Godfrey's goldenaster. Photo by Natalie Hooton

Performance of nine Florida native wildflower species grown in varying container substrates

Adrienne M Smith, Sandra B Wilson, Mack Thetford, Keona L Nolan, and Carrie Reinhardt Adams

ABSTRACT

Rising costs of container substrates and increased interest in use of native wildflowers for landscapes necessitates the continued evaluation of production methods. The composition of a container substrate can directly affect not only propagation success but also future growth, development, and establishment. Thus, a number of container substrates have been formulated and marketed for improved drainage, root distribution, and plant growth. We evaluated performance of 9 wildflower species native to Florida in 4 commercially available substrates. Within each substrate treatment, plants were evaluated in the greenhouse for 20 wk prior to an additional 40-wk landscape evaluation. Survival, performance, and flower duration varied by treatment and species.

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KEY WORDS
trial gardens, *Balduina angustifolia*, *Callisia ornata*, *Chrysoma pauciflosculosa*, *Chrysopsis godfreyi*, *Dalea feayi*, *Licania michauxii*, *Polygonella macrophylla*, *Polygonella polygama*, *Polygonella robusta*

NOMENCLATURE
USDA NRCS (2013a)

An increasing number of Florida consumers are adopting landscaping principles that include an array of native plants that are low maintenance, ornamentally attractive, and environmentally functional (Wilson and others 2006; Kabat and others 2007). The use of wildflowers has gained popularity for residential, commercial, restoration, and roadside beautification purposes (Sabre and others 1997; Kemery and Dana 2001; Kabat and others 2007; Norcini and others 2009). The availability of wildflowers is, however, largely dependent on available seed sources, ecotype knowledge, propagation success, and large-scale seed handling methods (Norcini and others 2006; Hammond and others 2007; Thetford and others 2012). Likewise, Younis and others (2010) mentioned that the use of wildflowers in urban landscapes is increasing worldwide, yet unavailability and the need for species-specific propagation and maintenance information often limit commercial production.

A number of Florida native wildflowers have ornamental potential but production and propagation protocols have yet to be established for those species (Milstein 2005; Kabat and others 2007). In Florida, a recent emphasis on identifying wildflowers in their natural habitats could have significant landscape potential (Pérez and others 2009; Heather and others 2010; Thetford and others 2012), but little information is available on the methodology to successfully grow and cultivate wildflowers for homeowner use.

As part of a multiyear, multisite project, we developed propagation methodology for 9 native wildflower species (Thetford and others 2008). A subsequent experiment, described in this article, was designed to quantify plant growth in varying substrate compositions and to evaluate subsequent landscape performance. Previous research has shown that substrate composition can affect plant quality when grown in container substrates with properties different from that of the natural soils to which the plants are accustomed (Hammond and others 2004; Wilson and Stoffella 2006; Wilson and others 2006; Landis and Morgan 2009; Price and others 2009; Murphy and others 2011). Therefore, our study objectives were to 1) characterize the physical and chemical properties of various container substrates; 2) determine the effects of substrate composition on container plant growth and quality; and 3) evaluate subsequent plant establishment and landscape performance.

MATERIALS AND METHODS

Substrate Treatments

Four commercially available soilless substrates were selected for this study (Table 1). Atlas 7000, with a 30% sand component, was specifically chosen because the selected wildflowers are native to sandy scrub and sandhill habitats (Wunderlin and Hansen 2008) and are characterized by acidic, well-drained, infertile soils with low organic matter and low moisture retention (AFNN 1991). Coarse sand with its large macropores has a very low water-holding capacity (Beardsell and others 1979). Costing 1.3 to 2.1 times more than the other substrates, Metro-Mix 300 had the lowest proportion of peat (15%) and the greatest proportion of vermiculite (35%) (Table 1). We used Fafard 3B because of its commonality, availability, mid-price, and usefulness in growing a range of species. It has slightly lower bulk and particle densities compared with the other 3 treatments (Table 1).

Cation exchange capacity, electrical conductivity, and pH were determined for 3 samples of each substrate (A & L Southern Agricultural Laboratories, Pompano Beach, Florida) (Table

TABLE 1

Cost (US dollars) and components (% v:v) of 4 commercial substrates used to evaluate performance of 9 native wildflowers in the greenhouse and landscape.

		Substrate components (%)						
Substrate	Cost/bag[v]	Peat	Pine bark	Vermi-culite	Perlite	Coarse sand	Cypress dust	Bark ash
Atlas 3000[z]	$6.75	40	50			10		
Atlas 7000[y]	$5.15	40			10	30	20	
Fafard 3B[x]	$8.12	45	25	10	20			
Metro-Mix 300[w]	$10.86	15	35	35	10			5

[z] Atlas 3000 (Atlas Peat and Soil, Boynton Beach, FL) consisted of 4:5:1 peat:pine bark:sand.

[y] Atlas 7000 (Atlas Peat and Soil, Boynton Beach, FL) consisted of 4:3:2 peat:sand:cypress dust.

[x] Fafard 3B (Conrad Fafard, Agawam, MA) consisted of 4.5:2.5:1:2 peat:pine bark:vermiculite:perlite.

[w] Metro-Mix 300 (Sun Gro Horticulture, Orlando, FL) consisted of 1.5:3.5:3.5:1:0.5 peat:pine bark:vermiculite:perlite:bark ash.

