HortScience 44(5):1438–1443. 2009.

Effects of Irrigation Frequency during Establishment on Growth of *Ilex cornuta* 'Burfordii Nana' and *Pittosporum tobira* 'Variegata'

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Additional index words. water management, landscape management, root-to-shoot ratio

***Abstract*. Irrigation for establishing landscape plants is restricted to the first 60 days after planting by most water management districts in Florida, yet woody plants may require between 6 and 12 months to become established. Survival and growth of shrubs planted into landscapes depend on adequate irrigation until shrubs develop a root system capable of compensating for evapotranspiration losses. This study examined the effect of irrigation frequency on survival, quality, and growth of *Ilex cornuta* Lindl. & Paxt. 'Burfordii Nana' and *Pittosporum tobira* [Dryand] 'Variegata' planted in north (Citra, FL; USDA hardiness zone 8b) and central (Balm, FL; USDA hardiness zone 9b) Florida. Shrubs were planted into the landscape from 11.4-L (#3) containers at 3-month intervals for a total of eight planting dates over 2 years and irrigated every 2, 4, or 8 days with 3 L of water at each irrigation event. Scheduled irrigation was discontinued once roots grew to the canopy edge [12 to 22 weeks after planting (WAP)] and survival, quality, and growth were evaluated from that point through 104 WAP. *Ilex cornuta* 'Burfordii Nana' irrigated every 2 days had greater canopy growth index (52 through 88 WAP), canopy dry mass (52 and 104 WAP), and maximum root spread (20 through 64 and 88 WAP) when compared with shrubs irrigated every 8d in hardiness zone 8b. *Pittosporum tobira* 'Variegata' irrigated every 2 days had greater canopy growth index (12 through 104 WAP), maximum root spread (20 through 28 and 64 through 88 WAP), and canopy dry mass (52 and 104 WAP) when compared with shrubs irrigated every 8 days in hardiness zone 8b. However, there were no differences in shoot or root growth resulting from irrigation frequency for these shrubs planted in hardiness zone 9a. Irrigation frequency did not affect shrub survival or aesthetic quality at either location. Although more frequent irrigation (every 2 days) resulted in greater plant growth in zone 8b, the two shrub species tested survived and grew after planting in hardiness zones 8b and 9a on natural rainfall alone provided they were irrigated during establishment with 3 L every 4 to 8 days until roots reached the canopy edge. Subsequent supplemental irrigation was only needed in the following 18 months when plants showed visible signs of drought stress, which occurred when there was no measurable rainfall for 30 consecutive days.**

Rapid population growth and frequent droughts are placing a heavy demand on Florida's water resources. As water use increases, water management districts are regulating Florida's water use more strictly. Use of water for landscape irrigation in particular has been restricted throughout the United States (Salamone, 2002; Thayer, 1982). Some water management districts restrict irrigation for establishing landscape plants to the first 60 d after planting. Research suggests, however, that woody plants reach establishment between 6 and 12 months after planting (Gilman and Beeson, 1996; Trenholm et al., 2002).

Adequate water is necessary to establish plants in the landscape (Barnett, 1986; Gilman et al., 1996). When plants are produced in nurseries, roots are confined to a small volume in the container or field root ball. In contrast, root systems of established shrubs (Gilman and Kane, 1991) and trees (Gilman and Beeson, 1996) spread out into surrounding soil. During landscape establishment, plants do not have a sufficient root system to compensate for losses resulting from evapotranspiration (Barnett, 1986; Gilman et al., 1996; Montague et al., 2004). Transplanted shrubs could be considered fully established when the root spread-to-shoot ratio stabilizes (Gilman and Kane, 1991). However, previous research on multiple cultivars of juniper suggests shrubs can survive and grow under normal rainfall conditions when they have reached a posttransplant root-to-shoot ratio between 1.0 and 4.3 depending on shrub growth habit (Gilman and Kane, 1991). If irrigation is inadequate, root growth will be reduced (Balok and Hilaire, 2002; Witherspoon and Lumis, 1986), which will likely result in reduced vegetative (Gilman and Beeson, 1996; Shackel et al., 1997) and reproductive growth (Shackel et al., 1997). Symptoms of drought stress, including declining plant health and quality (Pittenger et al., 2001) and eventually plant death (Eakes et al., 1990), can occur when plants do not receive sufficient irrigation.

A number of studies reported increased irrigation frequency with the corresponding increase in total irrigation volume was correlated with an increase in canopy growth during establishment (Marshall and Gilman, 1998; Stabler and Martin, 2000). In addition to an increase in canopy growth, Marshall and Gilman (1998) and Harris and Gilman (1993) reported an increase in tree root mass as irrigation frequency and therefore total irrigation volume increased. Gilman and Beeson (1996) noted trunk growth rate of 'East Palatka' holly slowed when irrigation frequency was reduced 14 weeks after planting from daily to every 2 d. Reducing irrigation frequency from every 2 or 4 d to every 7 d delayed establishment of *Ilex cornuta* Lindl. & Paxton 'Burfordii Nana' by 4 to 8 weeks (Scheiber et al., 2007). Results of these studies suggest restricting irrigation to every 7 d might delay establishment, during which plants could succumb to drought.

