Evaluation of Drought Tolerance in Five Native Caribbean Tree Species With Landscape Potential

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Abstract

Seedlings of five tree species native to the U.S. Virgin Islands and Puerto Rico with potential for landscape plantings were grown in a greenhouse and subjected to three different watering intensities. We wanted to determine how fast nursery stock would reach an appropriate size for outplanting and how plant biomass would be allocated. Tree heights were measured weekly for 22 weeks, after which trees were harvested to determine root, stem, and leaf weights. All species survived under the different watering regimes but had different responses in both height growth and biomass allocation. Only one species, *Andira inermis*, when subjected to abundant watering reached outplanting height by the end of 22 weeks. *Plumeria alba* growth did not respond positively to increasing water and the soil's lack of field capacity wasted excess water. In terms of biomass allocation *A. inermis* was plastic in the allocation of biomass by dedicating more biomass to roots while under water stress and dedicating more biomass to stem wood when watered at field capacity. Other species, in particular, *Bucida bucera* did not change biomass allocation in response to watering levels. The results indicate that U.S. Virgin Islands nursery managers can save water during growing of these species by controlling watering levels and still obtain marketable local trees.

Introduction

The U.S. Virgin Islands (USVI) consists of four small islands in the Caribbean. When Europeans arrived in the Caribbean at the end of the 15th century, these islands were mostly covered in tropical dry forest and inhabited by natives. In the 17th and 18th centuries, African slaves cleared the islands of forest so sugar cane could be cultivated for the benefit of European planters. The cultivation of sugar cane has ceased, and the forests have grown back, but the islands are quickly urbanizing (Thomas and Devine 2005).

New urban and residential developments require bushes and trees to beautify the newly constructed areas and provide environmental services such as shade and protection from wind. Landscape planting around buildings, in parks, and along roads differs from reforestation or restoration plantings in scale (square yards and square meters versus acres and hectares) and in the size of the trees planted. The American National Standards Institute (ANSI) recommends that the minimum size for a nursery-grown tree planted for landscaping purposes is a 0.5-in (12.5-mm) diameter measured at 6 in (15 cm) above the ground, and 4.0 to 5.0 ft (1.2 to 1.5 m) (ANLA/ANSI 2004). By comparison, bare root seedlings planted for reforestation purposes are typically 1- to 2-ft (30- to 60-cm) tall.

Plant nurseries use abundant water, particularly those specializing in showy tropical plants such as species in the *Heliconaceae, Musaceae,* and *Zingiberaceae* families. These plants, after being planted in their final location, continue to need abundant water—which is a problem. Nurseries and landscape plantings cannot depend on rainfall alone in the USVI. During the dry season, access to well, municipal, or pond water is necessary to keep these plants alive.

On the islands, supplies of fresh water are limited. Rainfall is seasonal. No perennial streams or lakes exist to provide fresh water. People collect rainwater from rooftop-fed cisterns, pump water from wells, or buy desalinated seawater from the Virgin Islands Water and Power Authority. Yet, drought in the USVI is a more serious concern than ever before in recent history. Subterranean reservoirs have become depleted, although according to records, the islands receive about the same amount of rainfall as in past periods of time. Subterranean water sources have also become contaminated with salt water intrusions, waste water, and petroleum (USDA NRCS 2000).

To reduce water use by plant nurseries and property owners, we proposed the use of native tree species adapted to landscaping uses. As mentioned previously, tropical dry forest was, and still is, the predominant vegetation type in the USVI. Tropical dry forests are adapted to seasonal rainfall regimes and low levels of precipitation. Worldwide, tropical dry forests and woodlands are characterized by annual precipitation between 40 and 80 in (1,000 and 2,000 mm) and very dry tropical forests have annual precipitation between 20 and 40 in (500 and 1,000 mm) (Holdridge 1978). Tropical thorn scrub forests 10 to 20 in (250 to 500 mm) rain yearly. Based on annual precipitation and temperatures, the USVI has both dry tropical forest and very dry tropical forest.

Most tropical forests experience seasonal droughts that last for weeks or months, even in forests classified as moist or humid (Mulkey and Wright 1996). Forest plants can also suffer water limitation daily, during the heat of the midday or even from competition with other plants in the shade of the understory (Kainer and others 1998). Fresh water is a limited resource and plants have various physiological responses and strategies in response to water availability. Some of the adaptations of tropical dry forest plants to drought are leathery leaves, leaves that are deciduous in times of drought, photosynthesis through the trunk instead of the leaves during times of drought, dedication of more growth to roots instead of leaves, and storage of water within the roots and tree trunk itself (Slayter 1967, Farquhar and Sharkey 1982, Sharkey and Badger 1982, Gardner and others 1985, Shulze 1986, Anderson and others 1995, Brodribb 1996, Sanford and Cuevas 1996, Manter and Kerrigan, 2004).

To remain profitable and in business, plant nurseries need to produce a sufficient supply of plants at a price people are willing to pay. Two ways to reduce costs are to closely monitor water use and to grow native plants that are adapted to the dry environment of the USVI. The objective of our study was to determine biomass production and allocation to leaves, stems, and roots for five different species subjected to three watering regimes. This information can be an asset to nursery growers and landscapers to better understand a plant species' water-saving strategy.

