

# Preliminary and Regional Reports

## Native and Non-native Shrub Post-transplant Performance under Low-volume Irrigation in Three Hardiness Zones

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**SUMMARY.** Previous research on #3 nursery container-grown shrubs suggests that some common shrub species could be established in the Florida landscape under natural rainfall when irrigated with 3 L of water every 4 days in U.S. Department of Agriculture hardiness zones 8b and 9a or every 2 days in zone 10b until first roots reached the canopy edge ( $\approx 20$  weeks after planting). The current study evaluated the effects of these irrigation frequency recommendations on plant vigor, canopy growth, root growth, and aesthetic quality of 21 common landscape shrub species (10 Florida native and 11 non-native) planted in Florida in zones 8b, 9a, or 10b. Data suggests that it may be appropriate to adopt the 20-week low-volume irrigation recommendations for the establishment of a wide variety of container-grown Florida native and non-native shrubs. However, Florida native and non-native shrubs should be monitored for symptoms of drought stress for 2 years after planting.

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Urban population growth and periodic droughts throughout much of the United States have led to increased restrictions on landscape water use. These water restrictions have increased interest in planting native shrub species because natives are often touted as having lower water needs than non-native ornamental species (Bodle, 2001; Haehle, 2004; Hostetler et al., 2003). However, there are few studies that support that

assertion. In fact, research indicates that water use is more likely to be a function of endemic habitat (Scheiber et al., 2008), shrub morphology (King and Wilson, 2006), plant growth rate (Fitzpatrick, 1983), and shrub maturity (Stabler and Martin, 2000) than its native range. For example, Scheiber et al. (2008) reported no differences in growth response or aesthetic appearance due to irrigation treatment for 8 of 10 native and 8 of 10 non-native species grown in northern Florida. Only two species, which were endemic to swamps and streams, showed increased growth in response to irrigation compared with no irrigation (Scheiber et al., 2008).

Previous research conducted at the University of Florida suggested that burford holly (*Ilex cornuta* 'Burfordii Nana'), pittosporum (*Pittosporum tobira* 'Variegata') (Wiese et al., 2009), and sweet viburnum (*Viburnum odoratissimum*) (Shoher et al., 2009) could be established in the Florida landscape under natural rainfall in U.S. Department of Agriculture (USDA) hardiness zones 8b and 9a when irrigated with 3 L every 8 d. Similarly, research suggested that wild coffee (*Psychotria nervosa*), copperleaf (*Acalypha wilkesiana*), orange jasmine (*Murraya paniculata* 'Lakeview') (Moore et al., 2009), and sweet viburnum (Shoher et al., 2009) could be established in the Florida landscape under natural rainfall in zone 10b with 3 L of supplemental irrigation applied every 4 d until roots reached the canopy edge. These studies also suggested that increasing the irrigation frequency from every 8 d to every 4 d in zones 8b and 9a, and from every 4 d to every 2 d in zone 10b could improve plant vigor. The objective of this study was to evaluate the effects of these irrigation frequency recommendations on plant vigor, canopy growth, root growth, and aesthetic quality of 10 Florida native and 11 non-native shrub species planted in three hardiness zones.

Units			
To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
0.0283	ft <sup>3</sup>	m <sup>3</sup>	35.3147
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

Table 1. Ten Florida native and 11 non-native species planted in U.S. Department of Agriculture hardiness zones 8b, 9a, and 10b to evaluate a reduced irrigation frequency scheme for establishment of shrubs after transplant into the landscape.

Hardiness zone	Common name	Scientific name	Florida native
8b	American beautyberry	<i>Callicarpa americana</i>	Yes
8b	Dwarf yaupon holly	<i>Ilex vomitoria</i> 'Schillings'	Yes
8b	Florida privet	<i>Forestiera segregata</i>	Yes
8b	Gardenia	<i>Gardenia jasminoides</i> 'Mystery'	No
8b	Golden dewdrop	<i>Duranta erecta</i> 'Sapphire'	Yes
8b	Indian hawthorn	<i>Rhaphiolepis indica</i>	No
8b	Japanese privet	<i>Ligustrum japonicum</i>	No
8b	Juniper	<i>Juniperus chinensis</i> 'Parsonii'	No
8b	Loropetalum	<i>Loropetalum chinense</i> var. <i>rubrum</i> 'Ruby'	No
8b	Sandankwa viburnum	<i>Viburnum suspensum</i>	No
8b	Southern wax myrtle	<i>Myrica cerifera</i>	Yes
8b	Walter's viburnum	<i>Viburnum obovatum</i> 'Whorled Class'	Yes
9a	Downy jasmine	<i>Jasminum multiflorum</i>	No
9a	Dwarf yaupon holly	<i>Ilex vomitoria</i> 'Schillings'	Yes
9a	Firebush	<i>Hamelia patens</i>	Yes
9a	Florida privet	<i>Forestiera segregata</i>	Yes
9a	Gardenia	<i>Gardenia jasminoides</i> 'Mystery'	No
9a	Golden dewdrop	<i>Duranta erecta</i> 'Sapphire'	Yes
9a	Indian hawthorn	<i>Rhaphiolepis indica</i>	No
9a	Japanese privet	<i>Ligustrum japonicum</i>	No
9a	Loropetalum	<i>Loropetalum chinense</i> var. <i>rubrum</i> 'Ruby'	No
9a	Sandankwa viburnum	<i>Viburnum suspensum</i>	No
9a	Simpson's stopper	<i>Myrcianthes fragrans</i>	Yes
9a	Walter's viburnum	<i>Viburnum obovatum</i> 'Whorled Class'	Yes
10b	Bush allamanda	<i>Allamanda schottii</i>	No
10b	Cocoplum	<i>Chrysobalanus icaco</i>	Yes
10b	Croton	<i>Codiaeum variegatum</i> var. <i>pictum</i>	No
10b	Downy jasmine	<i>Jasminum multiflorum</i>	No
10b	Dwarf yaupon holly	<i>Ilex vomitoria</i> 'Schillings'	Yes
10b	Firebush	<i>Hamelia patens</i>	Yes
10b	Florida privet	<i>Forestiera segregata</i>	Yes
10b	Hibiscus	<i>Hibiscus rosa-sinensis</i>	No
10b	Indian hawthorn	<i>Rhaphiolepis indica</i>	No
10b	Ixora	<i>Ixora</i> 'Nora Grant'	No
10b	Silver buttonwood	<i>Conocarpus erectus</i> var. <i>sericea</i>	Yes
10b	Simpson's stopper	<i>Myrcianthes fragrans</i>	Yes