Some research has indicated irrigation frequency with a corresponding increase in total volume may have a greater impact on growth of woody plants during establishment than increased irrigation volume alone (Renquist, 1987). Welsh et al. (1991) reported no changes in growth of *Photinia ×fraseri* in response to increased irrigation volume (50%, 75%, or 100% replacement of actual water use). Similarly, Gilman et al. (1998) did not find differences in growth or stem water potential of *Quercus virginiana* Mill. after transplanting when irrigated with 11, 22, or 33 L of water. Environmental factors, including soil type (Barnett, 1986; Kjelgren et al., 2000), species drought tolerance (Scheiber et al., 2008; Shaw and Pittenger, 2004), and cultivar (Paine et al., 1992), may also interact with irrigation treatment to influence establishment.

Although a number of studies investigated effects of irrigation frequency on tree establishment, few studies have evaluated the same effects on shrubs. As a result, there are few irrigation guidelines on establishment of shrubs. The objective of this study was to evaluate the influence of irrigation frequency during landscape establishment on canopy growth, root growth, and aesthetic quality of *Ilex cornuta* Lindl. & Paxt.'Burfordii Nana' and *Pittosporum tobira* [Dryand] 'Variegata' at two locations in Florida.

Materials and Methods

Experimental design. Two shrub species were obtained from a commercial nursery in 11.4-L (#3) smooth-sided containers and were planted at two sites in Florida: 1) Plant Science Research and Education Unit located in north Florida (Citra, FL; Arredondo sand, loamy, siliceous, semiactive, hyperthermic Grossarenic Paleudults; USDA hardiness zone 8b) and 2) Gulf Coast Research and Education Center located in central Florida (Balm, FL; Zolfo fine sand, sandy, siliceous, hyperthermic Oxyaquic Alorthods or Seffner fine sand, siliceous, hyperthermic Aquic Humic Dystrudepts; hardiness zone 9a). Shrubs were planted within 1 week of pickup and were in similar states of root growth in the container. Shrubs were planted at 3-month intervals at the following eight planting dates: Sept. 2004, Dec. 2004, Mar. 2005, June 2005, Sept. 2005, Dec. 2005, Mar. 2006, and June 2006. Planting dates were used as blocks; they were not a fixed factor. Six shrubs of both species were planted per irrigation frequency per planting date at each location. Shrubs were planted on 3.6-m centers and the root ball was positioned even with the soil surface. Root balls were left undisturbed at planting. Immediately after planting, pine bark mulch (7 to 10 cm long) was applied at a 7.6-cm thickness in 1.8-m-wide rows with shrubs positioned in the middle of the row. No mulch was placed on top of the root ball. *Paspalum notatum* Flüggé (bahiagrass) was maintained on 1.22-m-wide strips between planting rows. Shrub root balls were irrigated to saturation at planting and irrigation treatments started the day after planting.

Three irrigation frequencies (every 2, 4, or 8 d) were applied at each planting date randomly to six single plant replicates of each species at each location for a maximum total volume applied before irrigation was discontinued of 213, 116, and 58 L, respectively. Each shrub was irrigated with 3 L of water per irrigation event using three bubbler emitters (Model Shrubbler® 360°; Antelco®, Longwood, FL). Volume applied (3 L) was determined by an earlier, preliminary study, which indicated that there were no differences in growth among shrubs receiving 3, 6, or 9 L of irrigation per irrigation event when applied to 11.4-L container grown shrubs (Gilman et al., 2009). Each emitter was mounted 10.2 cm above ground level with an emitter located on the east and west side of each plant, 15 cm from the outside of the root ball, and the third emitter positioned on the root ball.

Irrigation frequencies were controlled as separate zones using a valve controller (Model SVC; Hunter® Industries Inc., San Marcos, CA) in north Florida or an automated irrigation time clock (Model Sterling 12; Superior Controls Co., Inc., Valencia, CA) in central Florida. Irrigation in north Florida began at 0800 HR and was completed by 0830 HR; irrigation in central Florida began at 0200 HR and was completed by 0230 HR. Flow meters (Model C700; AMCO, Ocala, FL) were installed for each irrigation treatment to confirm the volume of water applied to each plant. Irrigation was ended for each planting date once average root spread to canopy spread ratio of a given block (planting date) reached 1.0. This occurred when an average of *I. cornuta* 'Burfordii Nana' or *P. tobira* 'Variegata' shrubs in a given block produced roots that grew to the edge of the foliage canopy [within 12 to 22 weeks after planting (WAP) for all plantings]. Irrigation was discontinued for all shrubs installed at a particular planting date at the same time. After irrigation was ended, supplemental irrigation (3 L per plant) was only supplied to all shrubs for a particular planting date when signs of severe water stress (severe wilting, foliage drop) were apparent. Supplemental irrigation was applied five times in north Florida and four times in central Florida over a 2-year period when rainfall was less than 6 mm in any 24-h period consecutively for 32 d. Monthly rainfall data were collected at each planting location from the Florida Automated Weather Network stations located within 50 m of the planting sites. Cumulative rainfall data for each location were determined by summing daily rainfall for each month during the project (Sept. 2004 to June 2008). Historical averages for monthly rainfall were obtained from the National Oceanic and Atmospheric Administration (National Oceanic and Atmospheric Administration, 2002).