Methodology

Five native tree species were included in this study: *Andira inermis* (W. Wright) Kunth ex DC, *Bucera bucida* L., *Jacquinia arborea* Vahl, *Pimenta racemosa* (Mill.) J.W. Moore, and *Plumeria alba* L. Each species was grown from seed. After two adult leaves emerged, the plants were transplanted into 61 in^3 (1,000 cm^3) pots and grown until they reached a size of 6 in (15 cm) at which point 18 individuals of each species were transplanted again into 3-gal (11,400-cm^3) black plastic pots (Custom™ Containers) and allowed to recover from transplant for 5 weeks before the experiment started. The experiment ran from July 2012 to May 2013 (28 weeks for *A. inermis*, 24 weeks for *P. racemosa*, 20 weeks for *J. arborea*, 24 weeks for *B. bucera*, and 16 weeks for *P. alba*). Variations in the length different species were subjected to treatments resulted from delays in obtaining seeds of the various species and differences in seed germination. Because St. Croix is a tropical island, freezing temperatures and low levels of winter light were not a problem. Mean daily temperature is 79 ˚F (26 ˚C), and St. Croix has roughly 12 hours of sunlight per day, year round (NOAA 2013).

Each pot was filled with a potting mix of two parts *Sphagnum* peat, one part coarse sand, and one part top soil. Top soil was obtained from agricultural fields at the UVI-STX campus. A soil survey map indicates that the soil is a Sion Clay derived from alkaline marine deposits. It is considered prime agricultural soil if irrigation is available; elsewhere, it is used as rangeland (USDA NRCS 2013, 2000). The soil is moderately alkaline and sometimes causes problems for crops because of iron deficiencies. Soil tests contracted out by UVI to Waters Agricultural Laboratories indicate that the pH is 8.

One month after transplanting, plants were assigned a weekly watering regime: 100 percent field capacity (FC), 66 percent field capacity, and 33 percent field capacity (designated hereafter as 100 FC, 66 FC, and 33 FC, respectively). Six plants of each species were in each watering regime. The pots were color-coded blue, green, and yellow to avoid confusion while watering and to symbolize a gradient from abundant watering through drought. In a previous experiment using 3-gal pots (data unpublished), the watering treatments were field capacity, 50 percent field capacity, and 33 percent field capacity, but we found no increase in plant growth when watering was increased from 33 to 50 percent field capacity. By increasing watering to 50 and 66 percent of field capacity, we were able to test water-conserving treatments while still promoting plant growth.

To determine the amount of water that each plant would receive, we needed to determine the field capacity of the planting substrate. Field capacity refers to the amount of water held in the soil after excess water has drained away. Gravity causes the excess water to drain from the macropores; water for plant use is held within the micropores via capillary action (Brady and Weil 2002). We determined field capacity two different ways; the first is theoretical and the second empirical with the expectation that both methods would produce similar results. A theoretically ideal growing medium consists of 50 percent mineral or organic particles and 50 percent pore space (Brady and Weil 2002). To simplify calculations, we estimated pore space to be evenly divided between micropores and macropores although the proportion or ratio of macropores and micropores can vary among soils. From an example taken from a soils text book (Brady and Weill 2002: 151), a representative sandy loam had a 2:1 ratio of micropores to macropores; a representative silt loam with good structure had a 1:1 ratio of micropores to macropores; and a representative silt loam with poor structure had a 4:1 ratio of micropores to macropores. In our study, the planting substrate is a mixture of *Sphagnum* peat moss and coarse river sand with a component of field soil. For our theoretical calculation of field capacity, the volume of substrate within a pot was divided by 2 to estimate the volume of pore space to particles, then the volume of the pore space was divided again by 2 to estimate the volume of macropore and micropore space. The 3-gal pots we used have a volume of 0.402 ft^3 (11,400 cm^3). So 0.201 ft^3 (5,700 cm^3) would be considered pore space. Therefore, at field capacity, the theoretical amount of water held in the micropores would be 0.101 ft^3 (2,850 cm^3) or 0.79 gal (3 L).

Next, field capacity of our pots filled with potting mix was determined in an experimental or empirical fashion. Potted plants were allowed to dry down until wilting, thus indicating dry soils. The dry pots were then weighed. Then, the potting mix was watered until water ran out the bottom of the pots. We waited an hour, until all the gravitational water had drained out of the macropores. The moist pots were then weighed. The amount of water being held in the micropores of the potting mix was calculated by subtracting the weights of the dry pots from the moist pots. On average, the difference was 6.6 lb (3 kg or 3,000 cm^3), which is equivalent to 0.79 gal (3 L) of water, the same amount estimated during our theoretical determination.

