increasing irrigation volume during the months after planting (6).

Viburnum was the only species with canopy growth affected by irrigation treatment for plants installed in May 2004. *Viburnum* canopy growth 26 WAP was greater when irrigated every 2 days than every 4 days but not 34 or 52 WAP (Fig. 1A). This indicates that growth response to more frequent irrigation only occurred while plants were irrigated, with no lasting impact on growth once irrigation ceased. Trees also responded to more frequent irrigation during establishment with increased growth, but the difference in size persisted for 5 years (4). *Viburnum* canopy density was slightly but significantly reduced when shrubs received 6 liters irrigation compared with 3 or 9 liters (Table 1). Although *Ilex* canopy growth was not influenced by irrigation treatment, canopy dieback was significantly reduced when shrubs were irrigated every 2 days compared to every 4 days ($P = 0.03$) (Table 2).

Viburnum and *Ilex* installed in November 2004 were slightly influenced by irrigation treatment. *Ilex* canopy growth was greater 26 WAP when irrigated with 6 liters compared with 3 or 9 liters every 4 days, but not with every 2 days irrigation ($P = 0.02$) (Fig. 1B). We can not explain why shrubs would grow better at the 6 liter volume. There was no impact of irrigation volume or frequency on *Ilex* canopy growth after 26 WAP. *Viburnum* canopy growth was greater when supplied with 3 liters irrigation than 6 or 9 liters at 34 WAP ($P = 0.03$) (Fig. 1C), but there was no impact of irrigation on *Viburnum* canopy growth after that.

Table 2. Canopy and root measurements 52 weeks after May 2004 planting of *Ilex* with 2 irrigation frequencies and 3 irrigation volumes.

Irrigation frequency	Irrigation volume	Canopy growth (m^3)	Canopy density[z]	Canopy dieback[z]	Canopy dry weight[y] (g)	Root spread radius (cm)	Root dry weight[y] (g)	Root spread radius to canopy radius ratio	Root dry weight to canopy dry weight ratio[y]
Every 2 days	3 L	.19	128.00	143.50	968.93	73.17	287.87	1.83	.29
Every 2 days	6 L	.14	128.00	105.33	868.57	61.83	195.87	1.62	.22
Every 2 days	9 L	.16	128.00	143.50	943.60	77.33	325.33	1.98	.34
Every 4 days	3 L	.11	97.00	58.50	717.13	76.17	189.07	2.21	.26
Every 4 days	6 L	.11	74.33	67.17	781.97	47.33	167.02	1.25	.24
Every 4 days	9 L	.14	128.00	96.67	799.33	79.83	161.02	2.05	.23
Irrigation frequency		.22	.20	.04*[x]	.10	.69	.32	.89	.67
Irrigation volume		.55	.61	.61	.78	.002**	.58	.01*	.57
2 vs 4 days with 3 L		.05	.32	.08	.08	.62	.52	.16	.86
2 vs 4 days with 6 L		.57	.05	.32	.12	.27	.70	.37	.68
2 vs 4 days with 9 L		.69	1.00	.32	.37	.82	.19	.70	.14

[z]Density and dieback means were generated by the Proc RANK procedure in SAS.

[y]Biomass measurements were recorded 64 weeks after planting.

[x]Significance of treatment effects and interactions *($P < 0.05$) ** ($P < 0.01$).