[v] 2.8 cubic ft bag, price excludes shipping.

TABLE 2

Initial chemical and physical properties of each substrate treatment prior to transplanting.

Substrate	pH	Electrical conductivity (meq/l)	Cation exchange capacity (meq/l)	Moisture content	Air-filled porosity	Total porosity	Container capacity	Bulk density (g/cm^3)	Particle density (g/cm^3)
				(% by volume)					
Atlas 3000	6.90 a	0.79 a	14.53 a	69.06 c	7.53 a	68.73 a	61.20 a	0.23 b	0.74 b
Atlas 7000	6.23 b	0.09 c	2.90 d	47.95 d	4.43 bc	59.90 c	55.47 b	0.56 a	1.39 a
Fafard 3B	5.80 c	0.49 b	10.10 b	76.18 a	4.95 b	60.56 bc	55.61 b	0.13 d	0.33 d
Metro-Mix 300	6.17 b	0.52 b	7.33 c	72.27 b	3.31 c	63.58 b	60.27 a	0.19 c	0.52 c

Notes: Means within each column followed by the same letter are not significantly different at $P = 0.05$ level. Conversion: $g/cm^3 \times 27.7 = lb/in^3$.

2). Moisture content, air-filled porosity, total porosity, container capacity, bulk density, and particle density were determined on 5 samples of each substrate (Table 2). The air-filled porosity was determined with a random 500 ml (17 oz) sample of medium using the Wolverhampton submersion method that measures the volume of drained water in relation to the volume of the substrate (Bragg and Chambers 1988). The samples were then oven-dried for 1 wk at 70 °C (158 °F) to determine moisture content, total porosity, container capacity, bulk density, and particle density (see Niedziela and Nelson 1992 for equations).

Greenhouse Evaluation

The wildflower species (Figure 1) were chosen based on the following criteria: 1) plants are ornamentally attractive in their natural areas and have landscape potential for homeowner use; 2) sufficient wild-collected seeds are available for propagation; and 3) plants have limited or nonexistent presence in the current ornamental market.

Seeds were collected from natural areas in 2008 to 2010 under a state collection permit, cleaned, stored in a refrigerator at 4 °C (39 °F) until needed, and germinated following the protocols established for these species by Thetford and others (2008). On 25 August 2010, for all species except gopher apple, multiple seeds were planted in 7.6 cm (3 in) LS 606 Super Jumbo 6-pack cells (Landmark Plastic Corporation, Akron, Ohio) filled with Fafard Super Fine Germination Mix comprising peat moss, perlite, and vermiculite (Conrad Fafard, Agawam, Massachusetts). Because of its larger growth habit, gopher apple was single-seeded in 8.9 cm (3.5 in) X-30STPP seedling trays (Landmark Plastic Corporation, Akron, Ohio).

On 30 September 2010, upon sufficient seedling growth and root development (that is, roots had the ability to make a cohesive root plug), plugs were transplanted to 4.4-l (1.2-gal) cylindrical pots filled with 1 of 4 substrate treatments. Five plugs for each species were transplanted for each substrate treatment. Immediately after transplanting, plants were top-dressed with a standard rate of 15 g/pot (0.53 oz) of $15N:3.9P_2O_5:10K_2O$ Osmocote Plus (The Scotts Miracle-Gro Company, Marysville, Ohio). On 17 December 2010, plants were treated with a 1% granular systemic insecticide (Marathon, Olympic Horticultural Products, Mainland, Pennsylvania) at a standard rate of 0.37 g/l (0.05 oz/gal) and a broad-spectrum fungicide drench (Banrot, The Scotts Miracle-Gro Company) at a manufacturer recommended rate of 0.49 g/l (0.06 oz/gal). Plants were inspected daily for sufficient soil moisture, and when soil was dry, plants were hand-watered as needed. Average minimum and maximum temperatures in the greenhouse during the 20-wk growing duration were 13.7 and 26.5 °C (56.7 and 79.6 °F), respectively, with a light intensity at bench level of 530.2 $\mu mol/(m^2 \bullet s)$. Plant height (from the soil surface to natural height of the primary stem) and perpendicular widths were measured every 4 wk for 20 wk.

Landscape Evaluation

On 9 March 2011, field rows located at the University of Florida Indian River Research and Education Center (Fort Pierce, Florida) were treated with halosulfuron-methyl (Sandia, 75.0% ai, Gowan, Yuma, Arizona) at a rate of 0.1056 g/l water and a 2% solution of glyphosate (Roundup WeatherMAX, 48.8% ai, Monsanto, St Louis, Missouri), slightly disked, and raised to 20 cm (8 in) using a vegetable bed press prior to covering with a semipermeable landscape fabric (Lumite, Gainesville, Georgia). Daily rainfall, temperature, and solar radiation were recorded by a Florida Automated Weather Network monitoring station located 32 km (20 mi) from the site (FAWN 2012). Soil characteristics were Ankona sand (USDA NRCS 2013b) with 2.8% organic matter, pH 5.9, and EC 0.08 mmhos/cm (A & L Southern Agricultural Laboratories, Pompano Beach, Florida).

