Effect of Four Growing Substrates on Growth of Ornamental Plants in Two Irrigation Systems

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ADDITIONAL INDEX WORDS. subirrigation, ebb and flood irrigation, overhead irrigation, areca palm, *Dypsis lutescens*, *Crossandra infundibuliformis*, *Pentas lanceoata*, *Philodendron*

SUMMARY. In this study, areca palm (*Dypsis lutescens*), crossandra (*Crossandra infundibuliformis*), pentas (*Pentas lanceolat*), and philodendron (*Philodendron*) 'Hope' plants were transplanted into containers filled with four growing substrates and watered daily, every 2 days, or every 3 days using subirrigation or overhead irrigation. Plants were grown in either a pine bark/sedge peat/sand substrate (BSS), Metro-mix 500 (MM), Pro-mix GSX (PM), or a 60% biosolid substrate (SYT). For both irrigation systems, final shoot dry weight of pentas, crossandra, philodendron, and areca palm plants in each substrate was greatest for plants watered every day and least for plants watered every 3 days. At all three irrigation frequencies, pentas, crossandra, and philodendron shoot dry weight in subirrigated pots filled with PM was greater than in overhead watered pots filled with PM. PM had the highest total pore space and moisture content of the four substrates examined. There was no difference in pentas, crossandra, or philodendron shoot dry weight between the irrigation systems, at all three irrigation frequencies, when plants were grown in BSS, MM, or SYT. However, for all four substrates and at all three irrigation frequencies, areca palm shoot dry weight was greater in overhead watered pots than in subirrigated pots. The final substrate electrical conductivity (EC) in all four subirrigated palm substrates was more than double the concentrations in overhead watered palm substrates. In this study, largest pentas, crossandra, and philodendron plants were grown in pots filled with PM and subirrigated daily, while largest areca palm plants were grown in pots filled with MM or SYT and watered overhead daily.

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Florida Agricultural Experiment Station journal series no. R-07662. We thank Iraida Rafols, Susan Thor, and Theodora Frohne for their technical assistance and Hatchett Creek Nurseries (Gainesville, Fla.) and Agri-Starts II, Inc. (Apopka, Fla.) for the plant material. This work was supported in part by a grant from the Florida Department of Agriculture and Consumer Services. Mention of any trade names does not imply endorsement of the products named or criticism of similar ones not named. The cost of publishing this paper was defrayed in part by payment of page charges. Under postal regulations, this paper must therefore be marked *advertisement* solely to indicate this fact.

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The use of subirrigation systems that capture and reuse the irrigation solution is one method of reducing fertilizer runoff in nurseries. The benefits of subirrigation systems include dry foliage, more uniform crops, reduced water use, reduced fertilizer use, and reduced runoff (Elliott, 1990; Klock-Moore and Broschat, 1999; Lieth, 1996; Newman, 1999).

However, growing substrates that are suitable for overhead irrigation may not be suitable for subirrigation (Biernbaum, 1993). Subirrigation substrates should be able to quickly take up water by capillary action and tend to be fine textured with abundant micro-pores (Biernbaum, 1993). Coarse textured substrates that do not have enough small pore spaces to allow for capillary water uptake will not wet efficiently in subirrigation systems (Biernbaum, 1993; Evans et al., 1992; Newman, 1999).

Some work has been published on tropical ornamental plant growth in different growing substrates that were subirrigated. For example, Poole and Conover (1992) reported greater plant height of subirrigated croton (*Codiaeum variegatum*) 'Petra', spathiphyllum (*Spathiphyllum*) 'Petite', and dieffenbachia (*Dieffenbachia maculata*) 'Camille' plants grown in Fafard container mix #4 (Fafard Inc. Apopka, Fla.) and Vergo container mix A (Verlite Co. Tampa, Fla.) than in a coarser Canadian sphagnum peat and pine bark substrate. However, few published studies have compared plant growth in different substrates between subirrigation and overhead irrigation systems in the same experiment. Furthermore, no studies have been published on the effect of varying irrigation frequencies when using subirrigation. It has been established that substrates with high water-holding capacities tend to require fewer irrigations and fertilizer applications than substrates with lower water-holding capacities (Argo and Biernbaum, 1995; Biernbaum, 1992). The objective of this experiment was to compare the growth of areca palms, crossandra, pentas, and philodendron 'Hope' plants grown in four different substrates that were watered daily, every 2 d, or every 3 d with subirrigation or overhead irrigation.