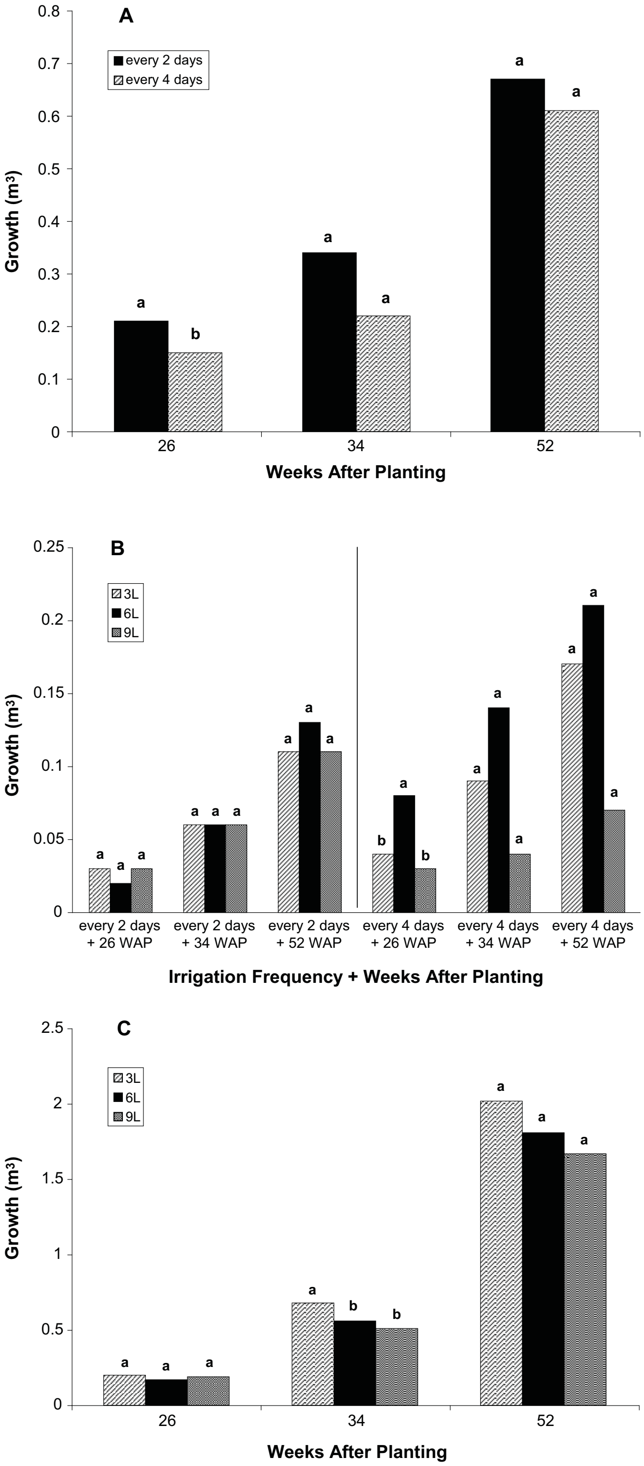

Fig. 1. Significant main effects and interactions on canopy growth of *Viburnum* (A, C) and *Ilex* (B). Letters denote significant differences ($P < 0.05$) between irrigation frequencies (A), volumes (C) or among irrigation volumes within a frequency and week after planting (B) at 26, 34, or 52 weeks after planting in May (A) or November (B, C).

Canopy growth and plant quality data combined with past research suggest that establishment of these shrub species may be more influenced by environmental conditions such as rainfall than by the irrigation frequencies and volumes used in this test. Rainfall was below average for the first 4 WAP in May 2004 while plants were being irrigated; rainfall was above average for the remainder of the irrigation period (4–11 WAP) (Fig. 2). Above average rainfall continued the next 8 weeks to 20 WAP (Fig. 2) which was 9 weeks after irrigation ceased. Total rainfall the first 6 months after planting was 384 mm (15.12 in) above normal which probably negated any irrigation treatment effects. Other research showed reduced effects of irrigation on canopy growth (17) or yield (13) in the wetter year of a multiple year study. Following the November 2004 planting, rainfall was below average for the 11 weeks when irrigation was supplied; however, rainfall was above average for approximately the next 16 weeks (Fig. 2) which may have similarly negated any irrigation treatment effects when shrubs were measured at 26, 34, or 52 WAP. Altogether, 182 mm (7.2 in) rainfall occurred above normal during the 16 weeks after irrigation was discontinued. The different volumes and frequencies of irrigation applied to the root ball and to the small area around the root ball did not appear to have greatly influenced canopy growth or health of #3 container grown shrubs in landscape soil under average or above average rainfall conditions. Irrigating every 4 days with 3 liters appears to efficiently establish shrubs of this size when average rainfall occurs after planting.

Viburnum root systems were not influenced by irrigation treatment at any time. Only *Ilex* root spread and root spread to canopy spread ratio were influenced by irrigation treatment. *Ilex* root spread radius 26 and 52 WAP (Fig. 3A) and root spread to canopy spread ratio 52 WAP (Fig. 3B) were greater when shrubs received 3 or 9 liters irrigation compared to 6 liters irrigation in the May planted plot. Root spread radius was not different among main effect treatments for shrubs planted in November, but the interaction between irrigation frequency and volume affected *Ilex* root spread to canopy spread ratio ($P = 0.04$) (Fig. 4). *Ilex* irrigated every 4 days produced the least root spread to canopy spread ratio when supplied with 9 liters compared to 3 liters (34, 52 WAP) or 6 liters (26 WAP). In agreement with Gilman et al. (7) this suggests that applying excessive irrigation volume (in this case 9 liters) reduced root spread to canopy spread ratio for this drought tolerant species, and could increase the time needed for plants to grow enough roots to survive without irrigation.