## Materials and methods

**EXPERIMENTAL DESIGN.** Six native and six non-native species (Table 1) were obtained from a commercial nursery in #3 smooth-sided nursery containers and were planted at three sites in Florida: 1) Plant Science Research and Education Unit located in USDA hardiness zone 8b (Citra, FL; Arredondo sand), 2) Gulf Coast Research and Education Center located in zone 9a (Balm, FL; Zolfo fine sand or Seffner fine sand), and 3) Fort Lauderdale Research and Education Center located in zone 10b (Fort Lauderdale, FL; Margate fine sand). Shrubs appropriate for each site climate were selected from a total of 21 shrub species (10 Florida native and 11 non-native) (Table 1). Six replicates of each shrub species were planted

into level plots at each site. Shrubs were installed on the two following planting dates at each site: Dec. 2006 (USDA hardiness zones 8a and 10b) or Dec. 2007 (zone 9a), and June 2007 (zones 8a, 9a, and 10b) as outlined in Shober et al. (2009). Shrubs were grouped in the field by planting date. The average minimum temperature at 2 m above the soil surface collected for each 52-week planting period from the Florida Automated Weather Network stations located within 50 m of the planting sites was as follows: 21.81 and 38.20 °F in zones 8a and 10b, respectively (Dec. 2007); 25.24, 27.35, and 37.21 °F in zones 8a, 9a, and 10b, respectively (June 2007); and 27.35 °F in zone 9a (Dec. 2007).

Irrigation treatments were applied, regardless of rainfall events, to

six plant replicates at each location for each planting date with the following frequencies: every 2 d in hardiness zone 10b and every 4 d in zones 8b and 9a. Irrigation treatments were selected based on recommendations for vigor that were developed by evaluating irrigation frequencies for burford holly and pittosporum grown in zones 8b and 9a (Wiese et al., 2009), for wild coffee, copperleaf, and orange jasmine grown in zone 10b (Moore et al., 2009), and for sweet viburnum grown in all three zones (Shober et al., 2009). Each shrub was irrigated with 3 L of water per irrigation event applied to the root ball using three bubbler emitters (Shrubbl® 360°; Antelco®, Longwood, FL). Each emitter was mounted 4 inches above ground level with an emitter located

**Table 2. Median visual density and dieback (quality) ratings ( $n = 6$ ) for selected Florida native and non-native shrub species established in the landscape under low-volume [3 L (0.8 gal) per plant] irrigation over two planting dates in U.S. Department of Agriculture hardiness zones 8b, 9a, and 10b.**

