Protocol for Water Needs of Shrubs during Establishment

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INTRODUCTION

Water is a vital part of every aspect of human life, preserving and managing it has become a challenge for every industry, including the landscape industry. It is not clear how much water shrubs need to be established in a landscape, or how long it takes for them to become established. Thus, the goal of this project is to determine how much irrigation is needed to establish and maintain shrubs installed in Florida landscapes. Specific objectives include:

1) Determine how much irrigation is needed to establish shrubs in the landscape
2) Determine the impact of location in the state on irrigation needs
3) Identify the most efficient frequency and rate to apply water to newly planted shrubs
4) Furthermore, the project seeks to correlate location in Florida and irrigation frequency with evapotranspiration to develop models for calculating water budgets for shrub establishment. We hope that this will enable us to predict water needs based on weather data.

PROGRESS

This project has been operating for 39 months. Details of the project procedures are included in the project proposal (FDACS Contract Number 008230). The following working objectives, as well as those included in Progress Report #1, #2, #3, #4 #5 and #6 have been met:

A. Phase One, Part 1

Objectives 1 thru 8 have been completed.

Objective 9 thru 11 are in progress. Two years of planting have been completed for test plots at Balm, Citra, and Fort Lauderdale. Three species of shrubs, *Viburnum odoratissimum* (Viburnum), *Ilex cornuta* 'Burfordii Nana' (Burford), and *Pittosporum tobira* 'Variegata' (Pittosporum) were planted from #3 containers at Balm and Citra. The three species for Fort Lauderdale were Viburnum, *Murraya paniculata* 'Lakeview' (Orange jasmine) and *Acalypha wilkesiana* (Copper Leaf), which replaced Wild Coffee in September 2005. Wild coffee performed poorly under full sun.

On September 2005, the irrigation treatments were modified. For Citra and Balm, the new irrigation treatments were either daily irrigation, or every 2 days, or every 4 days,

or every 8 days with 3 L/plant/irrigation event. For Fort Lauderdale, the treatments were either daily with 9 L/plant/irrigation event, or daily irrigation, or every 2 days, or every 4 days with 3 L/plant/irrigation event. The daily irrigation with 3 L/plant/irrigation event replaced on all sites the Mix treatment (daily for 2 weeks, then every 2 days for 2 weeks, then every 4 days for 4 weeks, then once weekly until established).

The experimental design for each site included 4 irrigation treatments X 3 species X 6 replications. A total of 72 plants at each site were planted per planting date, mulched, and maintained using best management practices. Shrubs are fertilized four times annually with LESCO Southern Landscape and Ornamental 12-2-14 fertilizer. Plots are maintained free of weeds by hand-removal and herbicide when appropriate. To determine when shrubs were established and able to thrive without irrigation, canopy growth indices, the ratio of root spread to canopy spread (called root to shoot ratio), xylem potential (a measurement of plant stress), and visual dieback and plant density ratings on a scale of 1 to 9 (where 9 = excellent quality and 1 = dead plant) were recorded 4, 8, 12, 20, 28 and 52 weeks after planting (WAP).

When test plots reach 52 WAP, 3 replications of each irrigation treatment and species were harvested. The harvested parts were all the above ground material and 1/8th of the roots extending beyond the root ball. Dry weights were collected for each. For the remaining 3 replicates, canopy growth indices and root to shoot ratio will be collected every 4 months to monitor growth until 104 WAP when they will also be harvested.

For all three sites, all replicates for the September 2004, December 2004, March 2005, and June 2005 have been harvested, as well as the first 3 replicates for, September 2005, December 2005, March 2006, and June 2006. Irrigation has been discontinued after an average of 19 WAP for all plots.

Results to date

Balm

March and June 2006 Plantings

There was a significant irrigation treatment effect on plant growth at 8 WAP (GI 8WAP-GI at week 0) for shrubs planted in March or June 2006 at Balm, FL. Statistics indicated that plants watered every eight days were growing faster than the plants that were watered every two days, but not faster than plants receiving water every four days or daily (data not shown). There was no difference in plant growth for these shrubs at any other time. At 12 WAP, Viburnum planted in June 2006 had grown significantly more than Viburnum planted in March 2006. At 20 WAP, all species planted in March 2006 had grown more than shrubs planted in June 2006. In contrast, all species planted in June 2006 had grown more than the shrubs planted in March 2006 at 28 and 52 WAP (Fig 1).

There was no significant effect of irrigation on root to shoot ratio for shrubs planted in March or June 2006. There were significant effects of plant species and/or date of planting on the root to shoot ratio for the shrubs. At 20 WAP, the root to shoot ratio was significant larger for Pittosporum than for Viburnum. At 52 and 64 (March 2006 planting only) WAP, the Burford Holly plants had a significantly higher root to shoot ratio than the other species. In addition, shrubs planted in March 2006 had a higher

root to shoot ratio at 20 WAP than shrubs planted in June 2006. This trend persisted at 52 WAP (Fig 2).

There was no significant effect of irrigation on plant density or dieback for shrubs planted in March or June 2006. There were significant effects of plant species and/or date of planting on plant density and dieback. At 8 WAP, shrubs planted in June 2006 had better density and dieback ratings than shrubs planted in March 2006. This trend continued to persist at 52 WAP. At 52 WAP, density and dieback ratings for Viburnum were higher than for Pittosporum (data not shown).

Citra

Irrigation treatment did not show a consistent significant effect on plant density and dieback (data not shown). The average plant density and dieback of all treatments in all plots was between 8 and 9 for all three species (with 9 representing the well established indicator plants and 1 equal to a dead plant) Very little die-back occurred for all species despite significant drought conditions in April and May 2007.

Growth of Pittosporum, Viburnum, and Burford Holly were significantly affected by time of year when plants were installed (Fig 3). During the establishment period (0-28 WAP), Burford Holly planted in March 2005 and March 2006 exhibited the greatest growth. The December 2004 and 2005 plots had the least growth and the June and September plots had intermediate growth. Pittorsporum exhibited the greatest growth during the establishment period in the March 2005 and September 2004 plots, followed by the March 2006, June 2005, and the June 2006 plots. The December plots exhibited the least growth from 0-28 WAP. Viburnum had the greatest growth in the March 2005, June 2005 and June 2006 plots from 4 to 8 weeks and then showed greater growth in the Dec 2004 and the June 2005 plots from 12 to 28 WAP.

Growth following the establishment period (when irrigation was discontinued) was significantly different between planting dates for each species; however there was no consistent trend of significantly greater growth seen in shrubs installed at any one planting date (Fig 3). Growth after the discontinuation of irrigation may have been most affected by rainfall and other weather conditions during a particular year.

The root to shoot ratio of all species had reached 1.0 or greater by 20 WAP in all plots (Fig 4). There were few significant differences in root to shoot ratio between irrigation treatments after that point. Fluctuations in root to shoot ratio that occurred were not consistently significant among treatments.

Root to shoot ratio was significantly affected by time of year of planting (Fig 4). Root to shoot ratio in Burford Holly during the establishment period (12-28 WAP) was significantly greater among shrubs planted in September 2005 and March 2006. After 28 WAP, the greatest root to shoot ratio was seen in the shrubs planted in December 2004. Root to shoot ratio in Pittosporum during establishment was significantly greater among shrubs planted in September 2005 followed by shrubs planted March 2006. After 28 WAP, the greatest root to shoot ratio was seen in shrubs planted in June 2005. Viburnum exhibited significantly greater root to shoot ratio during establishment in shrubs planted in September 2005, March 2006, and December 2004. After 28 WAP, the greatest root to shoot ratio was in shrubs installed in September 2005 and December 2004.

The irrigation treatments significantly affected shoot growth of Burford Holly and Pittosporum 52 WAP for December 2005 and March 2006 plots (data not shown).

Canopy dry weight was greater for the 1-Day and 2-Day treatments than for other treatments. Irrigation treatments significantly affected root dry weight of Viburnum for the December 2005 and March 2006 plots. Root dry weight was greatest under the 8-Day treatment for the December 2005 plot, but was greatest under the 1-Day treatment for the March 2006 plot. The 2-Day and 4-Day treatments resulted in intermediate root dry weights in both plots.

For North Florida, based on the data collected thus far, shrubs can be established with as little as three liters of water applied every 8 days, at all planting dates, but more information is needed to make conclusive recommendations and to indicate the most efficient season to plant.