All plots were fertilized according to University of Florida–Institute of Food and Agricultural Sciences best management practices (Trenholm et al., 2002). Controlled-release fertilizer was applied every 3 months beginning 30 d after planting at a nitrogen (N) rate of 0.45 kg/100 m^2. A 12N–0.9P–11.6K Southern Ornamental and Landscape Fertilizer (LESCO, Inc., Cleveland, OH) was broadcast to a 0.84 m^2 area around each shrub. Weeds were controlled by hand or with periodic applications of *N*-(phosphonomethyl) glycine (glyphosate) (Monsanto Company, St. Louis, MO). Shrubs were not pruned during the study.

Plant survival and quality. Plant survival was documented at 28, 52, and 104 WAP. In addition, quality (plant density and dieback) was rated visually on a scale of 1 (dead) to 9 (proportional form, dense, full canopy with no dieback).

Growth index. Measurements of canopy height (H), widest canopy width (W1), and width perpendicular to the widest width (W2) were recorded at planting (0), 4, 8, 12, 20, 28, 52, 64, 76, 88, and 104 WAP to calculate canopy growth index [GI (m^3) = H × W1 × W2].

Maximum root spread and root to canopy spread ratio. Maximum root spread was measured at 12, 20, 28, 52, 64, 76, and 88 WAP by carefully excavating the longest surface roots on the east and west sides of the plant and measuring their length from the trunk. Roots could not be evaluated at 104 WAP because they had begun to grow into the compacted turf zone adjacent to the plots. Roots were excavated by gently removing mulch from a section of soil ≈30 cm wide and 100 cm from the trunk and digging by hand toward the plant until outermost new roots were identified. Maximum root spread radius was then determined as the average of the east and west maximum root lengths {maximum root spread radius (cm) = 1/2 × [east root length (cm) + west root length (cm)]}. Root to canopy spread ratio was then calculated as: maximum root spread radius (cm)/canopy radius (cm), where canopy radius (cm) = 1/4 × (W1 + W2).

Dry biomass. Canopy dry weight and root system dry weight of three replicates of each irrigation treatment for each species were measured at 52 and 104 WAP. The entire aboveground canopy was harvested and dried at 105 ± 5 °C for 4 d to determine dry mass of shoots. Two wedge-shaped sections of soil containing ≈1/8 (north Florida) or 1/4

Received for publication 13 Apr. 2009. Accepted for publication 3 June 2009.

This work was supported by the Florida Agricultural Experiment Station, the Florida Department of Agriculture and Consumer Services, the South Florida Water Management District, the Southwest Florida Water Management District, the St. Johns River Water Management District, and the Florida Nursery, Growers and Landscape Association.
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(central Florida) of roots extending beyond the trunk were harvested from each shrub where canopy was removed. Soil material was removed using a sieve and root material was then dried at 105 ± 5 °C for 4 d to determine the dry mass of roots. Total root system dry weight was calculated by: root mass (g) = dry root mass harvested × 8 (north Florida) or root mass (g) = dry root mass harvested × 4 (central Florida).

Data analysis. The experiment was designed as a randomized complete block design with three irrigation frequencies applied randomly to six single plant replicates of each of two plant species within each block (eight planting dates) for a total of 288 shrubs. Irrigation frequency was the only fixed effect analyzed. The field location for each of eight plantings was assigned randomly at each location. Canopy GI, maximum root spread radius, and root to canopy spread ratio were analyzed separately for each hardiness zone by WAP using the PROC MIXED procedure in SAS Version 9.1.3 (SAS Institute, 2003). For analysis of GI, initial GI (0 WAP) was included in the model as a covariate to account for variation in initial plant size at different planting dates. Quality, survival, and harvest biomass data were analyzed separately for each location at 28, 52, and 104 WAP (as applicable). Harvest biomass (shoot biomass and root biomass) was analyzed using the PROC MIXED procedure in SAS Version 9.1.3 (SAS Institute, 2003). Plant quality was analyzed using the PROC GLIMMIX program in SAS Version 9.2 (SAS Institute, 2003) using multinomial distribution and the cumulative logit link function. Plant survival was analyzed using the PROC GLIMMIX program in SAS Version 9.2 (SAS Institute, 2003) using binomial distribution and the logit link function. Dead plants were treated as missing data. All pairwise comparisons were completed using the Tukey's honestly significant difference test with a significance level of $\alpha = 0.05$.