Species	Planting date	Density (1–9 scale) <sup>z</sup>				Dieback (1–9 scale) <sup>z</sup>			
		12 WAT <sup>y</sup>	20 WAT	28 WAT	52 WAT	12 WAT	20 WAT	28 WAT	52 WAT
Hardiness zone 8b									
American beautyberry	Dec. 2006	1	8	8	9	7	8	7	9
Dwarf yaupon holly	Dec. 2006	9	8	9	9	9	9	9	9
Florida privet	Dec. 2006	1	8	6	9	7	8	6	9
Gardenia	Dec. 2006	9	8	4	9	9	8	4	9
Golden dewdrop	Dec. 2006	1	2	4	— <sup>x</sup>	6	3	4	—
Indian hawthorn	Dec. 2006	9	8	9	9	9	9	9	9
Japanese privet	Dec. 2006	9	9	9	9	9	9	9	9
Juniper	Dec. 2006	9	9	9	9	8	8	8	9
Loropetalum	Dec. 2006	9	9	8	9	9	9	8	9
Sandankwa viburnum	Dec. 2006	9	9	8	9	9	9	8	9
Southern wax myrtle	Dec. 2006	9	8	9	9	9	9	9	9
Walter’s viburnum	Dec. 2006	8	8	8	9	9	9	8	9
American beautyberry	June 2007	9	9	3	9	9	9	3	7
Dwarf yaupon holly	June 2007	9	9	9	9	9	9	9	9
Florida privet	June 2007	8	8	9	9	8	9	8	9
Gardenia	June 2007	9	9	9	7	9	9	9	7
Golden dewdrop	June 2007	9	8	2	2	9	8	3	2
Indian hawthorn	June 2007	9	9	9	9	9	8	9	9
Japanese privet	June 2007	9	9	9	8	9	9	9	8
Juniper	June 2007	9	9	9	9	9	9	8	9
Loropetalum	June 2007	9	8	8	8	8	8	8	8
Sandankwa viburnum	June 2007	9	9	9	8	8	9	9	7
Southern wax myrtle	June 2007	9	9	9	9	9	8	9	9
Walter’s viburnum	June 2007	8	7	7	6	9	8	7	7
Hardiness zone 9a									
Downy jasmine	June 2007	9	9	9	9	9	9	9	9
Dwarf yaupon holly	June 2007	9	9	9	9	9	9	9	9
Firebush	June 2007	6	8	9	9	7	8	9	9
Florida privet	June 2007	8	8	9	9	9	9	9	9
Gardenia	June 2007	2	2	1	—	2	2	1	5
Golden dewdrop	June 2007	8	7	7	8	9	8	8	8
Indian hawthorn	June 2007	9	7	8	9	8	7	8	9
Japanese privet	June 2007	8	7	7	8	9	8	8	8
Loropetalum	June 2007	7	5	7	5	7	6	7	5
Sandankwa viburnum	June 2007	9	8	8	9	8	8	8	9
Simpson’s stopper	June 2007	9	9	9	9	8	9	9	9
Walter’s viburnum	June 2007	9	9	7	9	8	7	5	9
Downy jasmine	June 2007	8	8	9	9	8	8	9	9
Dwarf yaupon holly	Dec. 2007	9	9	9	9	9	9	9	9
Firebush	Dec. 2007	3	9	9	3	2	9	9	4
Florida privet	Dec. 2007	7	8	8	5	8	9	9	5
Gardenia	Dec. 2007	7	9	9	8	8	9	9	8
Golden dewdrop	Dec. 2007	9	9	9	8	9	9	9	8
Indian hawthorn	Dec. 2007	9	8	9	9	9	9	9	9
Japanese privet	Dec. 2007	8	8	8	6	9	8	8	7
Loropetalum	Dec. 2007	9	8	8	7	9	8	8	6
Sandankwa viburnum	Dec. 2007	8	7	7	7	8	8	8	7
Simpson’s stopper	Dec. 2007	9	9	9	9	9	9	9	8
Walter’s viburnum	Dec. 2007	9	9	9	8	9	9	9	7
Hardiness zone 10b									
Bush allamanda	Dec. 2006	7	8	7	3	7	7	7	3
Cocoplum	Dec. 2006	7	7	8	7	7	8	8	8
Croton	Dec. 2006	7	8	8	7	8	9	9	7
Downy jasmine	Dec. 2006	8	8	9	8	8	9	9	9

(Continued on next page)

Table 2. (Continued) Median visual density and dieback (quality) ratings ( $n = 6$ ) for selected Florida native and non-native shrub species established in the landscape under low-volume [3 L (0.8 gal) per plant] irrigation over two planting dates in U.S. Department of Agriculture hardiness zones 8b, 9a, and 10b.

Species	Planting date	Density (1–9 scale) <sup>z</sup>				Dieback (1–9 scale) <sup>z</sup>			
		12 WAT <sup>y</sup>	20 WAT	28 WAT	52 WAT	12 WAT	20 WAT	28 WAT	52 WAT
<i>Hardiness zone 10b continued</i>									
Dwarf yaupon holly	Dec. 2006	7	7	8	7	7	8	8	7
Firebush	Dec. 2006	7	7	8	7	8	8	8	7
Florida privet	Dec. 2006	7	8	8	8	7	8	9	9
Hibiscus	Dec. 2006	8	8	9	8	8	9	9	9
Indian hawthorn	Dec. 2006	7	7	8	7	8	8	8	8
Ixora	Dec. 2006	7	7	7	8	8	8	9	8
Silver buttonwood	Dec. 2006	7	8	7	8	7	9	8	8
Simpson’s stopper	Dec. 2006	7	7	7	7	8	8	8	7
Bush allamanda	June 2007	7	8	8	9	7	8	8	9
Cocoplum	June 2007	7	7	8	9	8	8	8	9
Croton	June 2007	7	8	8	7	8	8	8	8
Downy jasmine	June 2007	8	8	8	9	8	8	8	9
Dwarf yaupon holly	June 2007	8	7	8	9	8	8	8	9
Firebush	June 2007	7	7	7	9	8	7	8	9
Florida privet	June 2007	8	8	7	7	8	8	8	7
Hibiscus	June 2007	7	7	7	8	8	8	8	9
Indian hawthorn	June 2007	8	7	8	9	8	8	8	9
Ixora	June 2007	7	7	8	9	8	8	8	9
Silver buttonwood	June 2007	8	8	8	9	8	8	8	9
Simpson’s stopper	June 2007	8	8	7	7	8	8	8	8

<sup>a</sup>1 = dead plant; 9 = dense, full canopy with no dieback.

<sup>b</sup>WAT = weeks after transplant.