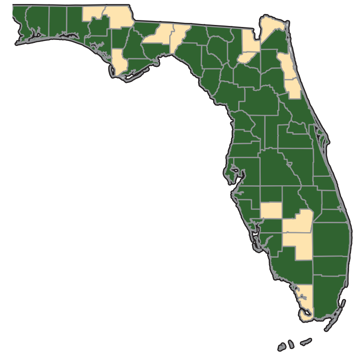
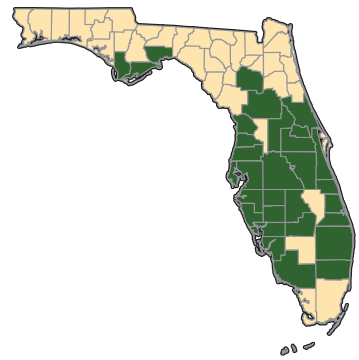
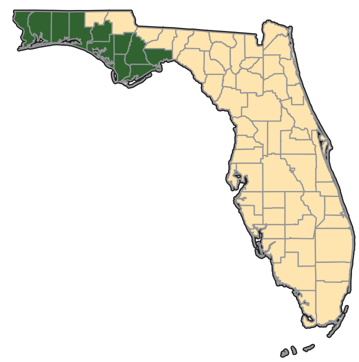
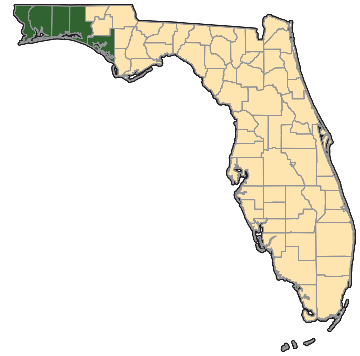
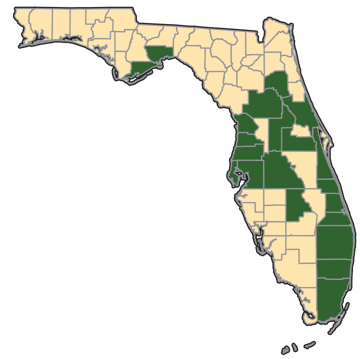
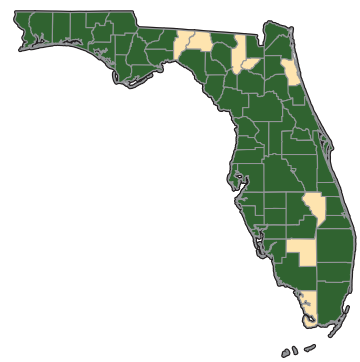
Plant name	Plant form	Flower	Distribution
Coastal plain honeycombhead (*Balduina angustifolia* (Pursh) B.L. Rob. [Asteraceae])			
Florida scrub roseling (*Callisia ornata* (Small) G. Tucker [Commelinaceae])			
Woody goldenrod (*Chrysoma pauciflosculosa* (Michx.) Greene [Asteraceae])			

Figure 1. Plant form (in natural areas), flowers, and geographic distribution (green indicates vouchered specimen) in Florida (Wunderlin and Hansen 2008).

On 15 March 2011, plants were removed after 20 wk in the greenhouse and outplanted into field rows with 0.91 m (3 ft) on center spacing. Plants were top-dressed at planting with 15 g (0.53 oz) of 15N:3.9P_2O_5:10K_2O Osmocote Plus (The Scotts Miracle-Gro Company). Plants were drip irrigated 3 times/wk for 45 min (2.83 l/plant [2.5 gal/plant]) until established and then once per wk for the remainder of the 40-wk field trial.

At planting and every 4 wk thereafter (for 40 wk), visual quality and flowering were assessed by 3 observers. Visual quality was based on a scale of 1 to 5, where 1 = very poor quality, not acceptable, severe leaf necrosis or yellowing, nearly dead; 2 = poor quality, not desirable, sparse/uneven form, leaf yellowing, unhealthy appearance; 3 = acceptable quality, somewhat desirable form and color, moderately healthy; 4 = good quality, very acceptable, nice color and good form, healthy and vigorous; and 5 = excellent, perfect condition, premium color and form, extremely healthy and vigorous, very attractive. Flowering was based on a scale of 1 to 5, where 1 = no flowers or flower buds; 2 = flower buds visible, no open flowers; 3 = one to several open flowers; 4 = many open flowers, average to

Plant name	Plant form	Flower	Distribution
Godfrey's goldenaster (*Chrysopsis godfreyi* Semple [Asteraceae])			
Feay's prairie clover (*Dalea feayi* (Chapm.) Barneby [Fabaceae])			
Gopher apple (*Licania michauxii* Prance [Chrysobalanaceae])			

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good flowering; and 5 = abundant flowering, possible peak bloom. Overall plant survival was evaluated following 40 wk (January 2012).

Statistical Analysis

A randomized complete block design was used for the greenhouse evaluation with each species replicated once in 5 blocks, with 4 substrate treatments as independent variables and soil characteristics and plant height as dependent variables. Plant height was reported by month with a mean separation after 20 wk. Data were subjected to an analysis of variance (ANOVA) using Statistical Analysis Software (SAS 9.2 for Windows, Cary, North Carolina) with significant means separated by Duncan's multiple range test, $P \leq 0.05$.