Materials and methods

Liners of areca palm, crossandra, pentas, and philodendron were transplanted into 800 mL (27.1 fl oz) [11.4 cm diameter × 11.6 cm tall (4.5 × 4.6 inches)] pots filled with 1) a pine bark/sedge peat/sand substrate (BSS) (50% pine bark: 40% Florida sedge peat: 10% sand, by volume) (Atlas Peat and Soil Inc., Boynton Beach, Fla.); 2) Metro-Mix 500 (MM) (40-50% composted pine bark: 20-35% vermiculite; 12-22% Canadian sphagnum peat, by volume) (The Scotts Company, Marysville, Ohio); 3) Pro-Mix GSX (PM) (greenhouse subirrigation medium; 55% to 65% Canadian sphagnum peat moss: 12% to 25% composted softwood bark: 12% to 25% perlite, by volume) (Premier Horticulture Inc., Red Hill, Pa.); or 4) biosolid substrate (SYT) (60% biosolid and yard trimming compost from the Sold Waste Authority of Palm Beach County, Fla: 25% vermiculite: 15% perlite, by volume). At transplanting, all pots were top-dressed with the manufacturer's recommended label rate of 7 g/pot (14 lb/100 ft^2) of Nutricote 13–13–13 (13N–5.7P–10.8K) plus minors [100-d release at a constant 25 °C (77 °F)] (Florikan Corp., Sarasota, Fla.).

One hundred twenty pots per species were placed onto Ebb-Flow subirrigation benches (MidWest Gro-

Master, St. Charles, Ill.) and 120 pots were placed onto overhead irrigation benches. All pots were watered to saturation with 0.5 fl oz of AquaGro L surfactant (Aquatrols, Cherry Hill, N.J.) per gallon of water (3.9 mL·L^{-1}) and allowed to sit overnight. The following day, 40 pots per species and irrigation type were randomly separated into one of three watering frequencies (daily, every 2 d, or every 3 d) with four benches dedicated to each frequency for a total of 12 subirrigation benches and 12 overhead irrigated benches. The irrigation frequencies were chosen to emulate current industry practices that apply water using automated systems that deliver water at equal time intervals. Within each irrigation frequency and irrigation type, all plants received the same amount of water regardless of the type of growing substrate.

All watering was done prior to 0900 HR. The subirrigated benches were flooded to a depth of 2.5 to 3 cm (1.0 to 1.2 inches) and drained after 10 min. The irrigation water in the subirrigation tanks was not changed throughout the experiment. Water was added to the subirrigation tanks weekly to bring them back to initial volume. The overhead benches had Roberts No. 435 sprinkler head irrigation (Hummert International, Earth City, Mo.) that was set 0.5 m (19.7 inches) above the surface of the bench. The overhead irrigation system ran for 30 min to deliver 1 to 2 cm (0.4 to 0.8 inches) of water or 100 to 200 mL (0.03 to 0.05 gal) per pot to establish a 0.20 leaching fraction. Pots watered overhead received equivalent amounts of water as pots watered using subirrigation. No signs of wilting or water stress were evident in any of the treatments. The irrigation water used throughout the experiment had 0.36

Table 1. Final pentas, crossandra, philodendron, and areca palm shoot dry weight (g) of plants grown in a pine bark/sedge peat/sand substrate (BSS), Metro-mix 500 (MM), Pro-mix GSX (PM), or a 60% biosolid substrate (SYT). Plants were watered every day (1), every 2 d (2), or every 3 d (3) using subirrigation or overhead irrigation (n = 40).

Irrigation	Irrigation	Shoot dry wt (g)[z]			
type	frequency (d)	BSS	MM	PM	SYT
		Pentas (SE = 0.53)			
Subirrigation	1	3.93	5.48	6.69	5.12
	2	2.38	4.65	6.32	4.51
	3	2.18	2.79	4.65	1.93
Overhead	1	4.12	4.71	5.11	5.00
	2	2.47	4.01	4.16	4.41
	3	1.65	2.68	2.60	1.31
		Crossandra (SE = 0.43)			
Subirrigation	1	5.15	8.68	9.44	8.37
	2	4.72	7.09	9.20	6.16
	3	2.73	5.29	7.18	5.23
Overhead	1	5.95	8.62	7.47	8.44
	2	4.45	7.19	6.36	5.57
	3	2.24	4.86	3.91	4.62
		Philodendron (SE = 0.58)			
Subirrigation	1	5.10	9.82	11.18	8.17
	2	3.47	7.80	9.75	5.97
	3	2.69	6.54	7.29	4.26
Overhead	1	6.16	9.47	7.52	8.45
	2	2.67	7.14	6.34	6.11
	3	2.39	5.51	4.77	3.98
		Areca palm (SE = 0.78)			
Subirrigation	1	2.60	4.10	7.32	9.37
	2	1.10	2.77	5.76	6.02
	3	1.02	2.50	3.32	5.76
Overhead	1	5.68	13.02	9.15	11.53
	2	3.83	9.37	7.83	7.74
	3	2.69	4.72	5.12	7.45

Significance	Pentas	Crossandra	Philodendron	Areca palm
Irrigation type	**	**	**	***
Substrate	***	***	***	***
Irrigation × substrate	**	***	***	***
Irrigation frequency	***	***	***	***
Frequency × irrigation	***	***	*	***
Frequency × substrate	***	***	**	***
Frequency × irrigation × substrate***	***	***	***	

[z]28.35 g = 1.0 oz

*,**,***Significant response at $P \leq 0.05$, 0.01, or 0.001, respectively.