Fort Lauderdale

In December 2006, March 2007, and June 2007, we harvested the first three rows of plants that were planted in December 2005, March 2006 and June 2006, respectively (52 weeks after planting - WAP). We also harvested the remaining three rows of plants that were planted in December 2004, March 2005, and June 2005 (104 WAP). As reported in previous progress reports, there was no significant difference in canopy and root dry weights among the four irrigation treatments. Shrubs watered every 2 days appeared to grow better than shrubs watered every 4-days, 8-days or every day (Table 1).

From the work completed in phase one, it appears that time of year for planting had a greater impact on shrub performance than irrigation treatment. Growth of Wild Coffee at 52 and 104 WAP was greater in plots planted in September 2004, December 2004 and June 2005 than in March 2005 (Fig 5). Growth of Copperleaf 52 WAP also was greater for plots planted in September 2005, December 2005, and June 2006 than for March 2006. Similarly, growth of Orange Jasmine 52 and 104 WAP were greater in plots planted in September, December and June than plots planted in March. Growth of Viburnum 52 and 104 WAP was greater in plots planted in September or December than in plots planted in March or June (Fig 5). The weather data for March and April indicate that potential evapotranspiration is high (7 to 10 cm/month), solar radiation is high (211 to 263 W/m^2), and relative humidity is lower (around 65-66%) compared to other months (Table 2). Rain levels are often variable. The warm, dry, sunny weather in March and April may be the reason for poor shrub performance when shrubs were planted in March. Based on the data collected thus far in phase one, it seems that planting shrubs during September to December and watering every 2 days provides for maximum effectiveness. Depending on the variety of shrub, some varieties could also be planted in June and watered every 2–days during establishment to maintain effective irrigation practices. Establishment time varies but it appears that the species studied in phase one were considered established approximately 28 WAP.

B. Phase One, Part 2.

Objectives 1 through 9 have been completed. The lysimeters were built. The irrigation components, percolate collection apparatus, and data collection instrumentation was purchased. The plumbing for the irrigation and electrical components were installed. The backfilling and calibration of the lysimeters was completed. The lysimeters and the

companion fields were planted in December 2005 and 2006, and June 2006. The two species planted in Apopka were Viburnum and Burford Holly. The data being collected is the same as that described on Phase One, Part 1.

Results to date

Viburnum and Burford holly were grown in three separate experimental plots (drainage lysimeters, high water field plot, low water field plot) in Apopka and data were analyzed separately. Drainage lysimeters and the high water field plot received 1.9 cm (0.75 in) of irrigation per plant per event and the low water plot received 3 liters per plant at each application. All plants received an additional 7.8 inches of rainfall over the course of the experiment.

Canopy size increased overtime for both species and all locations (i.e. lysimeters, high water field plot, and low water field plot). For lysimeter and high volume field – grown Viburnums, canopy size was greatest for plants receiving daily irrigation (Fig. 6A-B) with canopy sizes decreasing as irrigation frequency decreased (Fig. 6A-B). Similar results were found within the low volume field plot (Fig. 6C). Regardless of location, final canopy sizes of plants receiving 2-day or 4-day irrigation ranged from 0.3-0.4 cm^3 and 0.2-0.25 cm^3, respectively (Fig. 6A-C). Daily irrigation of lysimeter grown plants increased total application volumes approximately 2.5- and 3.5-fold compared to 2-and 4-day frequencies, respectively (Table 3). However, cumulative ET_A was similar among frequencies. There were no differences in total irrigation volumes among frequencies in either field plot (data not shown).

Growth rates for all Burford hollies were not affected by irrigation frequency (Fig. 7A-C). Final growth indices were similar among frequencies for each respective plot (data not shown). However, total irrigation volume applied and cumulative ET_A were greater for lysimeters irrigated daily than lysimeters irrigated less frequently (Table 3). Total irrigation volumes were similar among frequencies in both the low and high volume field plots (data not shown).

C. Phase Two

Phase two is designed to verify the irrigation requirements determined in phase one. Twelve additional species have been chosen and will be maintained according to the irrigation treatment in phase one found to use the minimum water volume while resulting in nearly 100% survivability. The irrigation treatment in this phase may be modified according to results from the water balance study in phase one, part 2.

Objective 13 thru 17 have been completed.

Objective 18 thru 20 are in progress. Twelve additional species were selected for Balm, Citra and Fort Lauderdale (Progress Report #5) and three indicators were installed in each site on May 2006 (Progress Report #6). These shrubs were watered every 2 days with 3 L of water per irrigation event. Irrigation was discontinued March 2007. They were mulched as described in phase one and are being maintained using best management practices.

The first experimental plot was installed in December 2006 and the second experimental plot was installed in June 2007 on all three sites. Six replicates were installed for each of the 12 species at each site. They were mulched as described in Phase one and are being maintained using best management practices as described in phase one. Data collection includes: canopy growth indices, the ratio of root spread to canopy spread (starting 12 WAP), xylem potential (a measurement of plant stress), and visual dieback and plant density ratings on a scale of 1 to 9 (9 = excellent quality and 1 = dead plant) Data are recorded 4, 8, 12, 20, 28 and 52 weeks after planting (WAP).

When test plots reach 52 WAP, 3 replications of each irrigation treatment and species will be harvested. The harvested parts include all above ground material and $1/8^{th}$ of the roots extending beyond the root ball. Dry weights will be collected for each. For the remaining 3 replicates, canopy growth indices and root to shoot ratio will be collected every 4 months to monitor growth until 104 WAP when they will also be harvested.

For the Balm and Citra, shrubs are irrigated every 4 days. For Fort Lauderdale, shrubs are irrigated every 2 days. All sites will be irrigated for 20 weeks and survivability will be determined.

Irrigation was discontinued for the December 2006 plot on May 4 (20 weeks after planting).

Results to date

Balm

There was a significant species effect on growth at 4, 12 and 20 WAP for the twelve shrub species grown with irrigation every four days as part of Phase two. The Firebush, Dwarf Yaupon Holly and Indian Hawthorn grew the least, while the Japanese Privet, Downey Jasmine and Florida Privet exhibited the most growth by 28 WAP (Fig 8). In general, plant growth corresponded with expected plant growth rates, with the exception of Firebush. Firebush was killed to the ground during a freeze period in February and is rapidly producing new shoot growth. The highest root to shoot ratios at 28 WAP occurred for Firebush (due to frost dieback), Simpson's stopper, Indian Hawthorn, and Sandankwa Viburnum. In contrast, Golden Dewdrop and Downy Jasmine had the lowest root to shoot ratios.

Density and dieback ratings were highest for the Dwarf Yaupon Holly and Japanese Privet and lowest for Golden Dewdrop and Gardenia. More research must be done to determine if the differences in ratings are due to differences in water needs between species or other causes. Currently, Gardenia are exhibiting some symptoms of nematode infestation, which, if confirmed, may have contributed to lower density and dieback ratings.

Citra

Average density and dieback varied between species for shrubs planted in December 2006. All species except three (Florida Privet, Golden Dewdrop, Beautyberry) showed an average density and dieback of 8 or greater indicating healthy plants.

Growth also varied considerably between species for shrubs planted in December 2006 plot (Fig 9). A late cold snap in February after several weeks of unseasonably

warm temperatures during December resulted in considerable dieback and retarded growth in several species (Golden Dewdrop, Gardenia, Florida Privet, and Beautyberry).

All species except two (Gardenia, Loropetalum) in the December 2006 plot had reached a root to shoot ratio of at least 1.0 by 20 WAP. Root to shoot ratio also reached 1.0 about 20 WAP for the three species in phase one of the project. Root to shoot ratio could not be accurately calculated for Golden Dewdrop because the cold temperatures in January and February killed the foliage back to the ground. New foliage is emerging on several replicates, but was not significant enough for the calculation at 20 WAP.

Twenty weeks after planting only Loropetalum had xylem water potential measurements which indicated they were significantly more stressed than the indicator plants of that species. Two species (Ligustrum, Walter's Viburnum) were significantly less stressed than indicator plants of the same species. All other species were not significantly different (Table 4). This suggests that at 20 WAP, all examined species except Loropetalum could be considered established. Four species (Beautyberry, Golden Dewdrop, Gardenia, Florida Privet) could not be tested for xylem water potentials due to a lack of sufficient foliage following winter dieback and were not included in the table.