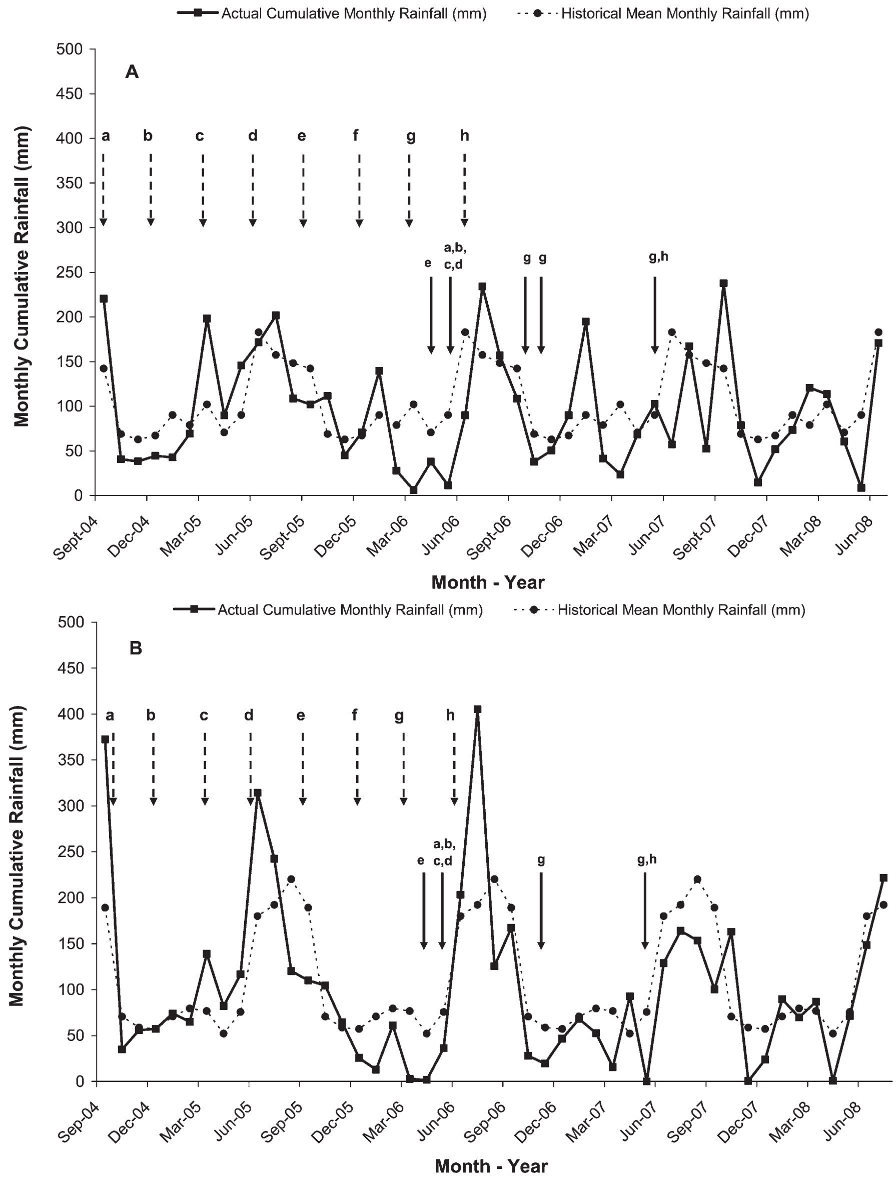

Fig. 1. Actual cumulative monthly rainfall, historical mean monthly rainfall, planting dates and timing of supplemental irrigation applications in north (Citra, FL) (**A**) and central Florida (Balm, FL) (**B**). Dashed arrows indicate planting date and letters above each dashed arrow identify a particular planting date. Solid arrow (↓) indicates supplemental irrigation applications and letters above solid arrows identify the planting date of shrubs that received supplemental irrigation at that time.

Results and Discussion

Plant survival and quality. Irrigation frequency treatments (applied through the initial 12 to 22 WAP depending on planting date) had no effect on survival of *I. cornuta* 'Burfordii Nana' or *P. tobira* 'Variegata' at either location (data not shown). Rainfall may have negated any irrigation treatment effects on shrub survival and shrub quality (Fig. 1). Scheiber et al. (2008) also reported multiple shrub species, including *P. tobira* 'Variegata', *I. glabra* (L.) A. Gray, and *I. vomitoria* Sol. Ex Aiton 'Nana', survived under normal rainfall conditions in Citra, FL, after receiving regular irrigation for only 11 weeks.