Based on our field capacity calculations, plants in the 100 FC treatment received 1.0 gal (3.8 L) of water once per week to ensure each pot would receive adequate water to achieve field capacity. Plants assigned the 66 FC treatment received 0.53 gal (2 L) of water weekly, and those assigned to the 33 FC treatment received 0.26 gal (1 L) water weekly. Macronutrients and micronutrients were supplied to the plants via a water soluble fertilizer (12-48-8 Sol-U-Gro™) once a week, when the plants were watered.

Each week, height and stem diameter were measured and recorded (figure 1). As per the guidelines for landscape planting, stem diameters were measured at 6 in (15 cm) above the soil surface (figure 2). At the end of the experiment, nine plants of each species were harvested, dried in an oven for 3 days at 122 ˚F (50 ˚C) (Ostertag and others 2008), and then separated into its components (leaves, stems, and roots) and weighed.

Each species was in a completely randomized experimental design. The data from each species were statistically analyzed separately using JMP software (John's MacIntosh Program), a menu-driven version of SAS (Statistical Analysis Software). We performed an ANOVA on the data to determine if significant differences existed among the treatments. If a statistical difference existed between treatments for a particular species, a Dunnet's test was performed. With a Dunnet's test, results are compared with a control treatment. In this study, the 100 FC treatment was considered the control treatment for purposes of the Dunnet's test.

Figure 1. Height (top) and diameter (bottom) were measured weekly on all plants in the study. (Photos by Michael Morgan with Kalunda Cuffey)

Figure 2. Stem diameter was measured 6 cm above the soil surface. (Photo by Michael Morgan)

Results and Discussion

Andira inermis

Andira inermis is an attractive, medium-sized tree with dark green leaves and small, showy, purplish pink pea-like flowers (figure 3). The round, hard fruit contains one seed (figure 4). These leguminous trees are usually 20- to 50-ft tall (6- to 15-m) with a 6- to 12-in (15- to 30-cm) diameter at breast height (dbh). In a forested setting, it can grow up to 100-ft (30-m) tall and 48 in (120 cm) in diameter. Within the forest, the tree has a narrow crown with a straight, cylindrical trunk and no low branches. Open-grown trees have a rounded, dense crown with many spreading branches (figure 5).

The English common names for *A. inermis* are dog almond, bastard mahogany, and cabbage angelin. Each name refers to a certain aspect of the tree. Dog almond refers to the tree's bat dispersed seeds that are poisonous to people. Cabbage angelin refers to the unpleasant rotting odor the bark gives off when cut. Bastard mahogany refers to its fine, furniture-quality wood. The Spanish common names are moca or motón. The species is found throughout the neotropics from south Florida to Peru and Bolivia. It is a common tree in Puerto Rico and the Virgin Islands and uncommon in Florida (Kirk 2009).

A. inermis trees grew best in the 100 FC treatment (figure 6, table 1). Trees in the 66 FC treatment grew at a slower rate, while those in the 33 FC treatment grew only 8 in (20 cm) and then stopped growing (figure 7A). Total biomass produced

Figure 3. *Andira inermis* has small, showy flowers. (Photo by Michael Morgan)

Figure 4. *Andira inermis* fruit. (Photo by Michael Morgan)

Figure 5. When open grown, *Andira inermis* forms a wide, branching canopy. (Photo by Michael Morgan)

Table 1. Tree height and diameter by species and weekly irrigation treatments at the beginning and end of each experiment.

Treatment	Initial height (cm)	Height growth (cm)	Final height (cm)	Initial diameter (mm)	Diameter growth (mm)	Final diameter (mm)
Andira inermis						
100 FC	44	82*	126	7	13*	20
66 FC	44	63	107	7	10	17
33 FC	44	19	63	7	5	12
Bucida bucera						
100 FC	36	52*	88	6.3	5.9*	12.2
66 FC	33	18	51	8.0	3.0	11.0
33 FC	36	14	50	6.0	3.0	9.0
Jacquinia arborea						
100 FC	20	19	39	4.3	4.4	8.7
66 FC	21	20	41	4.0	4.5	8.5
33 FC	20	10	30	4.0	3.2	7.2
Pimienta racemosa						
100 FC	19	55	74	4.0	4.3	8.3
66 FC	21	56	77	4.1	4.6	8.7
33 FC	20	46	66	3.6	3.6	7.2
Plumeria alba						
100 FC	84	8	92	11	4	15
66 FC	80	11	91	12	2	14
33 FC	89	7	96	12	1	13

Note: Within a species, asterisks denote instances when the 100 FC treatment was significantly different from the other two treatments ($\alpha \leq 0.05$).

Figure 6. Three *Andira inermis* trees at the end of the experiment. Weekly irrigation regime treatments from left to right are field capacity, two-thirds field capacity, and one-third field capacity. (Photo by Michael Morgan)

by *A. inermis* differed significantly among treatments ($p = 0.0002$). Significantly more biomass was allocated to roots in the drier treatments (figure 7B) suggesting an adaptation to water stress by increasing the plants water uptake capacity. The proportion of leaf biomass was similar among the 3 treatments. Allocation to stem tissue was higher for plants grown in the 100 FC treatment. During this experiment, the trees allocated all aboveground woody growth to a single stem and did not produce lateral branches. This species is often found along stream sides, but tolerates a wide range of sites; hence the differing allocations of biomass in response to site conditions (Little and Wadsworth 1964).