Ft. Lauderdale

In December 2006 and June 2006, six native and six non-native shrubs were planted as part of phase two. All shrubs were watered every two days until established when irrigation was or will be terminated. Growth of Jasmine, planted in December 2006, at 20 WAP exceeded the growth of the other shrubs (Fig 10, Table 5). Hibiscus, Silver Buttonwood, Firebush, Allamanda, Simpson Stopper, and Cocoplum 20 WAP were similar in growth and appear to be starting an active growth phase (Fig 10, Table 5). Indian Hawthorn, Ixora, Ilex, Florida Privet, and Croton are maintaining plant size but have not started to actively grow (Fig 10, Table 5). The plants that are showing growth 20 WAP are generally classified as fast to medium growers with medium to high drought tolerance (Table 5). Of the seven species actively growing 20 WAP, three are non-native and four are native. There does not appear to be a clear distinction at this time between native and non-native species with respect to establishment. However, growth rate and drought tolerance appear to be a better indication of plant performance.

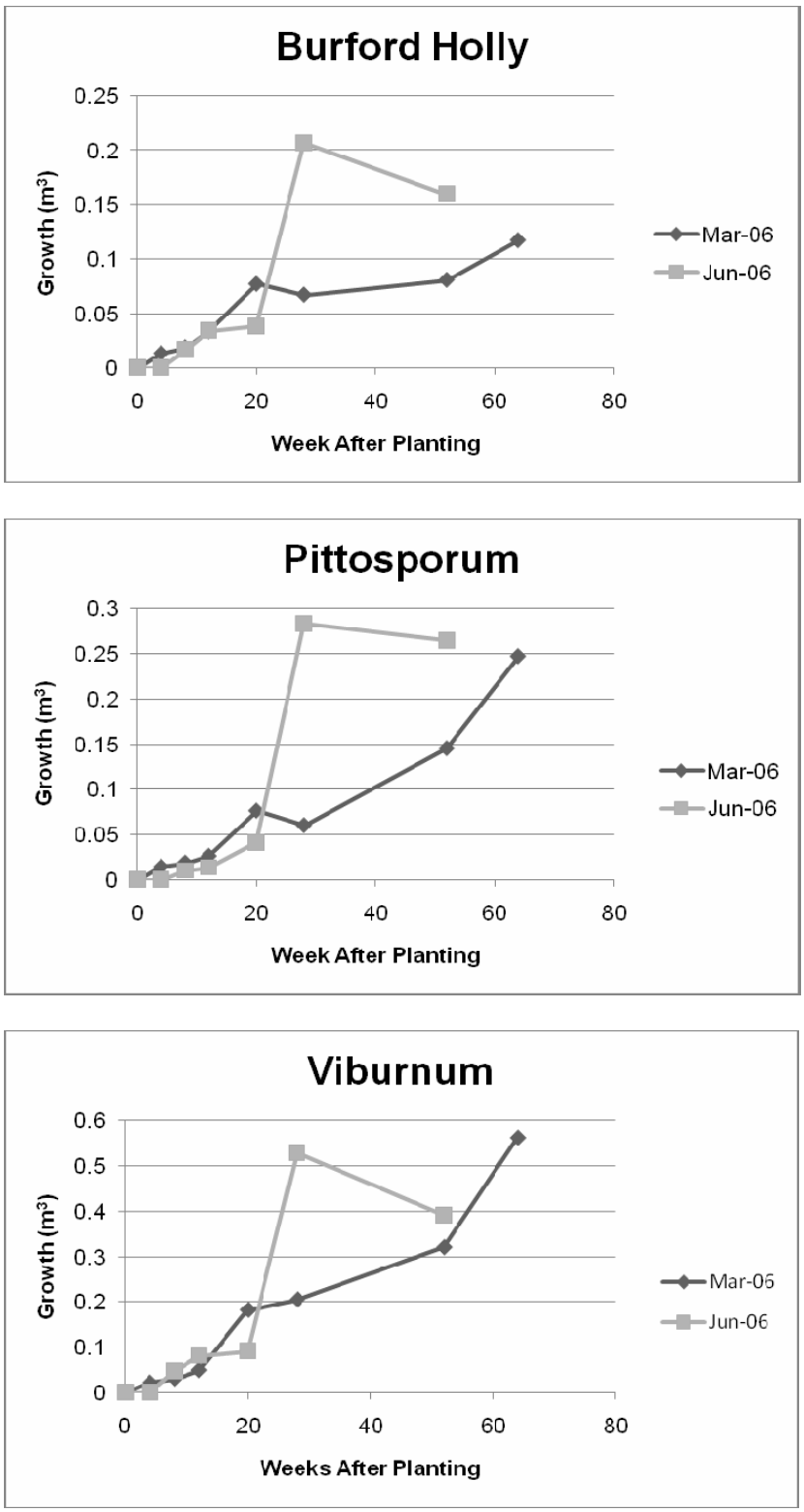

Figure 1. Growth (m^3) for Burford Holly, Pittosporum, and Viburnum averaged over irrigation treatment planted in Balm, FL.

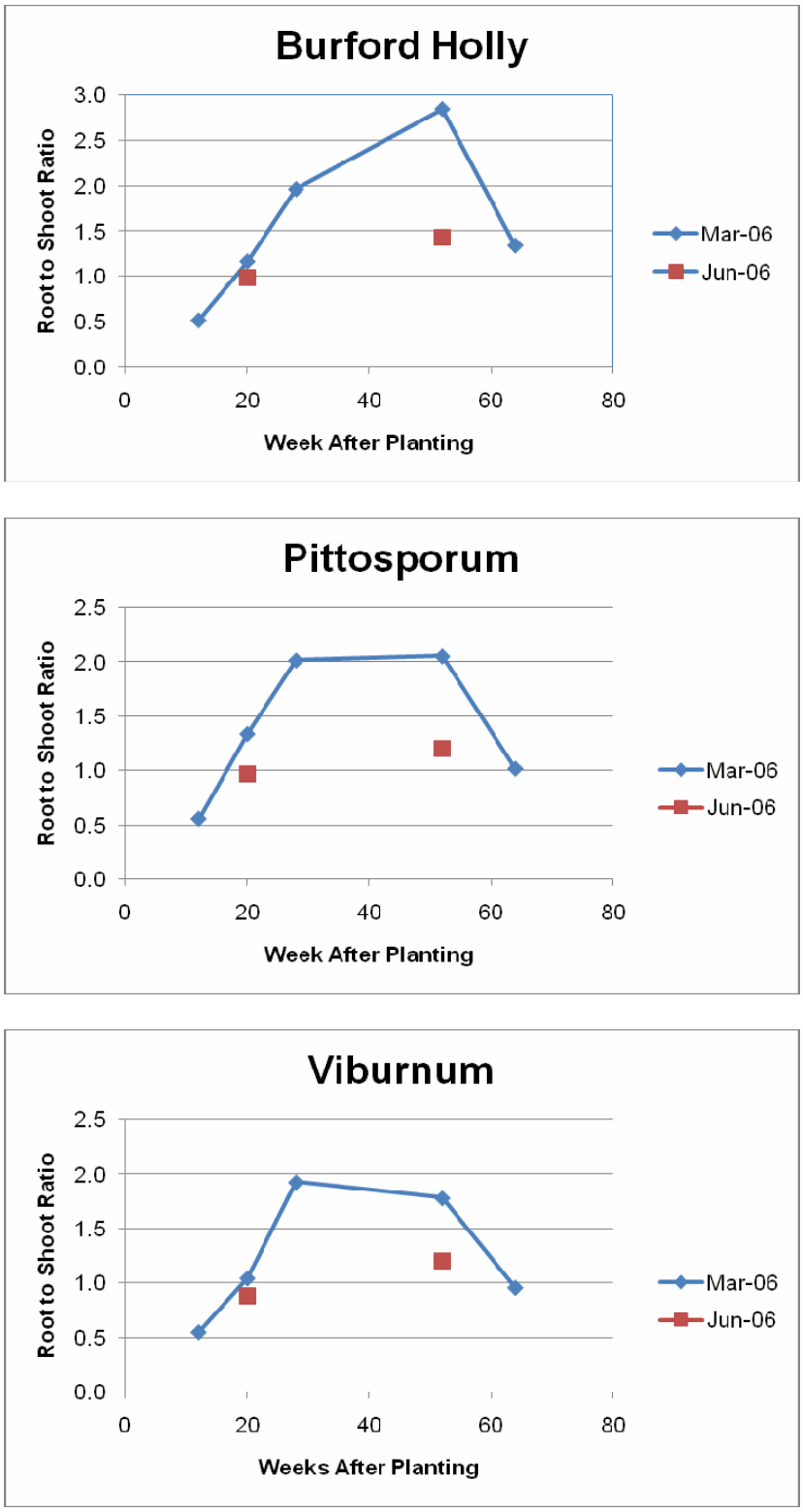

Figure 2. Root to shoot ratio response of March and June 2006 planted Burford Holly, Pittosporum, and Viburnum averaged over all irrigation treatments in Balm, FL. (Plot 8 line missing due to missing data for 12 and 28 weeks after planting.)