Irrigation frequency during the initial 5 months after transplant also had no effect on shrub quality at either location at 28, 52, or 104 WAP (data not shown). Similar results were reported by Scheiber et al. (2007) when *I. cornuta* 'Burfordii Nana' planted under a rainout shelter in Apopka, FL (hardiness zone 9b) were irrigated with 9 L of water every 2, 4, or 7 d.

Growth index. Growth index of *I. cornuta* 'Burfordii Nana' or *P. tobira* 'Variegata' was unaffected by irrigation frequency applied through the initial 12 to 22 WAP when planted in zone 9a, central Florida (data not shown). In contrast, *I. cornuta* 'Burfordii Nana' planted in zone 8b, north Florida, and irrigated every 2 d during the first 5 months after planting had greater canopy growth index when compared with shrubs irrigated every 8 d (52 through 88 WAP) and every 4 or 8 d (64 and 76 WAP) (Fig. 2A; Table 1). However, there was no irrigation frequency effect on growth at 104 WAP. Similarly, growth index was greater for *P. tobira* 'Variegata' planted in zone 8b, north Florida, and irrigated every 2 d during the same time period when compared with shrubs irrigated every 8 d from 12 through 104 WAP (Fig. 2B). Scheiber et al. (2007) also reported an increase in canopy growth index for *P. tobira* 'Variegata' plants irrigated every 2 d under a rainout shelter compared with plants irrigated every 4 or 7 d. Other studies also report an increase in canopy growth with increased irrigation frequency (Knox and Zimet, 1988; Marshall and Gilman, 1998; Stabler and Martin, 2000).

Maximum root spread radius and root to canopy spread ratio. Irrigation frequency during the initial 5 months after planting had no effect on maximum root spread of *I. cornuta* 'Burfordii Nana' or *P. tobira* 'Variegata' planted in zone 9a, central Florida (data not shown). However, in zone 8b, north Florida, roots of *I. cornuta* 'Burfordii Nana'