Bucida buceras

Bucida buceras has the English common name of black olive, yet does not bear olive-like fruits. Other common names are ucar in Spanish and gre-gre in the USVI (Kirk 2009). *B. buceras* trees produce small, greenish white flowers borne in spikes (figure 8) and can grow up to 100 ft (30 m) tall and 5.0 ft (1.5 m) dbh. Although it is considered a climax species of tropical dry forests in the Caribbean and northern South America, it is widely planted as a street tree throughout the Caribbean basin and south Florida (Francis 1998).

B. buceras did not respond well to water stress although it is often found growing close to the ocean shore on the drier east end of St. Croix, suggesting that this species has some drought tolerance. By the end of each week, all *B. buceras* plants, particularly the plants in the 66 FC and 33 FC treatments were wilting and under obvious water stress. Even the trees in the 100 FC treatment showed some signs of water stress, although they continued height growth. By the end of 16 weeks, no tree had reached the ANSI recommended size for landscape planting (table 1, figures 9A and 10). In fact, plants in the 33 FC and 66 FC had nearly no growth and were barely kept alive during the study. More frequent watering to

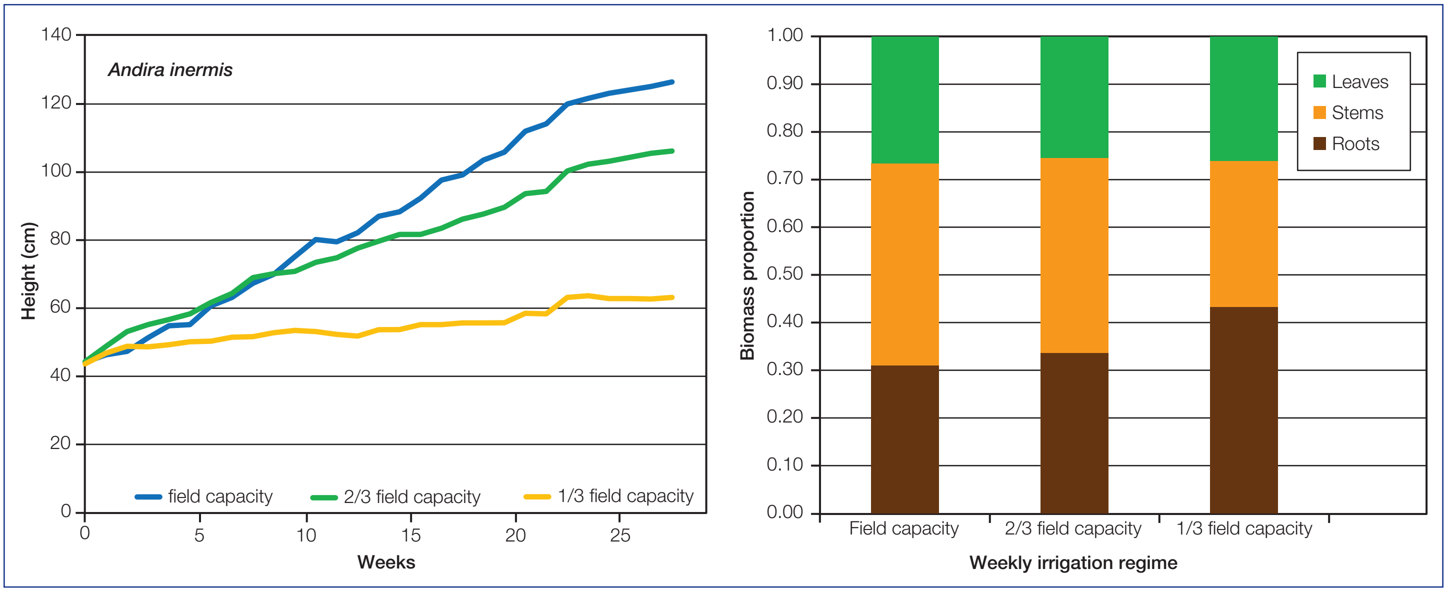

Figure 7. Height growth (left) and biomass proportioning (right) of *Andira inermis* trees subjected to three irrigation regimes.

Figure 8. *Bucida buceras* flowers. (Photo by Michael Morgan)

keep soil moisture levels more constant and at a higher level is likely to avoid water stress and encourage growth of this species.