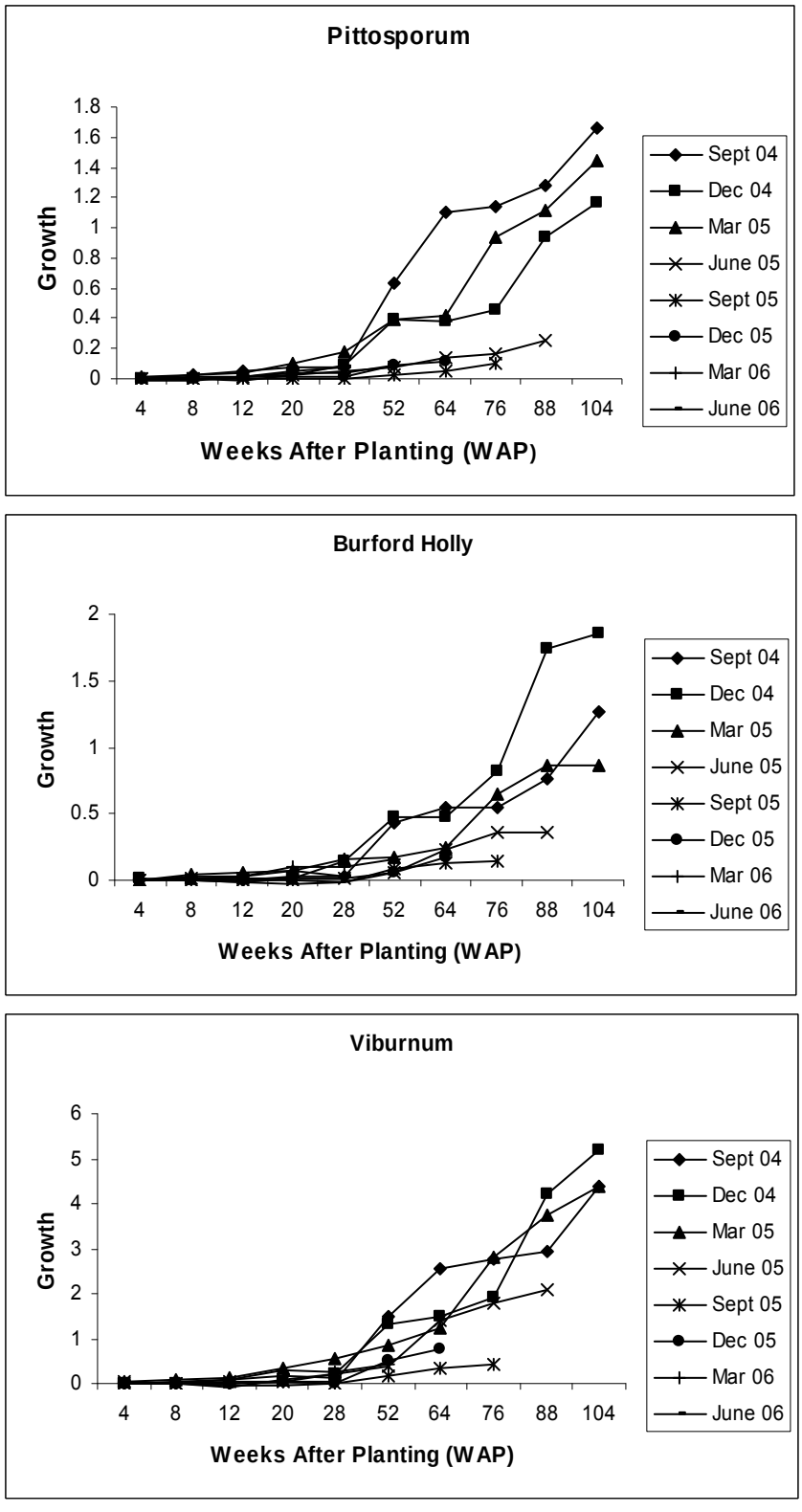

Figure 3. Average growth (m^3) for Pittosporum, Burford Holly, and Viburnum, Citra, FL. Values were averaged over irrigation treatments.

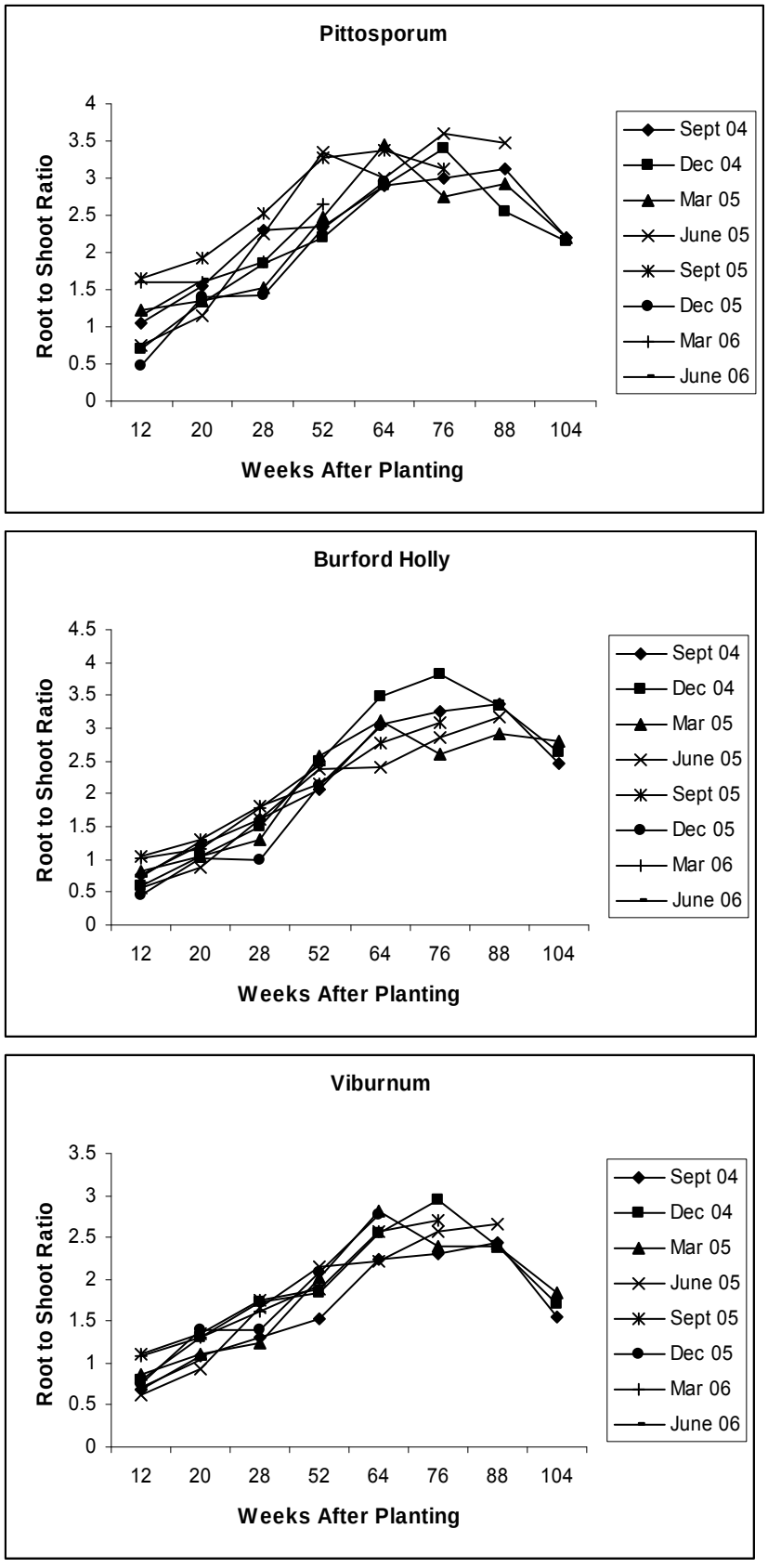

Figure 4. Average root to shoot ratio for Pittosporum, Burford Holly, and Viburnum, Citra, FL. Values were averaged over irrigation treatments.