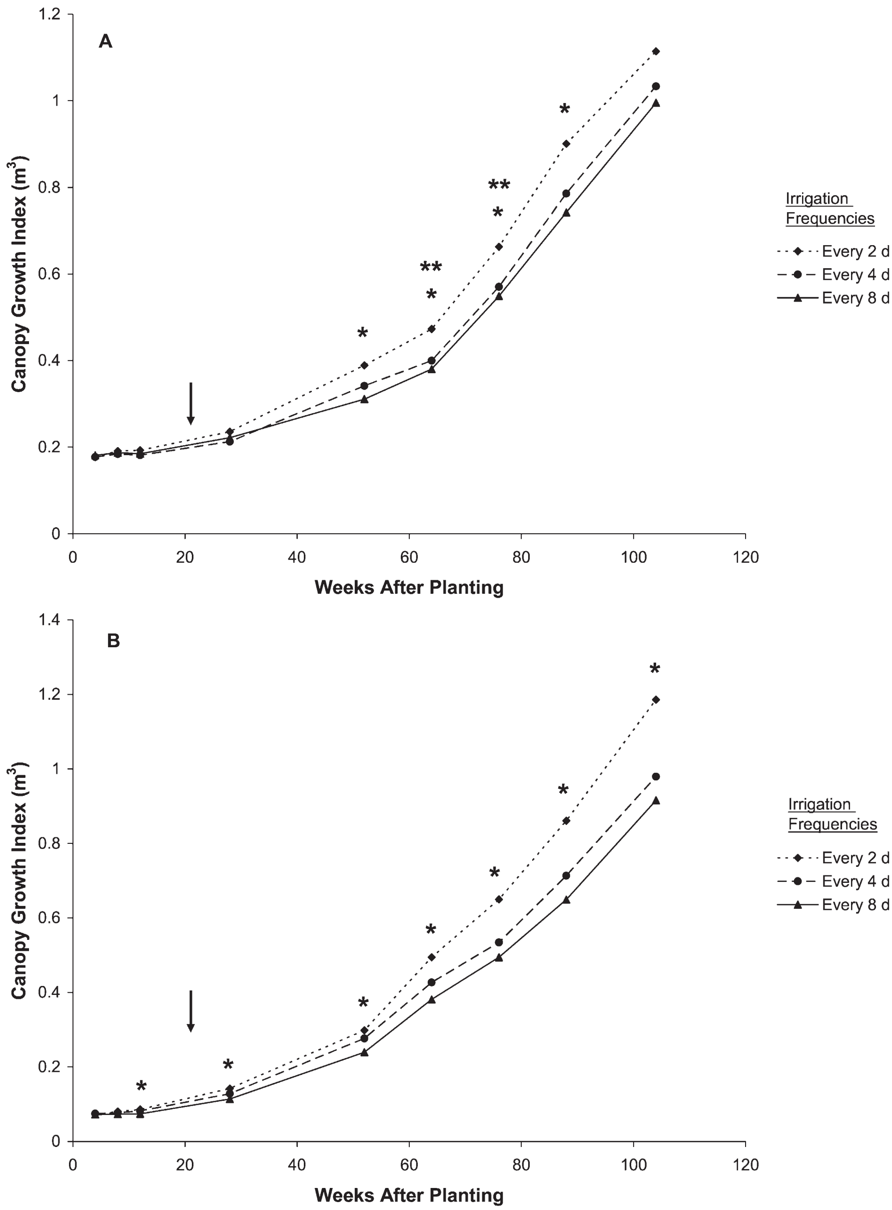

Fig. 2. Canopy growth index (calculated by multiplying canopy height by canopy width 1 by canopy width 2) 4 to 104 weeks after planting of *Ilex cornuta* 'Burfordii Nana' (**A**) and or *Pittosporum tobira* 'Variegata' (**B**) averaged across eight planting dates in north Florida (hardiness zone 8b, Citra, FL). Asterisk (*) indicates difference ($P < 0.05$) between every 2-d and every 8-d irrigation frequency treatments. Double asterisks (**) indicate difference ($P < 0.05$) between every 2-d and every 4-d irrigation frequency treatments. Arrow (↓) indicates the point after which irrigation had been discontinued in all plots.

Table 1. Shoot and root dry biomass for *Ilex cornuta* 'Burfordii Nana' irrigated every 2, 4, or 8 d averaged over eight planting dates over a 2-year period in USDA hardiness zones 8b and 9a (north and central Florida).

	Shoot biomass (g)		Root biomass (g)	
Irrigation frequency	52 WAP[z]	104 WAP	52 WAP	104 WAP
		Hardiness zone 8b		
2 d	551 a[y]	1,669 a	193	474
4 d	466 b	1,420 b	161	432
8 d	481 b	1,450 b	168	470
		Hardiness zone 9a		
2 d	512	1,366	551	681
4 d	488	1,274	577	734
8 d	489	1,301	577	822

[z]WAP = weeks after planting.
[y]Mean separations within column and location using Tukey ($P < 0.05$). Letters denote differences among irrigation frequencies at 52 or 104 WAP within a hardiness zone.

irrigated during this time period every 2 d extended further from the trunk base when compared with shrubs irrigated every 8 d at 20, 28, 52, 64, and 88 WAP (Fig. 3A). Maximum root spread of *I. cornuta* 'Burfordii Nana' irrigated every 2 d for a similar number of weeks (12 to 22 WAP) was greater compared with shrubs irrigated every 4 d at 28 and 64 WAP only (Fig. 3A). Comparable results were noted for *P. tobira* 'Variegata', in which root spread was greater for shrubs irrigated every 2 d compared with plants irrigated every 8 d at 20, 28, 64, 76, and 88 WAP (Fig. 3B). In the case of *P. tobira* 'Variegata', the 2-d frequency produced greater root spread compared with plants irrigated every 4 d at 64 WAP only (Fig. 3B). Other studies have reported an increase in root growth when irrigation frequency increased (Harris and Gilman, 1993; Marshall and Gilman, 1998). Frequently irrigated (irrigated daily from 2 to 9 WAP and then every 2 d from 9 to 24 WAP) red maples had a greater number of roots compared with infrequently irrigated treatments (weekly from 2 to 3 WAP, every 3 d from 4 to 9 WAP, and every 10 d from 10 to 19 WAP) at 24 WAP (Marshall and Gilman, 1998) and 5 years (Gilman et al., 2003) after planting. Data from the current study further support the idea that irrigation frequency during establishment may continue to influence root growth long after plants are established. Irrigation treatment effects on root extension for shrubs planted in north Florida were significant through 88 WAP, long after the plants were considered established and long after regular irrigation stopped. Although irrigation was applied only to a small area of the root ball and immediately adjacent to the root ball, this did not appear to restrict root growth because roots were found growing freely into soil outside the root ball in all treatments. Others have reported similar response of woody root extension when irrigating only the root ball under moist temperate environmental conditions (Barnett, 1986; Marshall and Gilman, 1998).

Irrigation frequency during the first 12 to 22 WAP had no effect on root to canopy spread ratio of *I. cornuta* 'Burfordii Nana' or *P. tobira* 'Variegata' at either location (data not shown). Average root-to-canopy ratio of all 288 shrubs in the study exceeded a value of 1.0 by 22 WAP at which time regular irrigation had been discontinued. This indicates that roots had grown to the edge of shrub canopy and the root system was sufficiently established to compensate for daily water loss under near normal rainfall conditions of this study (Fig. 1A). Root to canopy spread ratio of both species at both locations at 52 WAP (2.0 to 3.25) was similar to other well-established shrub species measured 3 years after planting from No. 3 containers (Gilman and Kane, 1991). A stable root–to-shoot ratio suggests that shrubs have established the natural relationship between root and shoot growth for that species. Gilman and Beeson (1996) reported a similar response of 5-cm trunk diameter (caliper) *Quercus*