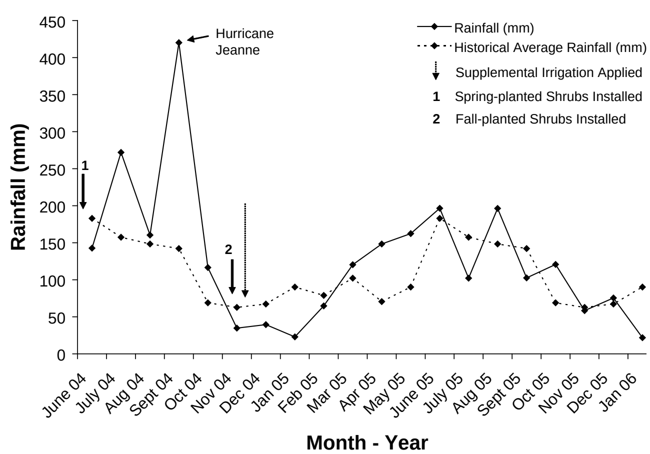

Fig. 2. Actual monthly rainfall June 2004 through January 2006 and historical average monthly rainfall. Arrows (↓) indicate planting dates (1 = May 27, 2004; 2 = November 16, 2004).

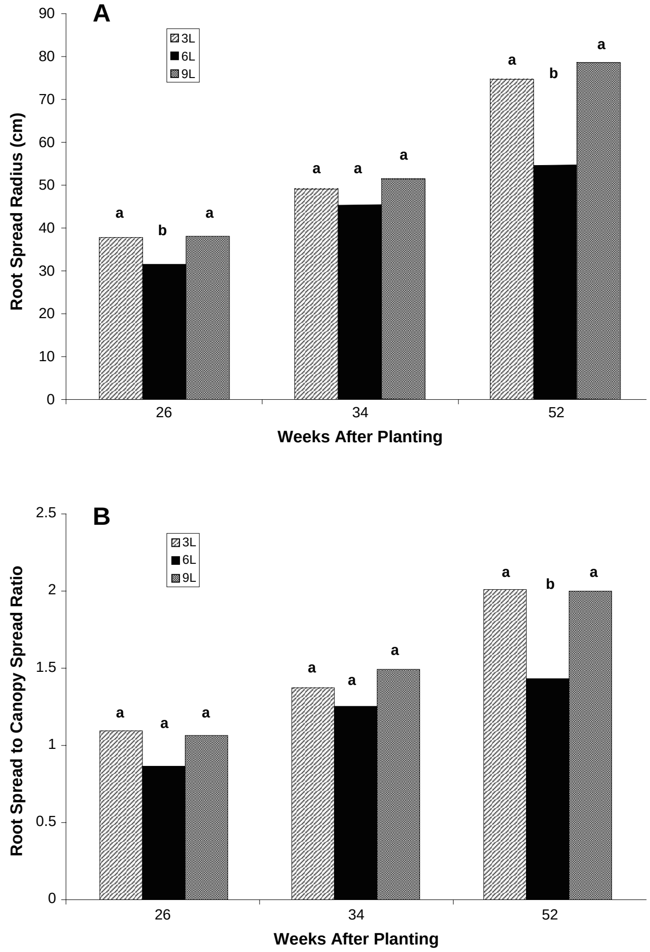

Fig. 3. Effects of irrigation volume on root spread radius (A) and root spread to canopy spread ratio (B) of *Ilex* 26, 34, or 52 weeks after planting in May. Means for each week with different letters are significantly different (P < 0.05).