<sup>c</sup>— = plant was not available for measurement due to freeze damage or plant death.

on the east and west side of each plant, 6 inches from the outside of the root ball, and the third emitter was positioned on the root ball. Irrigation frequencies were controlled as separate zones as described by Shober et al. (2009). Irrigation was ended 20 weeks after transplant, after which time supplemental irrigation (3 L per plant by hand) was supplied to all shrubs for a specific planting date over the 2-year post-planting period when signs of severe water stress, such as severe foliage wilting, were observed.

**PLANT QUALITY AND GROWTH INDEX.** Plant quality (plant density and dieback) was visually rated on a scale of 1 (dead plant) to 9 (dense, full canopy with no dieback) at 12, 20, 28, and 52 weeks after transplant (WAT). Growth index (GI) was used as a quantitative indicator of plant growth. GI in cubic meters for each plant was calculated as:  $GI = H \times W1 \times W2$ , where H is the plant height (meters), W1 is the widest width of the plant (meters), and W2 is the width perpendicular to the widest width (meters). Growth index was measured on three plant replicates per treatment at 0 (date of planting), 12, 20, 28, and 52 WAT.

#### ROOT-TO-CANOPY SPREAD RATIO.

Root spread was measured on three plant replicates per irrigation frequency at 12, 20, 28, and 52 WAT by excavating the longest root (near the soil surface) on the east and west side of the plant and measuring its length from the base of the plant. Root spread radius was calculated as the mean of the east and west root lengths. Root-to-canopy spread ratio was then calculated as: root spread radius/mean canopy radius with mean canopy radius =  $1/4 \times (W1 + W2)$ .

**DATA ANALYSIS.** Experimental design and data structure required that statistical analysis of growth and quality data be limited to descriptive statistics (mean, median, etc.). Therefore, median values were used to describe the effect of the selected irrigation treatment on plant quality ratings and mean values were used to describe the effects of the selected irrigation treatment on canopy and root growth for shrub species planted in each hardiness zone.

## Results and discussion

**PLANT QUALITY AND GROWTH INDEX.** All plants, with the exception of golden dewdrop (*Duranta erecta* 'Sapphire') in zone 8b and gardenia

(*Gardenia jasminoides* 'Mystery') in zone 9a, survived and were actively growing 52 WAT when watered with 3 L of water every 4 d (zones 8b and 9a) or every 2 d (zone 10b) for 20 WAT (Tables 2 and 3). In addition, most shrub species maintained high plant quality ratings (i.e., density and dieback) (Table 2). Poor performance of some species was not related to water stress. For example, gardenia planted in zone 9a was plagued by nutrient deficiencies that were related to pockets of alkaline soil (pH near 8.0) in the field (Tables 2 and 3). In addition, some species [firebush (*Hamelia patens*) in zones 8b and 9a, golden dewdrop in zone 8b] suffered a decline in growth and quality due to freeze damage.

Our data also suggest that there were no differences in canopy growth or aesthetic quality of native versus non-native shrubs at any of the planting locations (Tables 2 and 3). Our results are similar to those of Scheiber et al. (2008), who found that neither native species nor non-native species were, as a group, more responsive to irrigation. Scheiber et al. (2008) reported that growth of two of 10 Florida natives and two of 10

Table 3. Mean growth index and root to canopy spread ratio ( $n = 6$ ) for selected Florida native and non-native shrub species established in the landscape under low-volume irrigation [3 L (0.8 gal) per plant] over two planting dates in U.S. Department of Agriculture hardiness zones 8b, 9a, and 10b.