A randomized complete block design was used for the field evaluation with each species replicated twice in 3 blocks (rows were situated west to east), with 4 substrate treatments as independent variables and visual and flowering qualities as dependent variables. Data were subjected to an analysis of variance (ANOVA) using Statistical Analysis Software (SAS 9.2 for

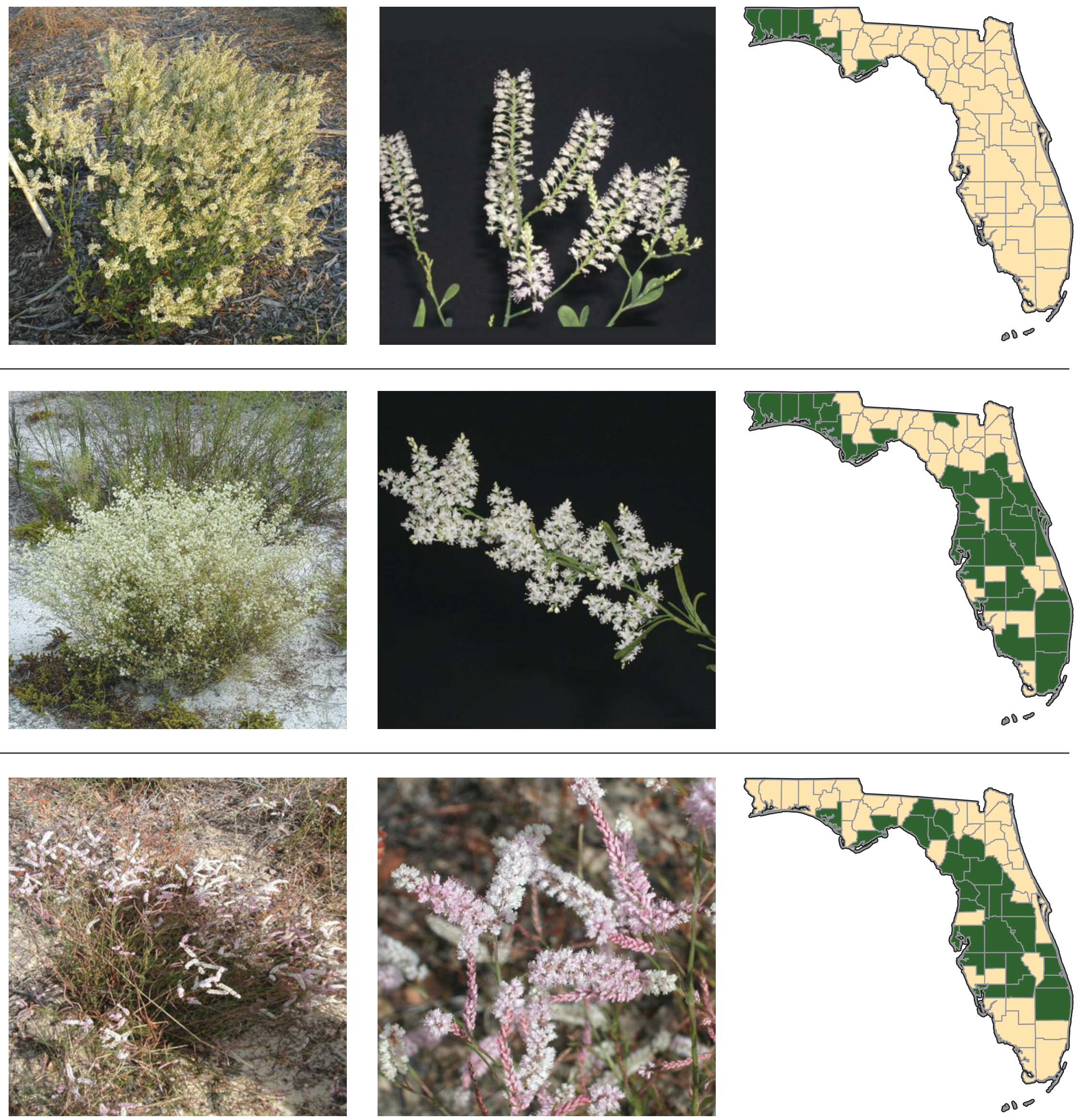

Figure 1. (continued)

Windows) with significant means separated by Duncan's multiple range test, $P \leq 0.05$. Visual quality and flowering are reported by month with standard error of means and additional mean separation for wk 32.

RESULTS AND DISCUSSION

Greenhouse Evaluation

Atlas 3000 had a higher pH, electrical conductivity, cation exchange capacity, and air-filled porosity compared with other substrate treatments (Table 2) while Atlas 7000 had the lowest electrical conductivity, cation exchange capacity, moisture content, and total porosity with greater bulk density and particle density. Metro-Mix 300 and Fafard 3B substrates had similar proportions of coarse (pine bark, perlite, sand) and fine (peat, vermiculite, cypress dust, bark ash) components; Metro-Mix 300 had the lowest percentage of peat among the substrates tested. Atlas 3000 had the greatest total porosity while Atlas 7000 had the least porosity and may be reflective of the greater proportion of coarse components in the Atlas 3000 compared to the least proportion of coarse components in the Atlas 7000. Total porosity for the dominant coarse substrate components such as peat, pine bark, and sand is inversely correlated to bulk density (Beardsell and others 1979), and a decrease in porosity

TABLE 3

Plant height and width of 9 wildflower species grown in 4 commercial substrates after 20 wk.