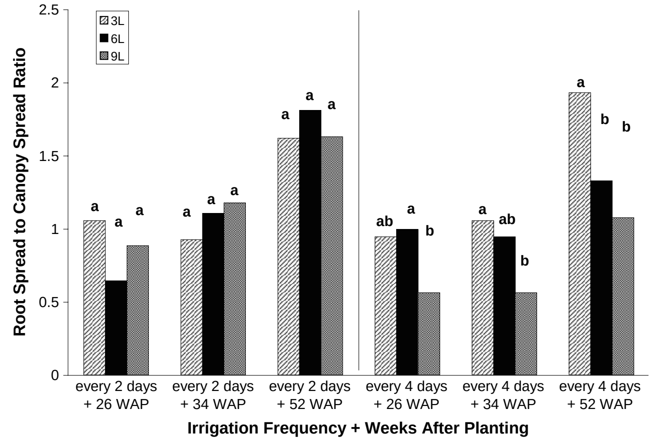

Fig. 4. Root spread to canopy spread ratio for *Ilex* planted in November and maintained with two frequencies and three volumes of irrigation. Means within an irrigation frequency for each time (WAP) with different letters are significantly different (P > 0.05).

Others report reduced root growth with increasing irrigation during establishment. For example, increased irrigation frequency in winter planted *Photinia* × *fraseri* decreased growth; however, neither increased frequency of irrigation (every 3.5 or 7 days) nor increased volume (50, 75, or 100% replacement of actual water use) significantly affected growth of summer installed plants (19). Our study found only slight influences in shrub growth from irrigation frequency and volume regardless of the time of year when data was collected. Although season of planting could not be compared in our study, it seems that under conditions of regular rainfall, *Viburnum*, *Pittosporum*, and *Ilex* shrubs were mostly established by about 19 WAP with 3 liters water supplied every 4 days. This is indicated by the similarity of xylem water potential between test plants of all treatments and established indicator plants (data not shown). However, significant and frequent rainfall occurred during much of the study. When the first prolonged dry period without rainfall for 33 days occurred after irrigation was discontinued on the May planted shrubs, a single irrigation application (in November 2004, Fig. 2) was needed to reduce water stress evidenced by wilting leaves or shoots on the shrubs. Indicator plants installed 7 months prior to test plants were not irrigated because they did not exhibit stress symptoms. This would indicate that test shrubs were not fully established and were not able to sustain themselves on rainfall alone, even 6 months after planting. It is possible then that during significant periods of dry weather the first year after planting shrubs may require occasional irrigation to maintain a favorable water status.

Irrigation frequency affected shrub growth during establishment when a similar study was conducted on the same three species under a rain shelter (14). *Viburnum* receiving 3 liters irrigation every 7 days had only 50% survival. Additionally, *Pittosporum* and *Viburnum* had greater growth (leaf area, shoot dry weight, total biomass) when irrigated every 2 days compared with every 4 or 7 days. Since our data showed little difference in plant response between every 2 and 4 day irrigation frequencies in the outdoor environment, rainfall appears very important in helping #3 container-grown shrubs during the establishment period. However, growth and survival of *Ilex cornuta* 'Burfordii Nana' under a rain shelter were not affected by irrigation frequency, indicating very high drought tolerance (14). Other research under a rain shelter showed that *Ilex cornuta* 'Burfordii Nana' could survive during the establishment period when receiving irrigation once every 14 days for 13 weeks after planting (7). While irrigation did not generally influence growth in our study under normal or greater rainfall, Scheiber et al. (14) suggest more frequent irrigation may be necessary to establish #3 container grown shrubs under drier conditions.

Perhaps small woody plants installed in the landscape from containers do not respond with increased growth from irrigation (11) because there are many roots on the outside surface of the container root ball compared to the amount inside the root ball (1); whereas on woody plants in larger containers (10, 16) there is a lesser amount of roots on the outside surface of the ball compared to what is inside. A large percentage of the total-plant root length on the outside surface of the root ball may offer small plants an advantage in establishing quicker (18). This might explain why small plants may not respond to irrigation provided there is some rainfall in the months after planting to moisten the root ball and surrounding soil. The larger plants remain stressed longer because there is a large portion of the root system still present in the original substrate even three years after planting (5). Gilman et al. (7) showed that root contact with landscape soil on recently planted containers is vital to managing post-planting stress, and this contact is attributed to the roots present on the outer periphery of the root ball.

As roots on the outer surface of the root ball that are in intimate contact with landscape soil grow into the soil under the mulch, they have access to ample moisture because in many new landscapes there are few other living plants with active roots in this soil. Mulch also reduces the evaporation that would occur with bare soil (8, 9), and this keeps soil moist following rainfall or irrigation.

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