Biomass allocation in *B. buceras* did not differ among the three watering treatments. Regardless of treatment, more than one-half of the plant biomass was allocated to stems and branches while the other one-half was more or less equally divided between roots and leaves (figure 9B). Foliar biomass allocation was underestimated for *B. bucera* plants in the 100 FC treatment. We sprayed the greenhouse with Malathion™ to control white flies (*Tria leurodes vaporarium* Westwood), and some of the trees in the 100 FC treatment lost their leaves because they were closest to the spray. They had not

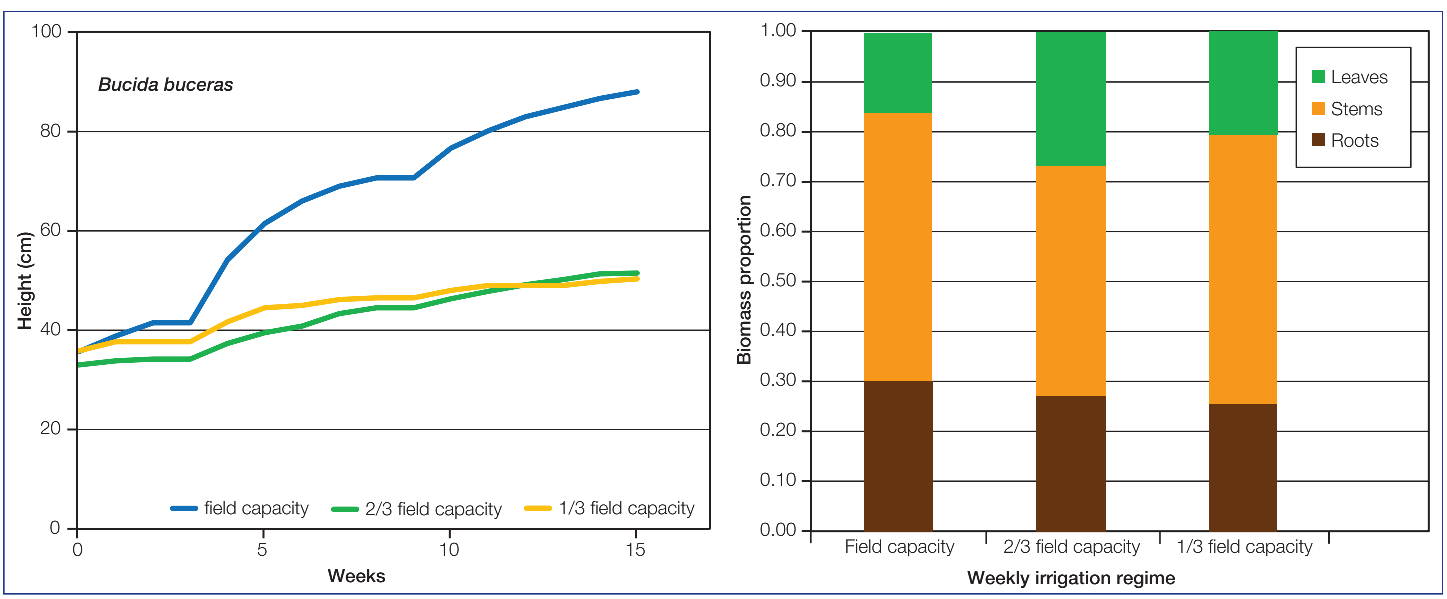

Figure 9. Height growth (left) and biomass proportioning (right) of *Bucida buceras* trees subjected to three irrigation regimes.

Figure 10. *Bucida buceras* trees arranged in a gradient of water stress. Weekly irrigation regime treatments from left to right are one-third field capacity, two-thirds field capacity, and field capacity. (Photo by Michael Morgan)

fully recovered 4 weeks later at the time of the experiment's end. We estimate that foliage allocation would have been approximately 25 percent of biomass for plants in the 100 FC treatment if the insecticide damage had not occurred.

B. buceras is a very branchy tree with many lateral branches (figure 11). The tree takes the form of a pagoda or a series of parasols that get smaller as they ascend the tree. Branches in young trees are kept close to the ground. This characteristic may serve to reduce evaporation of soil water around the tree by shading the soil in its root zone. Two other trees exist that share this pagoda-like growth form: *Terminalia catappa* L. and *Tabebuia bilbergii* (But & K. Schum) Standl ssp *ampla* A Gentry (Valverde Badillo 1998). *T. catappa* is originally from Asia, but is now a pan tropical tree species that goes by the common names of sea almond, Indian almond, and West Indian almond (Flores 2002). It often grows close to the shoreline where it tolerates sandy soils and salt from the wind and in the soil. *T. bilbergii* grows in the very dry tropical forests or tropical thorn scrub of the Ecuadorian and Peruvian coast.

Figure 11. Mature *Bucida buceras* tree. (Photo by Michael Morgan)

Jacquinia arborea

Jacquinia arborea is a shrub or small tree found on coastal outcrops and other places close to the ocean (figure 12). It has red berries and was used in the past to stupefy fish. The common name in the USVI is torchwood because of its bright red berries. In Spanish, it is called barbasco, as is any tree or plant used to stupefy and capture fish (Little and Wadsworth 1974).

J. arborea trees in the 33 FC treatment grew at a slower rate than those in the other two treatments (table 1, figure 13A). Little difference existed in height, diameter, and biomass growth between trees grown in the 100 FC and 66 FC treatments; therefore, we recommend watering with 0.53 gal (2 L) per week instead of 1.0 gal (3.8 L) to conserve water.