Substrate	Coastal plain honeycombhead	Florida scrub roseling	Woody goldenrod	Godfrey's goldenaster	Feay's prairie clover	Gopher apple	Largeleaf jointweed	October flower	Largeflower jointweed
Plant height (cm)									
Atlas 3000	31.6 a	41.4 a	23.8 a	14.8 b	20.0 a	13.3 a	21.0 a	48.0 a	30.4 a
Atlas 7000	33.8 a	43.0 a	27.8 a	14.4 b	22.4 a	12.3 a	26.4 a	46.2 a	26.6 a
Fafard 3B	26.2 ab	39.2 ab	27.6 a	15.6 b	22.4 a	14.5 a	22.8 a	51.0 a	26.6 a
Metro-Mix 300	22.6 b	34.4 b	28.2 a	17.8 a	20.7 a	14.5 a	18.5 a	47.6 a	27.2 a
Plant width (cm)									
Atlas 3000	31.2 a	41.8 a	27.2 a	27.2 a	21.6 a	10.1 ab	6.9 a	17.5 a	19.2 a
Atlas 7000	40.5 a	46.1 a	29.9 a	25.8 a	23.0 a	9.7 ab	9.0 a	18.1 a	24.9 a
Fafard 3B	40.2 a	31.7 a	29.6 a	30.8 a	26.5 a	12.1 a	7.2 a	17.6 a	22.9 a
Metro-Mix 300	30.5 a	38.1 a	30.1 a	30.5 a	23.2 a	7.0 b	7.7 a	20.1 a	26.2 a

Notes: Means within each column followed by the same letter were not significantly different at $P = 0.05$ level. Conversion: cm x 2.54 = in.

is expected with the addition of coarse or fine sand to peat substrates (Prasad 1979). The relationship between bulk density and total porosity is typical for that reported for container substrates (Poole and others 1981; Wilson and others 2006; Hammond and others 2007). Atlas 3000 and Metro-Mix 300 were dominated by pine bark while Fafard 3B and Atlas 7000 were dominated by peat, in relation to other components within each substrate. Pine bark–dominated substrates had similar water-holding capacity, which was greater than for peat-dominated substrates, which were similar to each other. Interestingly, Atlas 3000, which is composed of only 3 components, had a greater proportion of air capacity compared with the other substrates. Metro-Mix 300 and Atlas 3000 were more similar in water-holding capacity although they exhibited the least and the greatest air capacity. For all 4 substrates, total porosity was 60% or greater, which is reflective of a substrate with high organic matter content and expected to support good root growth (Roberts 2006).

Substrate treatments did not influence plant growth for most of the species tested during the container production portion of the study (Table 3), despite the significant differences in physical properties of the substrates. Exceptions noted were minor, but significant differences in plant height were observed for coastal plain honeycombhead, Florida scrub roseling, and Godfrey's goldenaster, and differences in plant width were observed for gopher apple. Height reductions were evident with Metro-Mix 300 for coastal plain honeycombhead, and Florida roseling was comparable to both Atlas substrates (Table 3). Heights of plants grown in Metro-Mix 300 did not differ from heights of plants grown in Fafard 3B, and both of these substrates had high moisture content values (Table 2). Of the 4 substrates, Metro-Mix 300 had the lowest air-filled porosity. The high moisture content and low air-filled porosity may have contributed to the reduced shoot growth for these 2 scrub species. In contrast, Godfrey's goldenaster exhibited an increase in plant height for plants grown in Metro-Mix 300. This response is not surprising considering the frequency of natural occurrence of Godfrey's goldenaster on the edges of intermittently inundated interdunal swales along the Florida panhandle coast (M Thetford, personal observation). Gopher apple is a low woody perennial with subterranean stems and a prostrate growth habit (Ward and Taylor 1999) so differences in plant width rather than height may be more reflective of the species response to differences in production substrates. Gopher apple was the only species to experience differences in width, and these were among Farfard 3B and Metro-Mix 300 treatments. The high moisture content and low air-filled porosity of Metro-Mix 300 may have contributed to the reduced shoot width of gopher apple, which occurs frequently in the deep, infertile sands of coastal scrub (Ward and Taylor 1999).

Atlas 3000 has been recognized as a suitable substrate alternative for the production of Florida plant species native to hammock, wetland, and flatwoods communities (Wilson and others 2004; Wilson and Stoffella 2006). Wilson and others (2004, 2006) reported differences in plant height, flower number, shoot dry weights, and root dry weights for various Florida native species in response to differences in substrates amended with compost as a replacement for peat. Wilson and others

(2004, 2006) noted that growth responses to the differing substrates varied by plant species thereby recognizing the broad diversity of the native species tested. Differences in substrate properties have been shown to affect plant height for red maple (*Acer rubrum* L. [Aceraceae]) (Roberts 2006). Roberts (2006) found that tree seedlings grown in substrates with higher bulk density, particle density, air-filled porosity, and container capacity had greater percentage growth. Our results demonstrate a potential to produce these native plants in peat and pine bark–dominated substrates with or without the addition of sand. Recognizing the broad diversity of species included in this experiment, additional improvements in plant production may be achieved by tailoring the specific substrate to the target crop. Although modification of watering and fertilization based on the growing medium may assist with improving plant growth during nursery production (Heiskanen 2013), outplanting success may require the selection of a substrate with physical properties compatible with the soils in the outplanting sites (Heiskanen 1999).