Species	Planting date	Growth index [m <sup>3</sup> (SE)] <sup>z</sup>					Root to canopy spread [ratio (SE)] <sup>x</sup>				
		0 WAT <sup>y</sup>	12 WAT	20 WAT	28 WAT	52 WAT	12 WAT	20 WAT	28 WAT	52 WAT	
Hardiness zone 8b											
American beautyberry	Dec. 2006	0.32 (0.04)	0.15 (0.03)	0.19 (0.03)	0.49 (0.02)	1.27 (0.38)	0.57 (0.08)	1.31 (0.22)	1.43 (0.06)	2.31 (0.35)	
Dwarf yaupon holly	Dec. 2006	0.11 (0.01)	0.12 (0.002)	0.10 (0.01)	0.14 (0.02)	0.21 (0.03)	0.74 (0.03)	1.23 (0.06)	1.66 (0.25)	2.52 (0.10)	
Florida privet	Dec. 2006	0.27 (0.03)	0.28 (0.07)	0.23 (0.05)	0.17 (0.05)	1.21 (0.19)	0.51 (0.08)	1.06 (0.02)	1.10 (0.13)	1.57 (0.13)	
Gardenia	Dec. 2006	0.50 (0.01)	0.41 (0.04)	0.42 (0.05)	0.41 (0.03)	0.41 (0.01)	0.34 (0.09)	0.37 (0.07)	0.74 (0.12)	1.10 (0.09)	
Golden dewdrop	Dec. 2006	0.52 (0.04)	0.60 (0.09)	— <sup>w</sup>	—	—	0.49 (0.15)	—	—	—	
Indian hawthorn	Dec. 2006	0.06 (0.01)	0.06 (0.01)	0.11 (0.01)	0.09 (0.02)	0.21 (0.02)	0.99 (0.16)	1.32 (0.22)	1.54 (0.21)	2.50 (0.10)	
Japanese privet	Dec. 2006	0.27 (0.02)	0.33 (0.03)	0.30 (0.004)	0.56 (0.06)	2.67 (0.30)	0.86 (0.11)	1.42 (0.07)	1.28 (0.12)	1.35 (0.03)	
Juniper	Dec. 2006	0.10 (0.01)	0.11 (0.002)	0.11 (0.02)	0.19 (0.01)	0.37 (0.01)	0.92 (0.06)	1.70 (0.34)	1.29 (0.10)	1.36 (0.07)	
Loropetalum	Dec. 2006	0.33 (0.02)	0.32 (0.04)	0.51 (0.13)	0.38 (0.03)	0.53 (0.02)	0.32 (0.05)	0.55 (0.11)	0.80 (0.07)	1.60 (0.08)	
Sandankwa viburnum	Dec. 2006	0.28 (0.03)	0.28 (0.06)	0.27 (0.01)	0.29 (0.07)	0.51 (0.05)	0.76 (0.16)	1.36 (0.06)	1.32 (0.12)	1.66 (0.21)	
Southern wax myrtle	Dec. 2006	0.34 (0.03)	0.34 (0.05)	0.59 (0.03)	0.72 (0.08)	1.68 (0.35)	0.98 (0.11)	1.54 (0.10)	1.59 (0.13)	2.36 (0.27)	
Walter's viburnum	Dec. 2006	0.17 (0.01)	0.20 (0.04)	0.24 (0.02)	0.28 (0.08)	0.65 (0.05)	0.81 (0.06)	1.36 (0.22)	1.67 (0.44)	1.94 (0.08)	
American beautyberry	June 2007	0.33 (0.02)	0.95 (0.09)	1.16 (0.19)	1.39 (0.15)	1.13 (0.13)	1.76 (0.02)	2.05 (0.18)	1.86 (0.10)	2.05 (0.24)	
Dwarf yaupon holly	June 2007	0.03 (0.002)	0.04 (0.003)	0.06 (0.004)	0.07 (0.01)	0.09 (0.01)	1.36 (0.22)	1.46 (0.06)	1.61 (0.10)	2.48 (0.24)	
Florida privet	June 2007	0.19 (0.02)	0.65 (0.06)	0.75 (0.14)	1.07 (0.15)	1.91 (0.38)	0.79 (0.19)	1.66 (0.10)	1.27 (0.16)	1.66 (0.16)	
Gardenia	June 2007	0.13 (0.01)	0.19 (0.04)	0.26 (0.08)	0.24 (0.07)	0.24 (0.06)	0.86 (0.09)	0.98 (0.31)	1.17 (0.08)	1.52 (0.21)	
Golden dewdrop	June 2007	0.33 (0.04)	0.87 (0.09)	1.82 (0.17)	1.21 (0.23)	—	0.84 (0.05)	1.17 (0.03)	0.91 (0.06)	—	
Indian hawthorn	June 2007	0.05 (0.002)	0.06 (0.004)	0.08 (0.01)	0.09 (0.002)	0.19 (0.02)	1.05 (0.20)	1.40 (0.06)	1.58 (0.36)	2.19 (0.16)	
Japanese privet	June 2007	0.31 (0.02)	0.40 (0.01)	0.73 (0.07)	0.92 (0.09)	1.00 (0.03)	0.85 (0.09)	0.94 (0.02)	0.98 (0.08)	1.80 (0.15)	
Juniper	June 2007	0.11 (0.01)	0.13 (0.01)	0.17 (0.01)	0.17 (0.01)	0.30 (0.02)	0.56 (0.08)	1.00 (0.05)	1.40 (0.07)	1.95 (0.04)	
Loropetalum	June 2007	0.17 (0.01)	0.19 (0.02)	0.32 (0.07)	0.43 (0.05)	0.51 (0.02)	0.83 (0.03)	1.02 (0.04)	1.18 (0.12)	1.94 (0.05)	
Sandankwa viburnum	June 2007	0.18 (0.01)	0.17 (0.01)	0.18 (0.01)	0.22 (0.03)	0.29 (0.03)	0.56 (0.10)	1.04 (0.06)	0.91 (0.09)	1.72 (0.29)	
Southern wax myrtle	June 2007	0.12 (0.01)	0.20 (0.03)	0.40 (0.13)	0.34 (0.02)	1.44 (0.12)	1.72 (0.12)	1.63 (0.07)	1.57 (0.20)	1.48 (0.17)	
Walter's viburnum	June 2007	0.08 (0.004)	0.08 (0.01)	0.07 (0.01)	0.09 (0.01)	0.12 (0.03)	0.77 (0.17)	0.89 (0.15)	0.78 (0.15)	1.94 (0.24)	
Hardiness zone 9a											
Downy jasmine	June 2007	0.16 (0.01)	0.59 (0.09)	0.83 (0.10)	1.19 (0.15)	2.20 (0.29)	0.27 (0.04)	0.39 (0.06)	0.64 (0.04)	0.75 (0.03)	
Dwarf yaupon holly	June 2007	0.03 (0.001)	0.04 (0.004)	0.06 (0.01)	0.05 (0.003)	0.06 (0.01)	0.67 (0.14)	0.80 (0.10)	1.15 (0.10)	1.89 (0.08)	
Firebush	June 2007	0.24 (0.01)	0.50 (0.03)	0.79 (0.08)	1.21 (0.13)	0.46 (0.07)	0.49 (0.07)	0.64 (0.04)	0.61 (0.07)	1.17 (0.07)	
Florida privet	June 2007	0.07 (0.003)	0.32 (0.04)	0.76 (0.05)	1.30 (0.16)	3.28 (0.20)	0.41 (0.07)	0.51 (0.07)	0.74 (0.04)	0.85 (0.03)	
Gardenia	June 2007	0.12 (0.01)	0.09 (0.01)	0.08 (0.01)	0.06 (0.02)	—	0.48 (0.07)	0.48 (0.10)	0.68 (0.17)	—	
Golden dewdrop	June 2007	0.25 (0.02)	0.86 (0.09)	1.04 (0.24)	1.60 (0.37)	1.65 (0.51)	0.49 (0.08)	0.59 (0.04)	0.68 (0.07)	0.98 (0.04)	
Indian hawthorn	June 2007	0.04 (0.002)	0.05 (0.01)	0.06 (0.01)	0.07 (0.02)	0.12 (0.03)	0.72 (0.16)	0.74 (0.13)	1.11 (0.22)	1.62 (0.08)	
Japanese privet	June 2007	0.22 (0.01)	0.35 (0.04)	0.62 (0.06)	1.05 (0.15)	1.34 (0.18)	0.39 (0.02)	0.52 (0.07)	0.65 (0.06)	0.82 (0.15)	
Loropetalum	June 2007	0.08 (0.01)	0.12 (0.01)	0.18 (0.01)	0.24 (0.01)	0.35 (0.04)	0.49 (0.10)	0.58 (0.08)	0.79 (0.15)	1.32 (0.13)	
Sandankwa viburnum	June 2007	0.13 (0.004)	0.15 (0.01)	0.18 (0.02)	0.21 (0.01)	0.37 (0.03)	0.51 (0.09)	0.56 (0.04)	0.86 (0.10)	1.28 (0.05)	
Simpson's stopper	June 2007	0.18 (0.01)	0.26 (0.03)	0.32 (0.04)	0.41 (0.09)	0.64 (0.08)	0.43 (0.03)	0.63 (0.13)	0.77 (0.06)	1.07 (0.12)	
Walter's viburnum	June 2007	0.06 (0.003)	0.06 (0.005)	0.06 (0.01)	0.07 (0.01)	0.09 (0.02)	0.56 (0.13)	0.75 (0.18)	0.96 (0.13)	1.37 (0.06)	
Downy jasmine	Dec. 2007	0.70 (0.04)	0.58 (0.11)	0.58 (0.07)	0.54 (0.07)	1.00 (0.13)	0.48 (0.02)	0.60 (0.18)	0.65 (0.16)	1.50 (0.20)	