Table 1. Root to canopy spread for Wild Coffee, Copperleaf, Orange Jasmine, and Viburnum plants.

Sep-04	**Wild Coffee**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.52	1.78	0.8	1.79	1.35
4-day	0.92	1.4	0.82	1.7	1.71
8-day	0.4	0.68	0.62	2.03	1.33
Mix	0.42	1.18	0.5	2.14	1.41
Average	0.57	1.26	0.69	1.92	1.45
Dec-04	**Wild Coffee**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.54	0.74	0.71	1.51	2.61
4-day	0.54	0.68	0.73	1.45	1.57
8-day	0.5	0.48	0.69	1.31	1.85
Mix	0.54	0.88	0.69	1.47	2.15
	0.53	0.70	0.705	1.44	2.05
Mar-05	**Wild Coffee**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.53	1.06	1.28	0.73	1.03
4-day	0.54	1.22	1.12	0.84	2.60
8-day	0.48	1.01	1.09	0.95	1.39
Mix	0.65	1.18	1.56	0.88	---
	0.55	1.12	1.26	0.85	1.67
Jun-05	**Wild Coffee**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.88	0.76	0.66	0.96	0.84
4-day	0.83	0.82	0.72	0.82	1.16
8-day	0.93	0.94	0.80	1.08	1.32
Mix	0.71	0.72	0.67	0.77	1.22
	0.84	0.81	0.71	0.91	1.14
Sep-05	**Copperleaf**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	1.33	1.62	2.34	1.91	
4-day	1.57	1.96	2.1	5.60	
1-day (3)	1.55	0.94	2.48	3.19	
1-day(9)	1.76	1.78	2.18	3.08	
	1.55	1.58	2.28	3.45	
Dec-05	**Copperleaf**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	1.4	1.58	1.93	2.75	
4-day	1.28	1.75	1.7	2.64	
1-day (3)	1.5	1.74	1.35	2.55	
1-day(9)	1.44	1.59	1.36	2.58	
	1.41	1.67	1.59	2.63	
Mar-06	**Copperleaf**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	1.62	1.86	1.62	4.15	

4-day	1.79	1.78	1.88	4.15	
1-day (3)	1.81	2.03	1.74	3.55	
1-day(9)	1.66	2.16	1.54	4.52	
	1.72	1.96	1.70	4.09	
Jun-06	**Copperleaf**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	1.62	2.06	2.58	3.80	
4-day	2.06	2.01	2.05	4.49	
1-day (3)	1.54	2.26	1.82	4.25	
1-day(9)	1.57	2.14	2.35	3.80	
	1.70	2.12	2.20	4.09	

Sep-04 **Orange Jasmine**

Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	1.10	1.14	0.79	1.76	2.04
4-day	0.78	0.94	1.14	1.98	1.83
8-day	0.66	0.98	0.96	1.98	2.21
Mix	1.06	1.24	0.76	1.91	2.29
Average	0.90	1.08	0.91	1.91	2.09
Dec-04	**Orange Jasmine**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.74	0.98	0.78	1.90	2.04
4-day	0.72	0.9	0.79	2.05	2.17
8-day	0.80	0.84	0.72	1.77	1.67
Mix	0.62	1.20	0.61	2.01	2.68
	0.72	0.98	0.73	1.93	2.14
Mar-05	**Orange Jasmine**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.41	1.04	0.96	2.38	2.54
4-day	0.52	1.08	1.37	2.5	3.62
8-day	0.51	1.22	1.42	2.23	2.54
Mix	0.39	1.02	1.05	2.61	2.05
	0.46	1.09	1.20	2.43	2.69
Jun-05	**Orange Jasmine**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.76	0.90	1.23	1.29	1.90
4-day	0.72	1.00	1.16	1.50	1.89
8-day	0.64	1.21	0.98	1.88	2.65
Mix	0.68	1.24	1.04	1.72	2.44
	0.70	1.09	1.10	1.60	2.22
Sep-05	**Orange Jasmine**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.86	1.53	1.32	1.85	
4-day	0.93	1.43	1.44	1.63	
1-day (3)	1.01	1.49	1.64	1.83	
1-day(9)	0.98	1.16	1.40	1.85	
	0.95	1.40	1.45	1.79	

Dec-05	**Orange Jasmine**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.65	1.13	1.44	2.03	
4-day	0.73	1.26	0.76	2.44	
1-day (3)	0.84	1.56	1.35	2.04	
1-day(9)	0.76	1.14	1.34	2.00	
	0.75	1.272	1.22	2.13	
Mar-06	**Orange Jasmine**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	1.47	0.92	1.42	2.51	
4-day	1.24	0.91	1.04	2.72	
1-day (3)	1.10	1.68	1.96	2.78	
1-day(9)	1.38	1.47	2.07	2.54	
	1.30	1.25	1.63	2.64	
Jun-06	**Orange Jasmine**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	1.08	0.89	1.71	2.18	
4-day	0.98	0.84	2.20	1.93	
1-day (3)	1.02	0.96	1.61	2.14	
1-day(9)	0.82	1.18	1.74	2.51	
	0.98	0.97	1.82	2.19	

Sep-04	**Viburnum**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.60	1.14	0.92	1.85	1.3
4-day	0.76	0.72	0.8	1.34	1.54
8-day	1.28	1.38	1.16	1.76	1.81
Mix	0.72	1.04	1.02	1.85	2.02
	0.84	1.07	0.98	1.70	1.68
Dec-04	**Viburnum**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.64	0.80	0.67	1.67	2.47
4-day	0.54	0.58	0.75	1.68	2.05
8-day	0.50	0.76	0.72	1.79	2.17
Mix	0.43	0.84	0.70	1.33	2.1
	0.53	0.745	0.71	1.62	2.20
Mar-05	**Viburnum**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.53	1.01	1.18	1.71	1.86
4-day	0.43	1.02	1.40	1.98	1.70
8-day	0.51	1.10	1.71	1.62	2.35
Mix	0.59	1.12	1.11	2.02	---
	0.52	1.06	1.35	1.83	1.97
Jun-05	**Viburnum**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.99	1.12	0.85	1.67	1.90
4-day	0.97	0.92	1.12	1.42	1.77

8-day	0.84	0.86	0.82	1.38	2.14
Mix	0.93	0.83	1.2	2.2	2.43
	0.93	0.93	1.00	1.67	2.06
Sep-05	**Viburnum**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.72	1.48	1.57	1.20	
4-day	0.88	1.58	1.61	1.29	
1-day (3)	1.01	1.11	1.76	1.45	
1-day(9)	0.88	1.35	1.86	1.01	
	0.87	1.38	1.70	1.24	
Dec-05	**Viburnum**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.68	1.31	1.13	2.00	
4-day	1.08	1.15	1.23	1.53	
1-day (3)	1.18	1.07	1.42	1.82	
1-day(9)	0.91	1.26	1.12	1.58	
	0.96	1.20	1.23	1.73	
Mar-06	**Viburnum**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	1.16	1.08	0.77	1.69	
4-day	1.43	0.67	1.31	2.01	
1-day (3)	0.79	1.02	1.43	1.20	
1-day(9)	0.99	0.83	0.93	1.51	
	1.09	0.90	1.11	1.60	
Jun-06	**Viburnum**				
Treatment	**12 WAP**	**20 WAP**	**28 WAP**	**52 WAP**	**104 WAP**
2-day	0.64	0.85	0.95	1.76	
4-day	0.55	1.12	1.19	2.26	
1-day (3)	0.74	0.95	1.26	1.97	
1-day(9)	0.60	0.95	1.22	1.95	
	0.63	0.97	1.16	1.99	