Landscape Evaluation

Landscape performance varied by species, substrate treatment, and month. Coastal plain honeycombhead was relatively short-lived (4 to 8 wk) for each treatment with the exception of Atlas 7000, which had high visual quality and flowering up to 28 wk (August and September; Figure 2). The short-lived response is not surprising because the species is an annual and the longer-term performance with the Atlas 7000 may be reflective of the greater proportion of inert, nonporous components that more closely mimicked the dry soils of deep sand ridges along rivers and on shallow dunes of the Atlantic and Gulf Coast beaches where this species naturally occurs (Parker and Jones 1975).

Visual quality and flowering of Florida scrub roseling gradually declined in quality and flowering as time increased, with Metro-Mix 300 generally having lower visual quality and flowering than other treatments. This decline in visual quality may have been a carryover from the initial reductions in height noted during the production period. Florida scrub roseling is a perennial species with a low frequency of occurrence (found in less than 10% of gaps at the Archbold Biological Station), found in xeric white sands of interior and peninsular Florida (Menges and others 2008). The overall decline in plant performance may be related to the combination of an increase in rainfall (Figure 3) and the low air-filled porosity of Metro-Mix 300 resulting in conditions too wet for this scrub species.

Woody goldenrod maintained high visual quality and flowering throughout the study, regardless of substrate, with peak flowering at 32 wk (November). Godfrey's goldenaster performed as very good to excellent for the first 20 wk, regardless of substrates; but at wk 32, plants grown in Metro-Mix 300 had significantly better visual quality than Atlas 7000 or Atlas 3000 treatments. Plants grown in Metro-Mix 300 were initially larger at planting but this did not seem to alter flowering performance. Interestingly, Godfrey's goldenaster grown in substrates with no sand had higher visual quality ratings while those grown with sand had lower ratings.

Feay's prairie clover had very good visual quality and 50 to 75% flower cover throughout most of study with the exception of those grown in Atlas 3000, where all plants declined by wk 12 and did not survive. This clover is a perennial species with a low frequency of occurrence, primarily found in xeric white sands of interior and peninsular Florida (Menges and others 2008), and did not exhibit differences in growth during container production. The dramatic decline of plants grown in Atlas 3000 by wk 12 corresponded to the driest period during the landscape trial. This substrate had the highest proportion of pine bark (50%) and the highest air capacity of the 4 substrates, which may have contributed to excessive drying of the rootballs during the initial weeks of landscape establishment. Visual quality of gopher apple gradually improved over time, with the exception of Metro-Mix 300 in which plants did not survive.

The 3 *Polygonella* species (largeleaf jointweed, October flower, largeflower jointweed) had similar visual quality trends upon planting, with the exception that largeleaf jointweed did not survive the Metro-Mix 300 treatment after the greenhouse evaluation, prior to outplanting, and largeflower jointweed in the Atlas 3000 treatment died at wk 36. The 3 *Polygonella* species had similar flowering times, with flower initiation and completion occurring in the fall (wk 28 to 32 for largeleaf jointweed and October flower or wk 28 to 36 for largeflower jointweed). Average daily weather data (Figure 3) showed excessive rainfall (from 27.3–55.9 cm [10.7–22 in]) and a drop in minimum temperature (from 20.3 to 12.3 °C [68.5 to 54.1°F]) between wk 24 and 28 (September to October). This correlated with increased flowering for each species, with the exception of Florida scrub roseling and gopher apple.

CONCLUSIONS

Results of this study encourage a greater use of container-grown wildflowers in Florida landscape settings. Use of container substrates with 30% sand (for example, Atlas 7000) can be beneficial for some species such as coastal plain honeycombhead. Use of container substrates with only 15% peat (Metro-Mix 300) can be beneficial to some species such as Godfrey's goldenaster, but detrimental to others such as Florida scrub roseling, coastal plain honeycombhead, gopher apple, and largeleaf jointweed. This study demonstrates a need for more work with individual species. While growers may successfully manage watering of this diverse group of scrub species during the production period, some subtle differences may remain in plant responses to establishment and growth in the landscape. Substrate factors such as composition, cost, availability, and