Figure 12. *Jacquinia arborea* tree with fruit. (Photo by Michael Morgan)

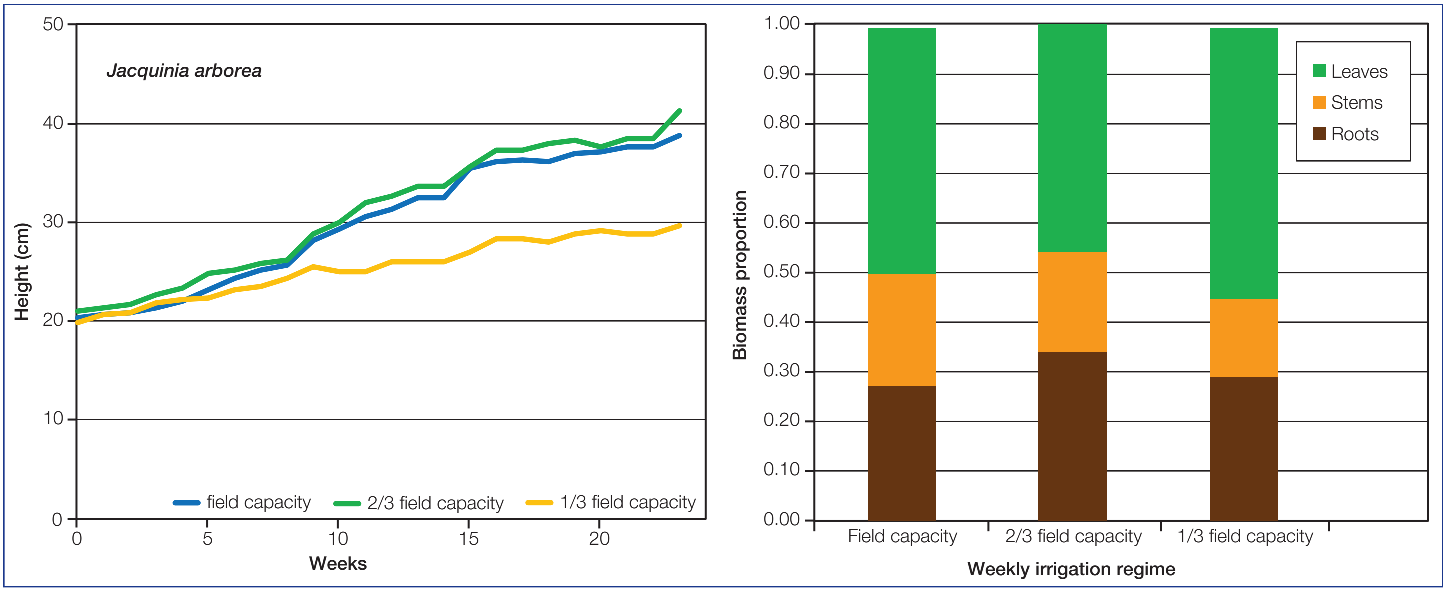

Figure 13. Height growth (left) and biomass proportioning (right) of *Jacquinia arborea* trees subjected to three irrigation regimes.

No difference existed among treatments for total biomass but differences in biomass allocation did exist (figure 13B). For all three treatments, most of the biomass was allocated to tough, leathery leaves instead of roots; in particular, the trees subjected to drought in the 33 FC treatment allocated an average of 55 percent of their biomass to leaves. Leathery leaves are a water conservation strategy.

Pimenta racemosa

The English common name for *Pimenta racemosa* is bay-rum tree, and the Spanish name is malagueta. It was extensively grown on the island of St. John in the late 19th and early 20th century for its aromatic leaf oil used in perfumes and cosmetics (Kirk 2009). It is a small- to medium-sized tree that averages 40 ft (12 m) tall and 8 in (20 cm) or more in dbh (figure 14). It has a dark green, columnar crown and peeling bark (Little and Wadsworth 1964). The berries are an important soft mast source for wildlife (Jones 1995) (figure 15). Trees of bay-rum grow throughout the Caribbean basin and have been introduced to south Florida as an ornamental (Kirk 2009, Little and Wadsworth 1964).

Figure 14. Mature *Pimenta racemosa* tree. (Photo by Michael Morgan)

Figure 15. Fruit of *Pimenta racemosa*. (Photo by Michael Morgan)

No statistical difference existed among treatments for height, stem diameter, and biomass although trees grown under the 33 FC tended to have the least growth (table 1, figure 16A). We noticed early in the experiment that the 100 FC treatment appeared excessive; the plants looked sickly and grew slower. By the end of the experiment, however, this condition was no longer evident. *P. racemosa* is moderately drought tolerant (Jones 1995) so the negative response observed in plants watered to field capacity was surprising. We did not observe this negative response for any other tree species in this study, not even for trees that normally grow on arid sites such as *Plumeria alba* and *Jacquinia arborea.*

We also observed another unusual phenomenon with *P. racemosa*—the main stem would often fall over, and the lateral branches would then grow into new terminal leaders. This phenomenon happened regardless of watering regime and resulted in a bushy plant. Little and Wadsworth (1964) make reference to a sometimes shrubby form of the tree. The reason for the main stem falling over is unknown, but this might explain why total biomass tended to be greater in the 100 FC treatment, yet tree heights were marginally taller in the 66 FC treatment. Two of the six trees in the 100 FC treatment became bushy, whereas only one tree in each of the 33 FC and the 66 FC treatments became bushy.