(Continued on next page)

Table 3. (*Continued*) Mean growth index and root to canopy spread ratio ( $n = 6$ ) for selected Florida native and non-native shrub species established in the landscape under low-volume irrigation [3 L (0.8 gal) per plant] over two planting dates in U.S. Department of Agriculture hardiness zones 8b, 9a, and 10b.

Species	Planting date	Growth index [m <sup>3</sup> (SE)] <sup>z</sup>				Root to canopy spread [ratio (SE)] <sup>x</sup>					
		0 WAT <sup>y</sup>	12 WAT	20 WAT	28 WAT	52 WAT	12 WAT	20 WAT	28 WAT	52 WAT	
		Hardiness zone 9a continued									
Dwarf yaupon holly	Dec. 2007	0.08 (0.002)	0.08 (0.01)	0.10 (0.01)	0.18 (0.09)	0.13 (0.01)	0.66 (0.08)	1.04 (0.18)	0.81 (0.12)	1.39 (0.05)	
Firebush	Dec. 2007	0.32 (0.01)	0.26 (0.01)	0.04 (0.01)	0.10 (0.01)	0.12 (0.01)	0.26 (0.05)	0.83 (0.10)	0.59 (0.18)	1.33 (0.20)	
Florida privet	Dec. 2007	0.25 (0.01)	0.27 (0.03)	0.37 (0.06)	0.38 (0.10)	0.51 (0.14)	0.42 (0.13)	0.46 (0.003)	0.68 (0.08)	1.81 (0.35)	
Gardenia	Dec. 2007	0.19 (0.01)	0.17 (0.02)	0.25 (0.02)	0.25 (0.03)	0.38 (0.04)	0.46 (0.09)	0.78 (0.16)	1.11 (0.34)	1.56 (0.14)	
Golden dewdrop	Dec. 2007	0.26 (0.02)	0.26 (0.05)	0.88 (0.12)	1.49 (0.29)	3.27 (0.26)	0.50 (0.12)	0.63 (0.06)	0.66 (0.04)	1.65 (0.24)	
Indian hawthorn	Dec. 2007	0.05 (0.002)	0.05 (0.004)	0.09 (0.01)	0.08 (0.02)	0.15 (0.03)	0.66 (0.19)	1.09 (0.30)	1.22 (0.20)	2.97 (0.29)	
Japanese privet	Dec. 2007	1.03 (0.09)	1.24 (0.16)	1.10 (0.11)	1.18 (0.09)	1.59 (0.11)	0.31 (0.11)	0.71 (0.06)	0.72 (0.05)	1.37 (0.13)	
Loropetalum	Dec. 2007	0.45 (0.03)	0.50 (0.06)	0.44 (0.04)	0.42 (0.03)	0.57 (0.07)	0.37 (0.04)	0.79 (0.02)	0.56 (0.02)	1.60 (0.13)	
Sandankwa viburnum	Dec. 2007	0.50 (0.01)	0.60 (0.05)	0.49 (0.03)	0.50 (0.06)	0.61 (0.09)	0.29 (0.05)	0.79 (0.06)	0.80 (0.07)	1.53 (0.19)	
Simpson's stopper	Dec. 2007	0.10 (0.01)	0.10 (0.01)	0.19 (0.02)	0.22 (0.04)	0.34 (0.07)	0.76 (0.09)	0.70 (0.09)	0.82 (0.06)	1.61 (0.06)	
Walter's viburnum	Dec. 2007	0.06 (0.002)	0.05 (0.004)	0.06 (0.01)	0.05 (0.007)	0.06 (0.01)	0.55 (0.13)	1.23 (0.46)	1.18 (0.26)	1.73 (0.24)	
		Hardiness zone 10b									
Bush allamanda	Dec. 2006	0.20 (0.004)	0.30 (0.05)	0.43 (0.07)	0.56 (0.16)	0.08 (0.07)	0.96 (0.08)	1.07 (0.09)	1.63 (0.01)	1.54 (0.39)	
Cocoplum	Dec. 2006	0.08 (0.01)	0.10 (0.03)	0.24 (0.09)	0.47 (0.10)	2.26 (0.82)	0.71 (0.07)	0.64 (0.08)	1.29 (0.18)	1.74 (0.33)	
Croton	Dec. 2006	0.09 (0.01)	0.11 (0.01)	0.07 (0.01)	0.16 (0.04)	0.10 (0.01)	0.59 (0.31)	0.43 (0.15)	0.75 (0.01)	0.94 (0.16)	
Downy jasmine	Dec. 2006	0.59 (0.06)	0.54 (0.15)	1.23 (0.04)	1.81 (0.51)	6.82 (0.88)	0.44 (0.03)	0.70 (0.13)	1.34 (0.06)	1.27 (0.12)	