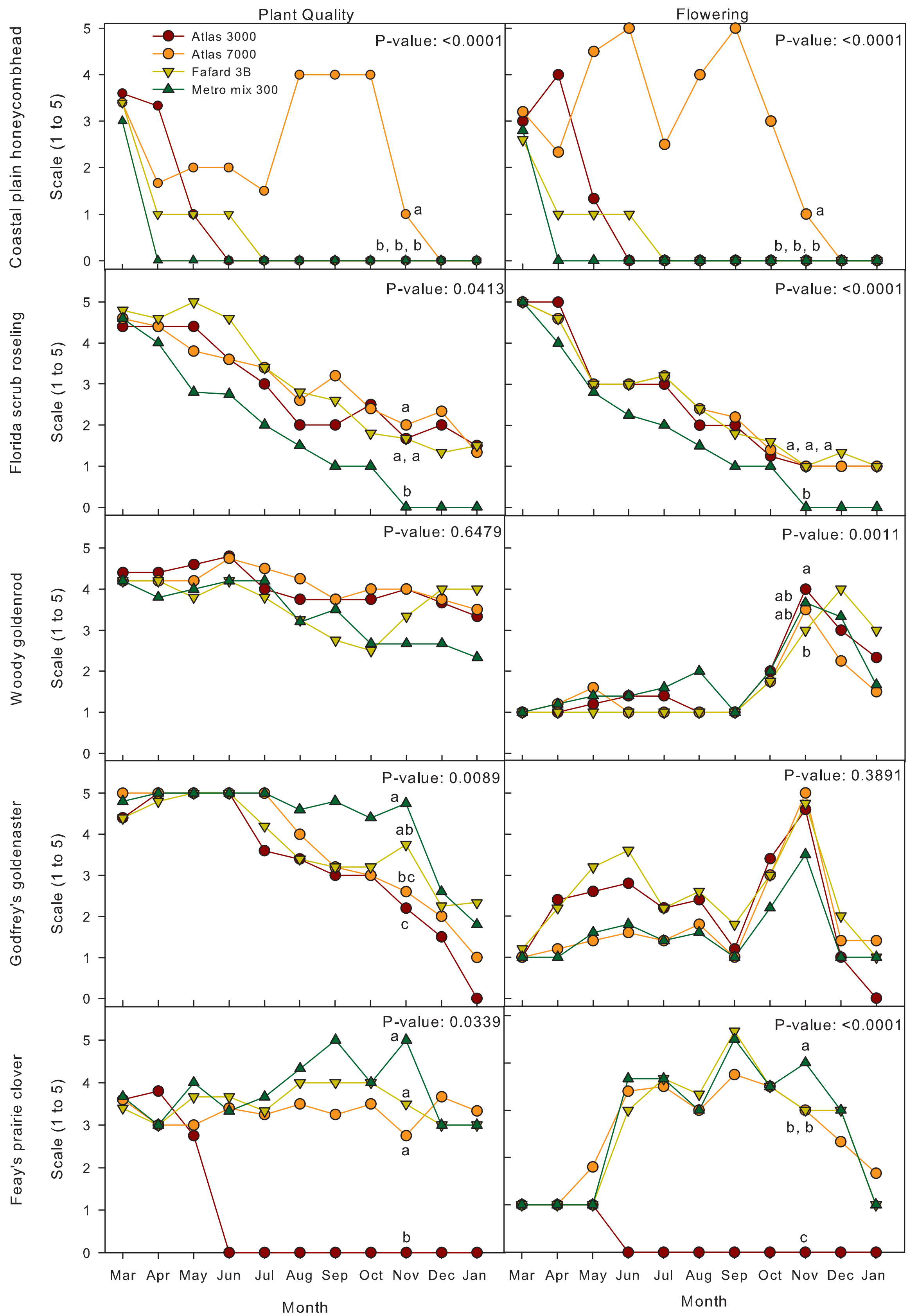

Figure 2. Monthly visual quality (color and form) and flowering of 9 wildflower species grown for 40 wk (March to January) after planting into landscape trials located in South Florida. Visual quality was rated 1 (very poor) to 5 (excellent). Flowering was rated 1 (no flower buds) to 5 (abundant flowers). Analysis of variance was conducted on wk 32 (November), as plants began to die after November. Means at wk 32 followed by the same letter are not significantly different at $P = 0.05$ level.

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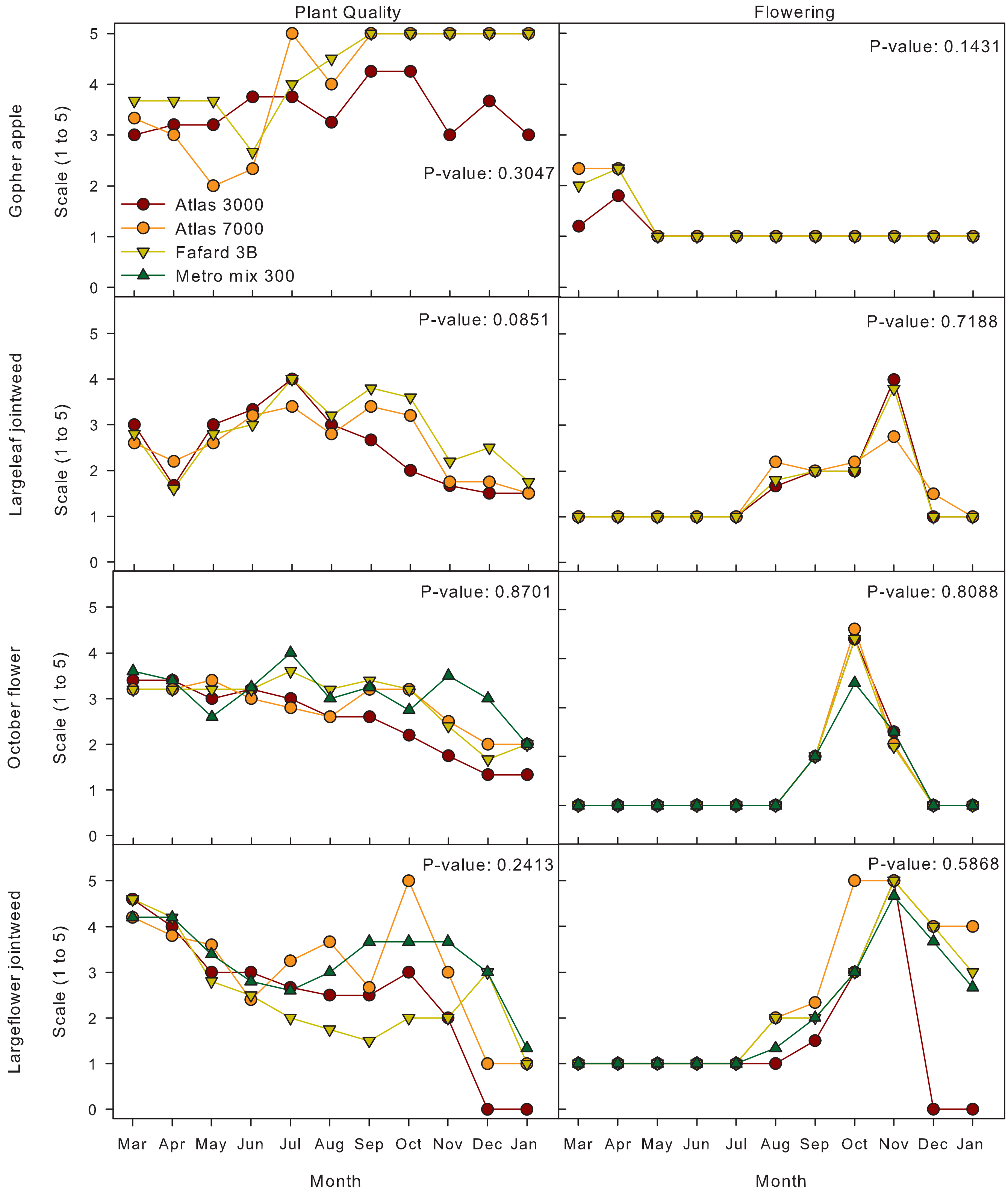