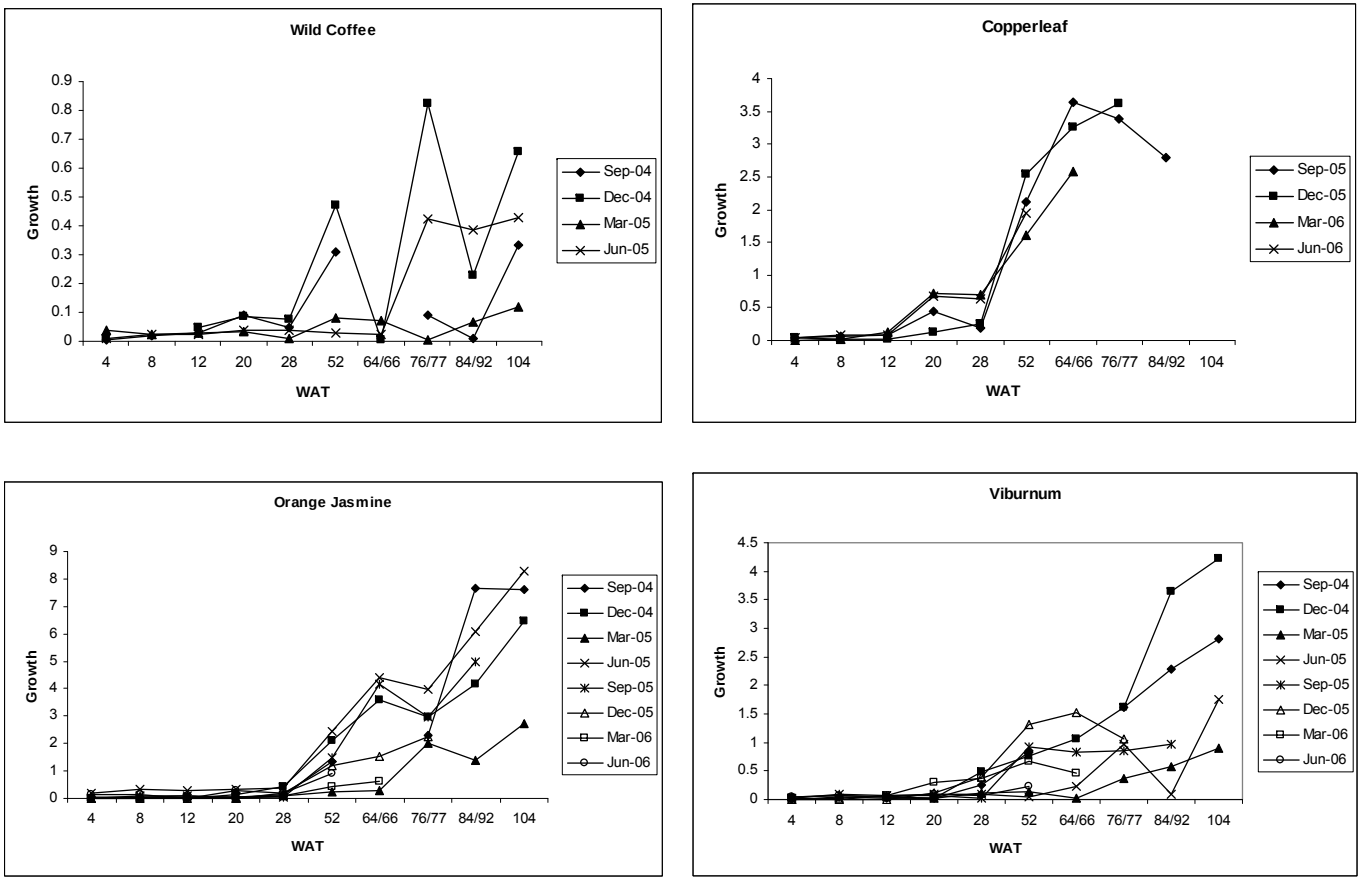

Figure 5. Average growth indices (m^3) for wild coffee, copperleaf, orange jasmine and viburnum plants. Values are averaged for irrigation treatment. Growth indices were calculated by subtracting initial growth indices from those measured 4, 8, 12, 20, 28, 52, 64, 77, 92, and 104 weeks after transplanting (WAT).

Table 2. Average monthly temperature, potential evapotranspiration (ET_p), solar radiation, relative humidity, and rainfall in Fort Lauderdale as recorded by the Florida Automated Weather Network (http://fawn.ifas.ufl.edu/scripts/reportrequest.asp).

Month and year	Temperature average (°C)	Potential ET_p*(cm/moth)	Solar radiation (W/m^2)	Relative Humidity (%)	Rainfall (cm)
Sep 2004	26.98	14.20	166	78	31.90**
Oct 2004	25.09	11.60	181	73	8.18
Nov 2004	22.83	8.86	151	71	1.19
Dec 2004	19.35	5.60	129	71	4.47
Jan 2005	19.18	5.06	149	71	2.95
Feb 2005	20.80	6.47	161	70	1.22
Mar 2005	23.00	8.77	216	70	10.67
Apr 2005	24.70	10.89	261	65	4.39
May 2005	26.20	13.01	241	71	11.81
June 2005	26.59	13.66	170	81	38.23
July 2005	28.79	17.25	236	74	15.85
Aug 2005	28.56	16.85	210	76	27.05
Sep 2005	27.69	15.39	193	76	19.35
Oct 2005	25.56	12.17	160	75	27.28***
Nov 2005	23.16	9.11	85	74	11.79
Dec 2005	19.48	5.48	105	74	6.10
Jan 2006	19.81	5.76	157	71	1.93
Feb 2006	18.69	4.86	192	70	11.02
Mar 2006	21.32	7.15	230	66	0.46
Apr 2006	24.29	10.48	263	66	3.43
May 2006	25.38	12.03	260	69	14.20
June 2006	27.40	14.81	225	74	14.94
July 2006	27.40	14.88	215	77	36.42
Aug 2006	27.90	15.63	210	76	22.45
Sep 2006	26.90	14.11	190	77	34.67
Oct 2006	25.50	12.05	197	70	6.68
Nov 2006	21.71	7.64	138	72	5.28
Dec 2006	23.19	9.17	143	75	0.05
Jan 2007	21.46	7.32	142	73	3.05
Feb 2007	19.62	5.65	166	73	5.59
Mar 2007	22.13	8.00	211	67	4.47
Apr 2007	23.31	9.31	258	66	4.77
May 2007	25.08	11.47	242	69	10.92
June 2007	26.36	13.30	223	76	21.64

*Potential evapotranspiration was calculated using the Thronthwaite procedure
Hurricanes Frances and Jeanne * Hurricane Wilma

Figure 6. Mean growth indices of *Viburnum odoratissimum* treated with one of four irrigation frequencies: (■) daily, (●) every 2 days, (▲) every 4 days, and (♦) every 8 days and grown in (A) lysimeters, (B) high volume companion field plot, and (C) low water companion field plot. Lysimeters and the high volume field grown plants received irrigation either daily, every 2 days, or every 4 days. The low volume field grown plants received irrigation every 2-, 4-, or 8-days. Each point represents the means of three replications with $\pm$ SE indicated by standard error bars.

Figure 7. Mean growth indices of *Ilex cornuta* 'Burford Nana' treated with one of four irrigation frequencies: (■) daily, (●) every 2 days, (▲) every 4 days, and (♦) every 8 days and grown in (A) lysimeters, (B) high volume companion field plot, and (C) low water companion field plot. Lysimeters and the high volume field grown plants received irrigation either daily, every 2 days, or every 4 days. The low volume field grown plants received irrigation every 2-, 4-, or 8-days. Each point represents the means of three replications with $\pm$ SE indicated by standard error bars.