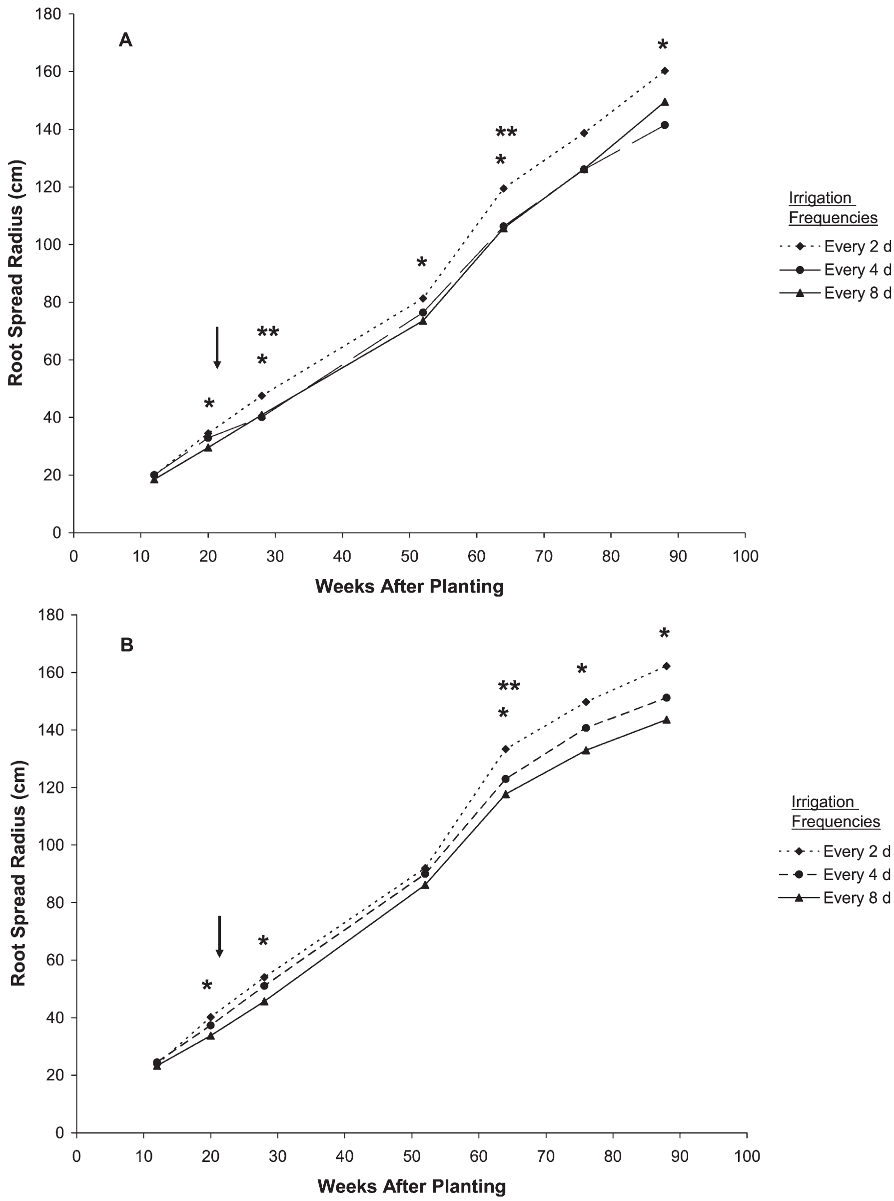

Fig. 3. Root spread radius {root spread radius (cm) = 1/2 × [east root length (cm) + west root length (cm)]} 12 to 88 weeks after planting of *Ilex cornuta* 'Burfordii Nana' (**A**) and *Pittosporum tobira* 'Variegata' (**B**) averaged across eight planting dates in north Florida (hardiness zone 8b, Citra, FL). Asterisk (*) indicates difference ($P < 0.05$) between every 2-d and every 8-d irrigation frequency treatments. Double asterisks (**) indicate difference ($P < 0.05$) between every 2-d and every 4-d irrigation frequency treatments. Arrow (↓) indicates the point after which irrigation had been discontinued in all plots.

laurifolia Michx. planted from fabric containers or field grown. Transplanted trees regenerated sufficient roots to fill the same soil volume with roots 1 year after transplanting as before transplanting.