Pimenta racemosa trees in all three watering regimes had similar proportions of biomass allocated to leaves and roots, (figure 16B) but the trees in the 100 FC treatment had a significantly greater proportion of biomass allocated to stem, probably because two of them were so branchy. Our recommendation for this species is to water with 0.53 gal (2 L) once a week, rather than 1.0 gal (3.8 L), at least for the first 10 weeks. After the trees reach 18 to 20 in (45 to 50 cm) tall, they are big enough to use more water if one wants to, or needs to, speed up tree growth to meet a sales contract. Elsewise, watering levels can continue at the 0.53 gal (2 L) rate until growth slows or signs of water stress appear. It is important to remember that bigger trees need more water.

Plumeria alba

The English common name for *Plumeria alba* is white or wild frangipani. This species is an unusual looking small tree; its stout, sparse limbs terminate in a cluster of leaves (figure 17) and, during some parts of the year, bear very fragrant white flowers (Kirk 2009) (figure 18). *P. alba* grows up to 35 ft (11 m) tall. *P. alba* is the wild growing member of a genus best known for the ornamental species frangipani (*P. rubra)* and bridal bouquet (*P. pudica)*; both of which are now pan tropical in distribution. Their wild cousin, *P. alba,* grows on rocky outcrops and coastal thickets in Puerto Rico and the Virgin Islands. The species is tolerant of both salt and drought. Although *P. alba* is not a cultivar, it still has ornamental potential. In fact, it has been introduced to south Florida for that purpose (Little and Wadsworth 1964, Jones 1995, Kirk 2009). Jones (1995) recommends the use of *P. alba* as an ornamental in small confined gardens for its size and its tolerance of both salt and drought. In fact, this tree is mainly reproduced using cuttings, but we were very lucky to get seeds from Buck Island National Monument off the coast of St. Croix. It produces seed very infrequently, only every few years (Daley, personal communication 2013, Lundgren, personal communication 2013, Morgan, personal observation 2013).

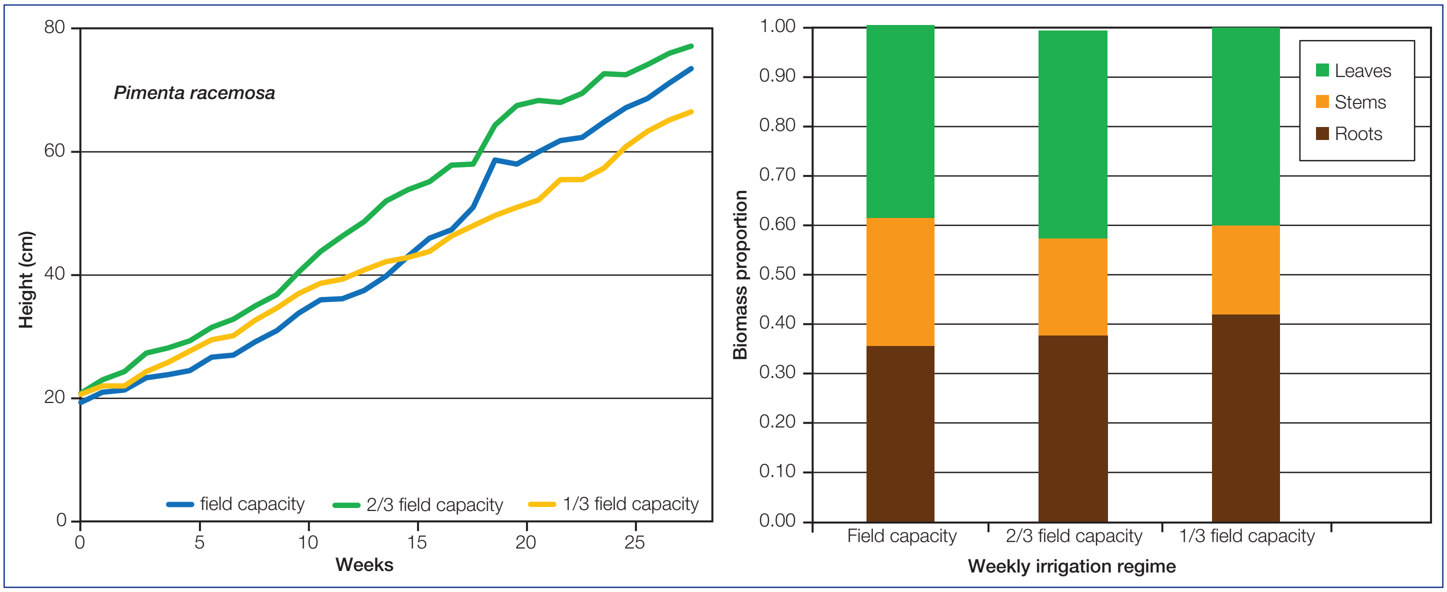

Figure 16. Height growth (left) and biomass proportioning (right) of *Pimenta racemosa* trees subjected to three irrigation regimes.