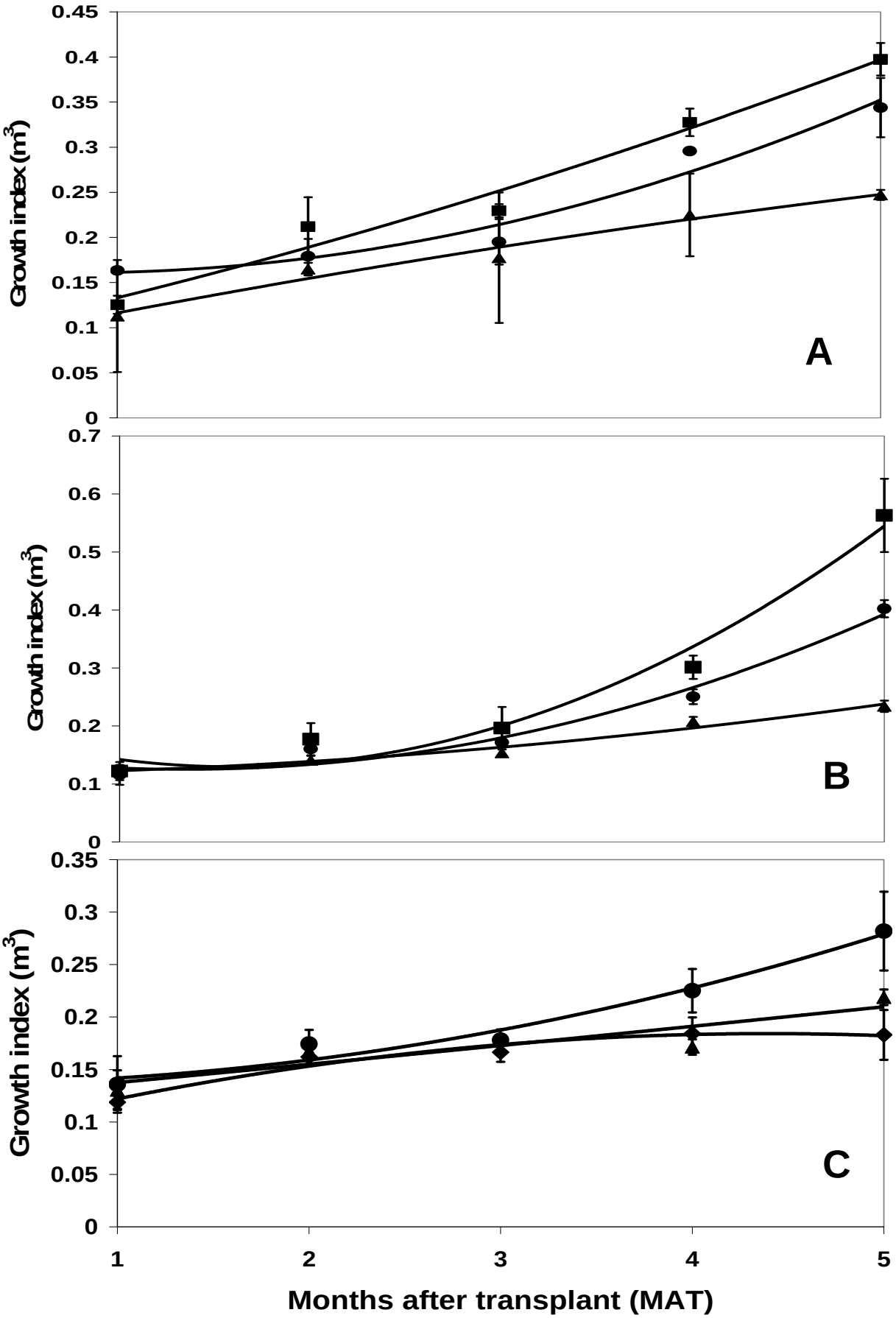
Growth index (m3)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
A
Growth index (m3)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
B
Growth index (m3)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
C
1
2
3
4
5
Months after transplant (MAT)

Figure 6

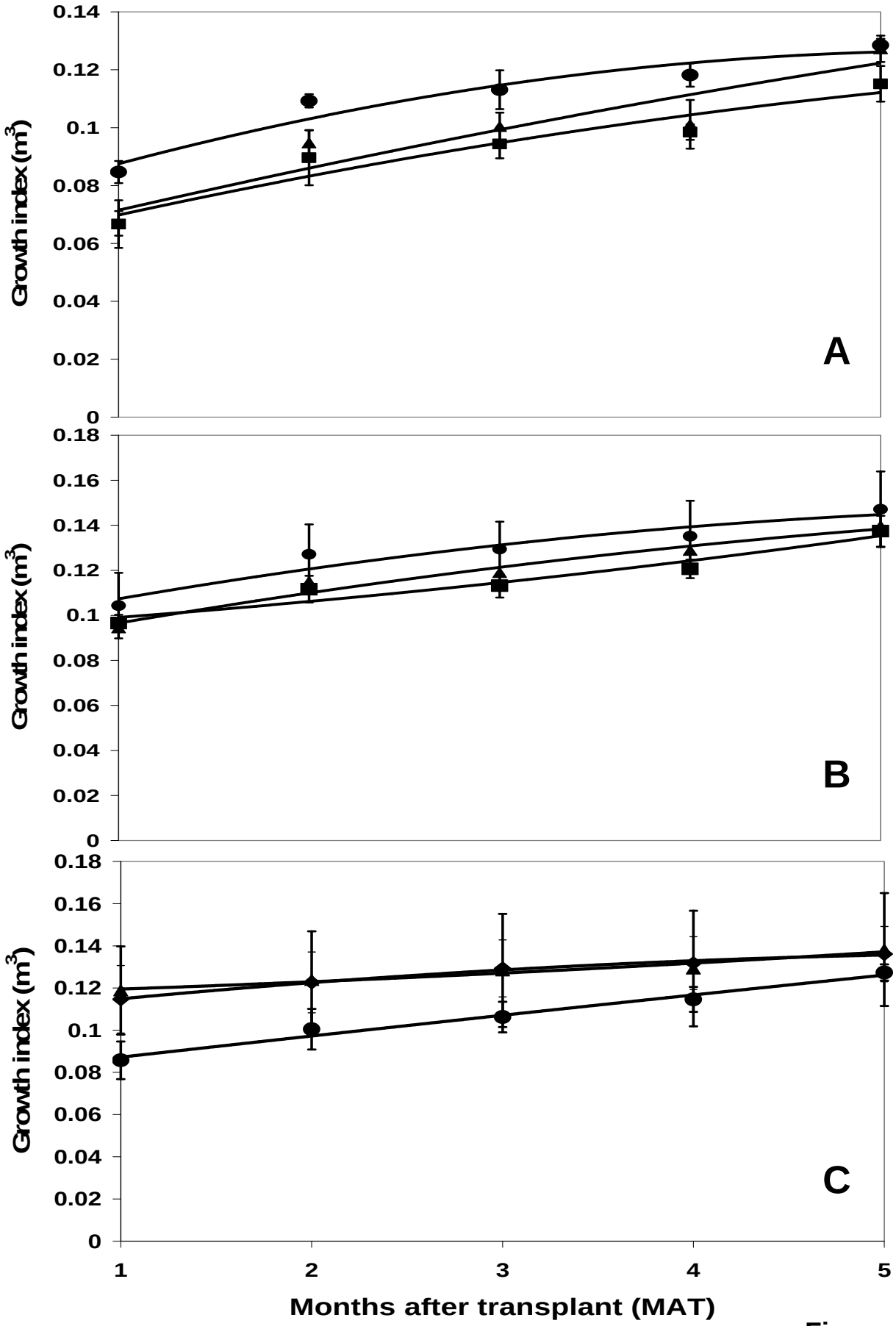
Growth index (m3)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
A
Growth index (m3)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
B
Growth index (m3)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
C
1
2
3
4
5
Months after transplant (MAT)

Figure 7

Table 3.

Species	Irrigation Frequency	Total irrigation volume (L)	Cumulative ET_A (L)
Ilex cornuta 'Burford Nana'	1-day	25963 a[zy]	13816 a
	2-day	13111 b	6419 b
	4-day	4519 c	1335 b
	p-value	< 0.0001	0.0028
Viburnum odoratissimum	1-day	24285 a	14054 a
	2-day	10315 b	5348 a
	4-day	6855 b	2695 a
	p-value	0.0038	>0.05

[z]Means representative of 3 lysimeter replicates.
[y]Mean separations within columns using Fisher Protected LSD, *P*=0.05.