Dry biomass. Irrigation frequency during the initial 12 to 22 WAP had no effect on canopy dry weight of *I. cornuta* 'Burfordii Nana' or *P. tobira* 'Variegata' at 52 or 104 WAP when planted in zone 9a, central Florida (Table 1). In zone 8b, north Florida, *I. cornuta* 'Burfordii Nana' irrigated every 2 d during that time had greater canopy dry weight when compared with shrubs irrigated every 4 or 8 d at 52 and 104 WAP, whereas *P. tobira* 'Variegata' had greater canopy dry weight when compared with shrubs irrigated every 8 d at 52 WAP and every 4 and 8 d at 104 WAP (Table 1). Comparable results were reported by Scheiber et al. (2007), in which shoot dry weight was greater for *P. tobira* 'Variegata' and *V. odorotissimum* irrigated every 2 d compared with plants irrigated every 4 or 7 d. Other studies also found canopy dry weight increased with increasing irrigation frequency (Knox and Zimet, 1988; Marshall and Gilman, 1998; Stabler and Martin, 2000). Conversely, irrigation frequency did not affect dry root biomass of *I. cornuta* 'Burfordii Nana' or *P. tobira* 'Variegata' at 52 or 104 WAP when planted in hardiness zones 8b or 9a (Table 2). Similarly, Gilman et al. (1996) found no differences in total regenerated root weight of *I. cornuta* 'Burfordii Nana' between irrigation frequency treatments.

Frequency of irrigation applied during the first 12 to 22 WAP influenced root and shoot growth of *I. cornuta* 'Burfordii Nana' and *P. tobira* 'Variegata' when planted in the landscape in zone 8b, north Florida, but not in zone 9a, central Florida. Near-normal (historical mean) rainfall occurred in the central Florida location during most of the study period and may have masked the influence of irrigation frequency (Fig. 1B). Data suggest irrigation may not need to be applied more than once every 8d when near normal rainfall occurs after planting. The longest drought in the central Florida location occurred from Feb. 2006 to June 2006 and differed from the historical average for that location by only 159 mm compared with a reduced cumulative rainfall of 351 mm in the north Florida location during the same period (Figs. 1A–B).

Additionally, plants in our study received greater total volume when irrigated more frequently, which may have contributed to increases in growth. Shrubs irrigated every 2, 4, or 8 d received a maximum total volume of 231, 116, and 58 L, respectively, before irrigation was discontinued. Although a number of studies set up with similar methodology reported similar increases in root and shoot growth with increased irrigation like those in central Florida (Gilman et al., 1998; Marshall and Gilman, 1998; Stabler and Martin, 2000), at least one study reported no differences in shrub growth as a response to irrigation frequency when the total volume received was the same over the study period (Paine et al., 1992). Greater total volume of irrigation applied by increasing the frequency of 3-L applications may also have initiated a faster release of nutrients from the slow-release fertilizer resulting in increased growth in the more frequently irrigated treatments, although Gilman et al. (2009) did not find this to be the case in a similar study.

Although regular irrigation was discontinued by 22 WAP, supplemental irrigation was required to maintain shrub quality and ensure survival during extended periods of dry weather (Fig. 1). Supplemental irrigation was applied five times in north Florida and four times in central Florida during the 2-year experiment as a result of extended dry periods. This suggests that although these shrub species can survive and grow after receiving irrigation for only 22 weeks, they should be monitored for symptoms of water stress during periods without rainfall for at least the first 2 years after planting.

Conclusions

Results of our study suggest *I. cornuta* 'Burfordii Nana' and *P. tobira* 'Variegata' planted from 11.4-L (No. 3) containers have the capacity to survive and grow after planting in hardiness zones 8b and 9a in Florida on natural rainfall alone provided they are irrigated with 3 L every 4 to 8 d until roots reach the canopy edge (≈22 WAP). Increasing

Table 2. Shoot and root dry biomass for *Pittosporum tobira* 'Variegata' irrigated every 2, 4, or 8 d averaged over eight planting dates over a 2-year period in USDA hardiness zones 8b and 9a (north and central Florida).

	Shoot biomass (g)		Root biomass (g)	
Irrigation frequency	52 WAP[z]	104 WAP	52 WAP	104 WAP
	Hardiness zone 8b			
2 d	485 a[y]	2,029 a	130	267
4 d	449 ab	1,657 b	138	272
8 d	387 b	1,599 b	108	303
	Hardiness zone 9a			
2 d	617	1,851	537	649
4 d	612	2,278	548	704
8 d	605	1,653	503	613

[z]WAP = weeks after planting.

[y]Mean separations within column and location using Tukey ($P = 0.05$). Letters denote differences among irrigation frequencies at 52 or 104 WAP within a hardiness zone.

irrigation frequency to every 2 d in hardiness zone 8b, north Florida, may stimulate additional shoot and root growth but will not affect plant survival or quality. Subsequent supplemental irrigation was only needed in the 18 months after irrigation termination when there was no rainfall for 30 consecutive days. Although these results suggest that a significant extension is needed in the length of time permitted for frequent irrigation of newly planted shrubs in Florida, total volume of irrigation required to establish shrubs with irrigation directed to the root ball is much less than commonly applied in a landscape with overhead sprinklers. We suggest that significant reductions in total volume of water applied to establish shrubs in Florida are possible without reducing shrub quality provided irrigation is applied at an appropriate frequency for several months after planting.

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