Dwarf yaupon holly	Dec. 2006	0.02 (0.001)	0.02 (0.01)	0.03 (0.003)	0.04 (0.01)	0.06 (0.002)	1.15 (0.37)	0.91 (0.34)	1.60 (0.22)	1.24 (0.30)	
Firebush	Dec. 2006	0.52 (0.01)	0.46 (0.06)	0.72 (0.08)	1.00 (0.10)	4.04 (1.02)	0.88 (0.06)	1.50 (0.05)	1.71 (0.24)	1.56 (0.18)	
Florida privet	Dec. 2006	0.10 (0.01)	0.22 (0.05)	0.53 (0.12)	1.54 (0.82)	4.26 (0.84)	0.80 (0.18)	1.10 (0.05)	1.39 (0.41)	1.81 (0.21)	
Hibiscus	Dec. 2006	0.36 (0.01)	0.52 (0.08)	0.69 (0.04)	2.25 (0.77)	6.49 (0.92)	1.03 (0.12)	2.23 (0.35)	2.89 (0.17)	2.57 (0.06)	
Indian hawthorn	Dec. 2006	0.08 (0.004)	0.11 (0.04)	0.11 (0.02)	0.18 (0.09)	0.19 (0.09)	0.74 (0.23)	1.35 (0.13)	1.28 (0.26)	1.39 (0.53)	
Ixora	Dec. 2006	0.06 (0.003)	0.12 (0.02)	0.07 (0.01)	0.20 (0.07)	0.39 (0.04)	0.42 (0.08)	0.75 (0.09)	0.88 (0.10)	0.97 (0.08)	
Silver buttonwood	Dec. 2006	0.08 (0.003)	0.11 (0.02)	0.36 (0.13)	0.47 (0.31)	4.94 (1.39)	0.51 (0.14)	1.06 (0.14)	1.03 (0.28)	1.58 (0.24)	
Simpson's stopper	Dec. 2006	0.10 (0.10)	0.17 (0.02)	0.26 (0.02)	0.46 (0.03)	0.84 (0.28)	0.85 (0.13)	0.78 (0.22)	1.32 (0.25)	0.92 (0.09)	
Bush allamanda	June 2007	0.26 (0.02)	0.65 (0.07)	1.29 (0.30)	1.48 (0.11)	2.17 (0.31)	1.05 (0.12)	1.04 (0.03)	1.04 (0.15)	1.70 (0.15)	
Cocoplum	June 2007	0.08 (0.01)	0.47 (0.09)	0.94 (0.25)	1.39 (0.26)	4.61 (0.91)	0.94 (0.12)	0.84 (0.12)	1.17 (0.13)	1.73 (0.15)	
Croton	June 2007	0.10 (0.004)	0.10 (0.01)	0.12 (0.02)	0.16 (0.01)	0.14 (0.02)	0.69 (0.27)	0.52 (0.15)	0.91 (0.21)	0.82 (0.04)	
Downy jasmine	June 2007	0.48 (0.06)	1.70 (0.40)	1.89 (0.46)	1.98 (0.61)	5.21 (1.59)	0.55 (0.07)	1.02 (0.17)	1.05 (0.06)	1.29 (0.10)	
Dwarf yaupon holly	June 2007	0.03 (0.003)	0.06 (0.01)	0.08 (0.02)	0.08 (0.01)	0.12 (0.01)	1.31 (0.20)	1.18 (0.34)	1.27 (0.03)	1.97 (0.33)	
Firebush	June 2007	0.35 (0.05)	0.31 (0.01)	0.49 (0.16)	0.38 (0.12)	1.53 (0.24)	0.87 (0.21)	1.35 (0.19)	1.60 (0.05)	2.67 (0.20)	
Florida privet	June 2007	0.16 (0.01)	0.39 (0.07)	0.72 (0.09)	0.71 (0.18)	0.75 (0.31)	0.63 (0.08)	1.15 (0.06)	1.38 (0.23)	1.70 (0.19)	
Hibiscus	June 2007	0.35 (0.01)	0.52 (0.02)	1.06 (0.05)	1.66 (0.38)	2.55 (0.28)	1.63 (0.07)	1.84 (0.03)	1.75 (0.13)	3.63 (0.28)	
Indian hawthorn	June 2007	0.06 (0.01)	0.07 (0.002)	0.11 (0.01)	0.08 (0.01)	0.24 (0.04)	0.58 (0.08)	0.80 (0.22)	0.93 (0.16)	2.16 (0.13)	
Ixora	June 2007	0.09 (0.01)	0.23 (0.03)	0.48 (0.03)	0.39 (0.05)	0.76 (0.02)	0.85 (0.05)	1.11 (0.06)	1.23 (0.10)	1.82 (0.11)	
Silver buttonwood	June 2007	0.17 (0.03)	0.55 (0.02)	1.02 (0.15)	1.55 (0.33)	3.82 (0.50)	0.86 (0.09)	1.38 (0.41)	1.01 (0.21)	2.27 (0.07)	
Simpson's stopper	June 2007	0.16 (0.02)	0.49 (0.10)	0.82 (0.10)	0.69 (0.22)	1.59 (0.60)	0.61 (0.13)	0.78 (0.05)	1.17 (0.16)	1.06 (0.14)	