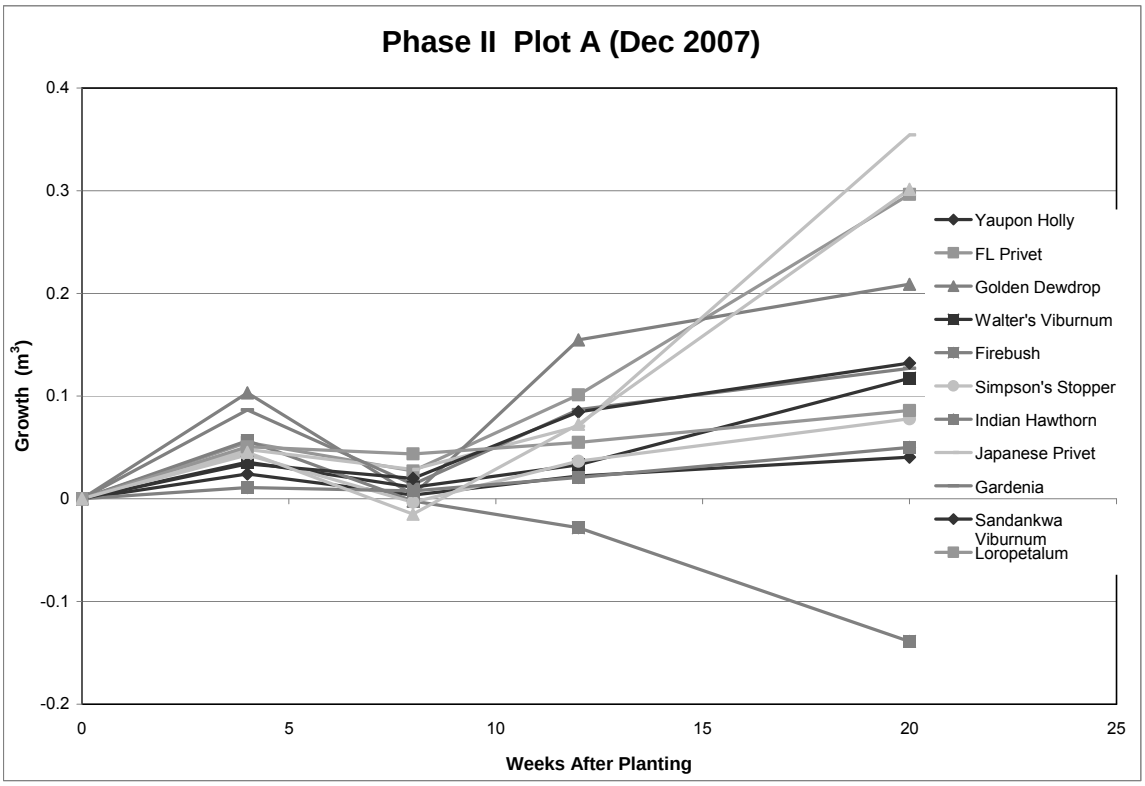

Figure 8. Plant growth response of twelve shrub species irrigated every four days during establishment at Balm, FL.

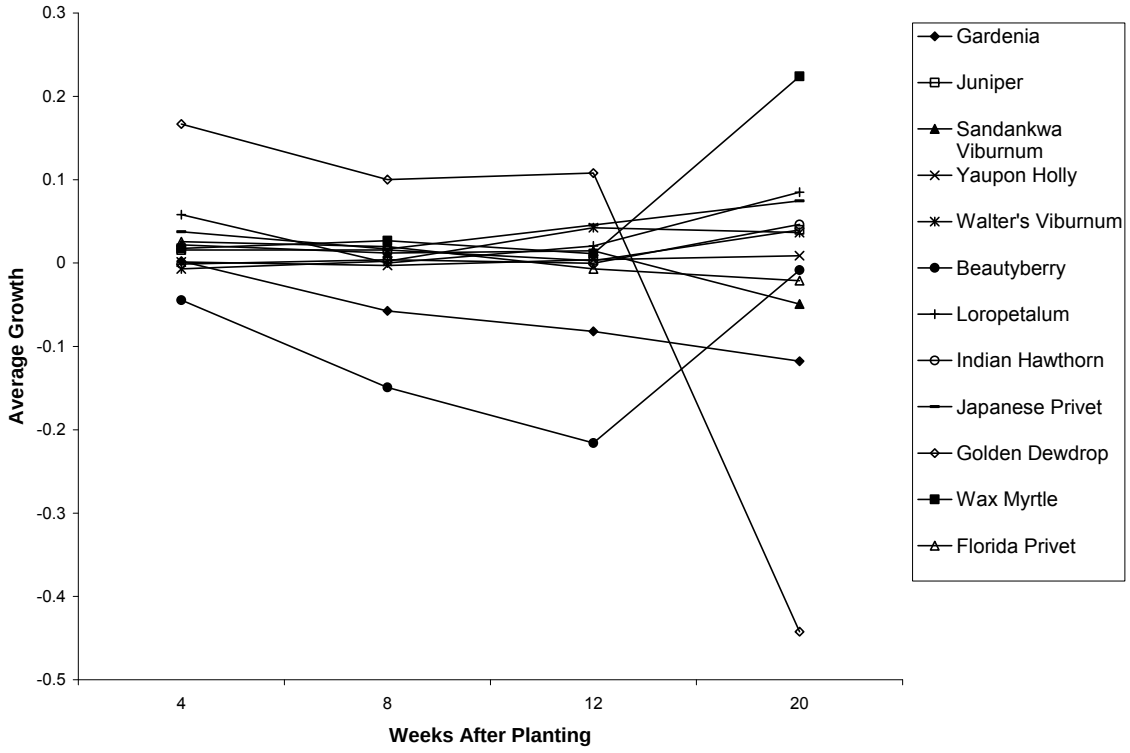

Figure 9. Average growth of phase two shrubs planted December 2006, Citra, FL.

Table 4. Mean xylem water potential for phase two shrubs, 20 weeks after planting, Citra, FL.

Species	4-Day	Indicator
Dwarf Yaupon Holly	106.5 a	101.27 a
Juniper	134.956 a	133.067 a
Japanese Privet	99.27 b	155.08 a
Loropetalum	175.98 a	121.28 b
Wax Myrtle	89.489 a	88.044 a
Indian Hawthorn	121.73 a	119.62 a
Walter's Viburnum	98.271 b	150.297 a
Sandankwa Viburnum	136.29 a	122.51 a

Values with different letters within rows are significantly different ($P<0.05$).

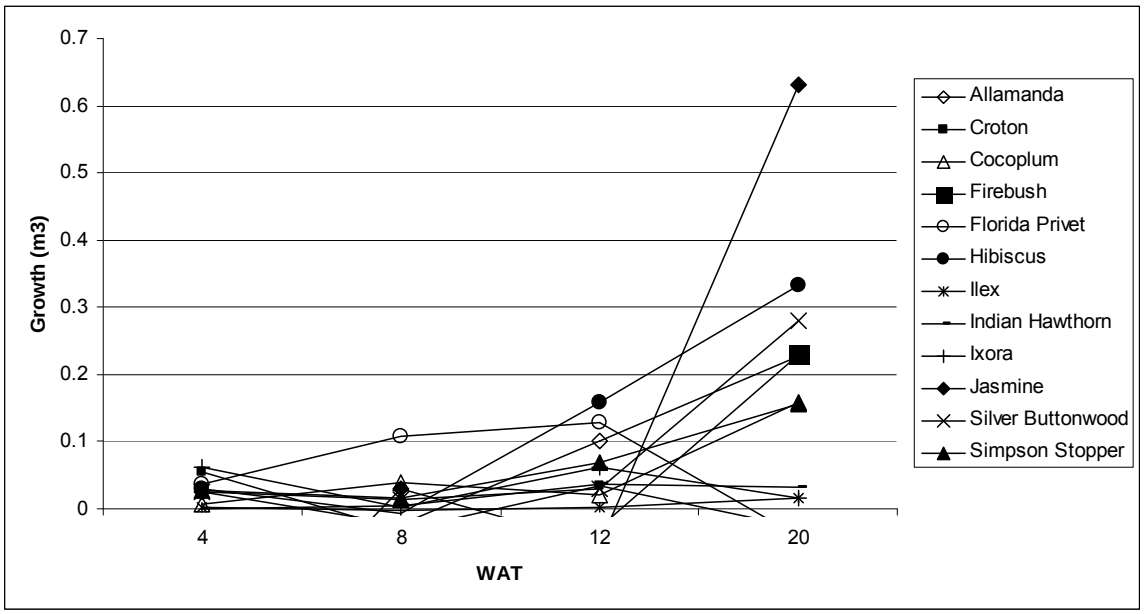

Figure 10. Average growth indices (m^3) for phase two shrubs planted in December 2006. Values are averaged for irrigation treatment. Growth indices were calculated by subtracting initial growth indices from those measured 4, 8, 12, and 20 weeks after transplanting (WAP).

Table 5. Reported growth rate, reported drought tolerance and root to canopy spread 12 and 20 weeks after transplanting (WAP) for phase two shrubs planted in December 2006.

Plant	**Growth rate**	**Drought tolerance**	**WAP**	
			12	**20**
Allamanda	Fast	Medium	0.967	1.07
Croton	Slow	High	0.275	0.43
Cocoplum (native)	Medium	Medium	0.706	0.64
Firebush (native)	Fast	High	0.882	1.5
Florida Privet (native)	Medium	High	0.794	1.1
Hibiscus	Fast	Low	1.034	2.23
Dwarf Yaupon Holly (native)	Medium	High	1.149	0.92
Indian Hawthorn	Slow	Medium	0.735	1.35
Ixora	Medium	Medium	0.422	0.75
Jasmine	Medium	Medium	0.439	0.7
Silver Buttonwood (native)	Medium	High	0.507	1.06
Simpson Stopper (native)	Slow	High	0.852	0.78