Figure 2. (continued)

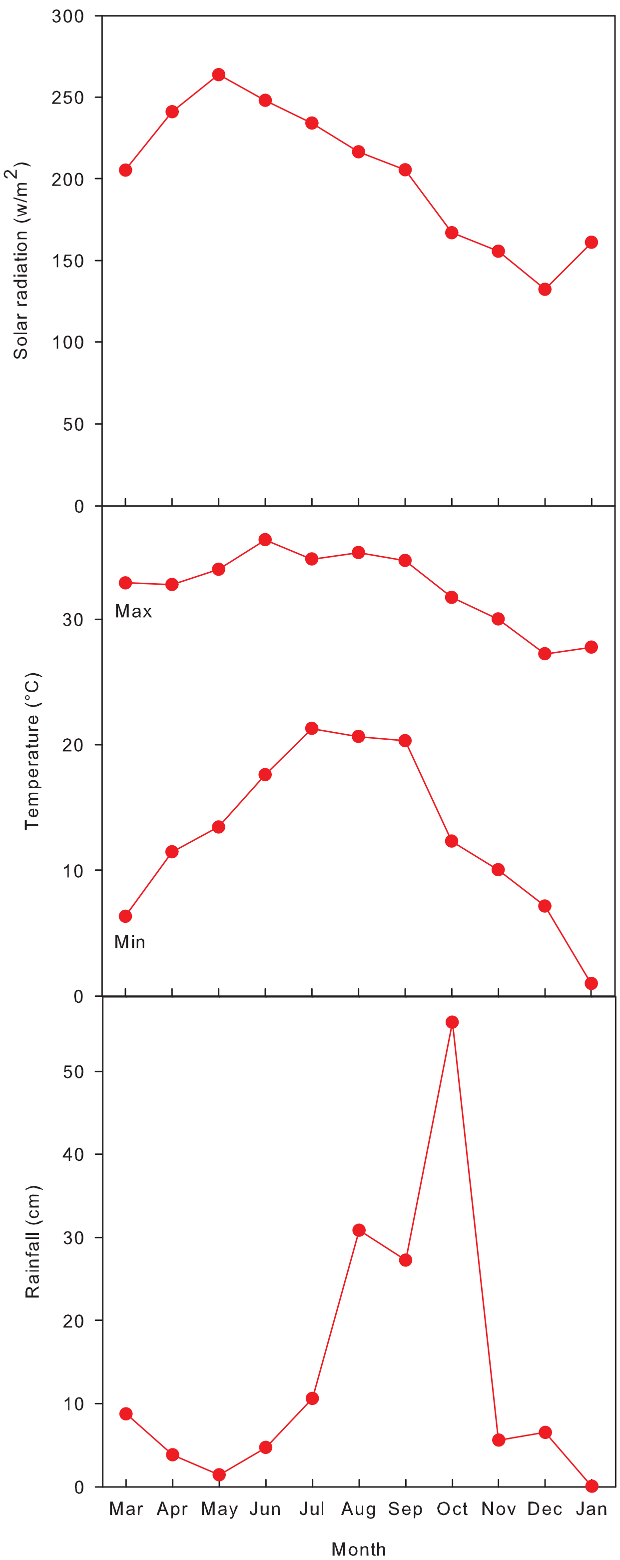

Figure 3. Monthly average total daily solar radiation, average maximum and minimum daily temperatures, and total rainfall (cm x 2.54 = 1 in) at the field site during a 40-wk trial to evaluate development of 9 native wildflower species in South Florida. Average monthly rainfall was 15.6 cm (6.1 in). Mean minimum and maximum temperatures were 14.6 °C (58.2 °F) and 32.1 °C (89.8 °F), respectively.

broad suitability for a range of species should be considered when growing wildflowers. The natural soil composition of species in their native habitat can often serve as an indicator of their substrate preferences when cultivated for container production.

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