Figure 17. One of the *Plumeria alba* trees in the study showing its distinctive growth form. (Photo by Michael Morgan)

Figure 18. *Plumeria alba* flowers. (Photo by Michael Morgan)

In our study, *P. alba* was the most drought tolerant species. Average height growth was 0.3 in (0.7 cm) per week for the trees in the 66 FC treatment, and 0.2 in (0.5 cm) per week for those in the other two treatments, although no statistical difference existed between treatments (table 1, figure 19). Diameter growth was not significantly different among treatments, although trees subjected to the 100 FC treatment had diameter growth from 0.4 to 0.6 in (11 to 15 mm), whereas the trees subjected to the 66 FC and 33 FC treatments had diameter growth of only 0.08 and 0.04 in (2 and 1 mm), respectively ($p = 0.07$). We recommend watering once per week with 0.53 gal (2 L) of water, but 0.26 gal (1 L) of water per week is acceptable.

P. alba was not subjected to biomass harvest because of the rarity of the species. Observations indicate that more biomass is allocated to stem compared with leaves, however. We estimated approximately 90 percent of the aboveground portion of the tree is stem, with only a few leaves at the top of the stem.

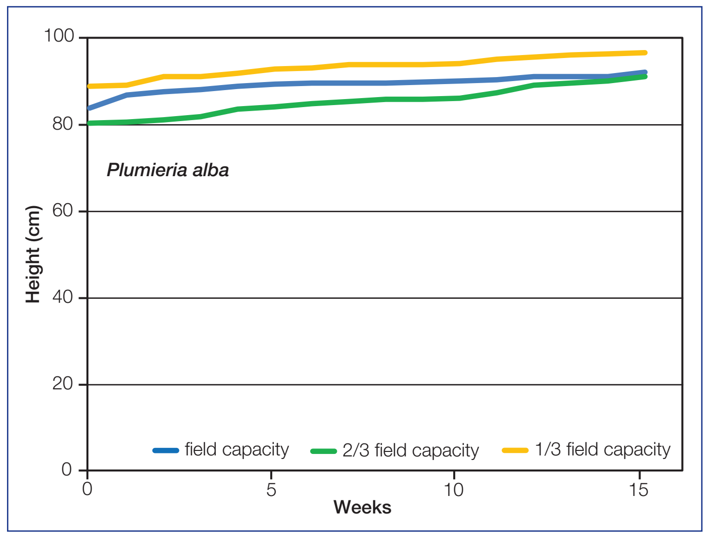

Figure 19. Height growth of *Plumeria alba* trees subjected to three irrigation regimes. Because this species is rare, no trees were harvested for measurement of biomass allocation.

Conclusions

Nursery managers ideally want to produce trees ready for landscape planting in the least amount of time possible with the least amount of water. We discovered that *A. inermis* and *B. bucera* grew best when watered to 100 percent field capacity weekly, *J. arborea* and *P. racemosa* grew best when watered to 66 percent field capacity weekly, and *P. alba* had similar growth rates regardless of irrigation regime. These relative differences are also reflected in total biomass (figure 20). Growth and biomass allocation among

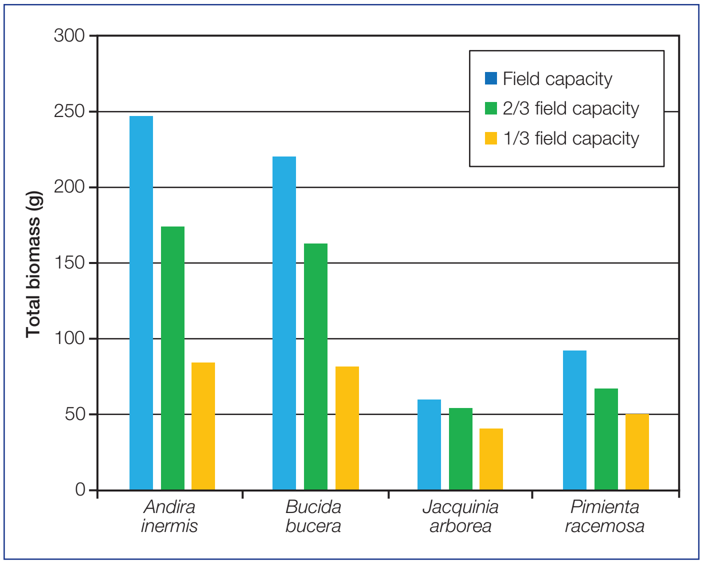

Figure 20. Total biomass of four species subjected to three irrigation regimes. Because *Plumeria alba* trees are rare, they were not measured for biomass.

treatments suggests that differences among species (although not compared statistically) can be attributed to their relative drought tolerance and natural habitats. It would be worthwhile to continue evaluation of native tree species for landscaping uses by conducting this study with other tree species as well as with the same species grown in larger pots.

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