<sup>z</sup>Growth index =  $H \times W1 \times W2$ , where H is the plant height in meters, W1 is the widest width of the plant in meters, and W2 is the width perpendicular to the widest width in meters; 1 m = 3.2808 ft, 1 m<sup>3</sup> = 35.3147 ft<sup>3</sup>.

<sup>x</sup>WAT = weeks after transplant.

<sup>y</sup>Root-to-canopy spread ratio = root spread radius/mean canopy radius with mean canopy radius =  $1/4 \times (W1 + W2)$ .

<sup>w</sup>— = plant was not available for measurement due to freeze damage or plant death.

non-natives increased when irrigated (daily for 17 d, then every 2 d for 7 weeks, then every 7 d). Enhanced growth of irrigated shrubs seemed to be associated with species habitat preference because all species that increased in growth as a response to irrigation were endemic to wet habitats (e.g., swamps and streams) (Scheiber et al., 2008).

**ROOT SPREAD-TO-CANOPY SPREAD RATIO.** Most shrub species evaluated, regardless of geographic origin, approached a root spread-to-canopy spread ratio of 1.0 by 28 WAT and had exceeded 1.0 by 52 WAT. The majority of shrubs planted in zones 8b and 10b had reached a ratio of 1.0 by 20 WAT, which corresponds to the time when irrigation was discontinued. Root spread-to-canopy spread ratio of tree species has been reported to be species dependent (Gilman and Kane, 1991; Kummerow et al., 1977; Rogers, 1934; Rogers and Vyvyan, 1934), but roots generally extended two to three times the distance from trunk to drip line on established nursery-grown trees (Rogers, 1934; Rogers and Vyvyan, 1934) and 1.7 to 3.7 times the drip line for shrubs (Gilman and Kane, 1991). Shrubs may be considered fully established when the root spread-to-canopy spread ratio has stabilized (Gilman and Kane, 1991). Root spread-to-canopy spread ratio of all shrubs evaluated continued to increase throughout the 52-week period of study, which suggests that shrubs, although not fully established, were able to compensate for evapotranspiration losses without additional irrigation under normal or greater rainfall conditions.

Results of our study show that additional shrub species can be established in the predominantly sandy soils of the Florida landscape in USDA hardiness zones 8b, 9a, and 10b when following the irrigation recommendations for plant vigor published by

Shober et al. (2009), Moore et al. (2009), and Wiese et al. (2009). A total of 21 commonly planted native and non-native landscape shrubs was established using these procedures. Despite the public perception of an increased drought tolerance of native shrubs, our research suggests that there were no differences in irrigation needs based solely on native range. This suggests that it may be appropriate to adopt the 20-week low-volume irrigation recommendations for the establishment of a wide variety of Florida native and non-native shrubs. The ability to adopt the 20-week low-volume irrigation recommendations for native and non-native landscape shrubs will provide the industry with greater choice of plant material, while continuing to conserve valuable water resources. However, Florida native and non-native shrubs should be monitored for symptoms of drought stress for 2 years after planting.

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