$dS\cdot m^{-1}$ electrical conductivity (EC), 94 $mg\cdot L^{-1}$ (ppm) $CaCO_3$ total alkalinity (1.88 $meq\cdot L^{-1}$), 0.6 $mg\cdot L^{-1}$ NO_3-N, 28 $mg\cdot L^{-1}$ Ca, 6 $mg\cdot L^{-1}$ Mg, and 22 $mg\cdot L^{-1}$ Na.

All plants were harvested when the control plants had reached a marketable size determined by industry standards for each crop grown. Pentas were harvested 5 weeks after transplanting while crossandra, philodendron, and areca palm plants were harvested 9, 11, and 28 weeks, respectively, after transplanting. At harvest shoots were cut at the surface of the growing substrate and dried at 60 °C (140 °F) for shoot dry weight determination.

At harvest, the surface 2 to 3 cm (0.8 to 0.12 inches) of the 11.6 cm (4.6 inch) substrate column was removed to ensure that substrate samples were taken from the active root-zone in the remaining substrate column. Three samples of each substrate also were collected at the initiation of the experiment. Nutrients in all of the substrate samples were extracted with distilled water using the saturated media extraction method (SME) (Warncke, 1986). Initial substrate pH and initial and final substrate EC were determined on the extracted solution using a pH/conductivity meter (Accumet model 20; Fisher Scientific, Pittsburgh) at a standard 25 °C (77 °F). Initial percent air-filled porosity (AFP), container capacity (CC), moisture content (MC), and total pore space also were determined on the three initial samples of each substrate in 11.4 cm diameter × 11.6 cm tall (4.5 × 4.6 inches) [800 mL (27.1 fl oz)] pots by volume displacement methods (Niedziela and Nelson, 1992).

This experiment was conducted from October 1998 to May 1999 in an open-sided greenhouse with ambient air temperatures averaging 30/21 °C (86/70 °F) day/night. All data were analyzed by analysis of variance as a split plot with irrigation type as the main plot, substrate type as the subplot, and irrigation frequency as the sub-subplot (SAS Systems, SAS Institute, Cary, N.C.). Mean separations were performed using Duncan's multiple range test.

Results and discussion

For both irrigation systems and in all four substrates examined, final shoot dry weight of pentas, crossandra, philodendron, and areca palm plants was greater in pots watered daily than in pots watered every 3 d (Tables 1). Average pentas, crossandra, philodendron, and areca palm shoot dry weight of plants in subirrigated pots watered daily were 2.0, 1.6, 1.7, and 2.0 times greater, respectively, than in pots watered every 3 d. However, average pentas, crossandra, philodendron, and areca palm shoot dry weight of plants in overhead watered pots watered daily were 2.5, 2.1, 2.0 and 2.1 times greater, respectively, than in pots watered every 3 d. Conover et al. (1994) also observed that dieffenbachia plant fresh weight and quality rating increased as overhead irrigation frequency increased from one time a week to three times a week.

At all three irrigation frequencies, pentas, crossandra, and philodendron shoot dry weight was greater in subirrigated pots filled with PM than in overhead watered pots filled with PM (Table 1). The initial substrate CC, MC and total pore space of PM also was greater than in the other three substrates (Table 2). In general, subirrigation systems tend to be more effective with substrates that have a high capacity for capillary water uptake (Barrett, 1991; Biernbaum, 1993). Factors that influence capillary water uptake include substrate pore size distribution and substrate moisture content (Biernbaum, 1993).

There was no difference in pentas, crossandra, or philodendron growth between the irrigation systems at all three irrigation frequencies when plants were grown in BSS, MM, or SYT (Table 1). There also was no difference in initial total pore space between these substrates (Table 2).

Pentas, crossandra, and philodendron plants are all categorized as requiring moderately fertile substrates with high CC (Black and Gilman, 1997; Griffith, 1998). Although initial and final substrate EC concentrations were higher in SYT than in the other three substrates (Table 2 and 3), concentrations were within the optimum range for greenhouse substrates (Warncke and Krauskopf, 1983). The initial and final substrate EC concentrations in the other substrates were between the low and acceptable EC concentration ranges of 0 to 0.75 $dS\cdot m^{-1}$ to 0.75 to 2.0 $dS\cdot m^{-1}$, respectively (Warncke and Krauskopf, 1983). Average pentas, crossandra, and philodendron growth, regardless of irrigation type or frequency, was greater in MM and PM than in BSS or SYT (Table 1). This was probably due to a combination of both the physical and chemical properties of these substrates.

Average areca palm growth also was greater in pots filled with MM, PM, or SYT than in pots filled with BSS (Table 1). At all three irrigation frequencies, areca palm shoot dry weight of plants grown in BSS, MM, PM, and SYT was greater in overhead watered pots than in subirrigated pots containing the same substrate (Table 1). Final EC concentrations in

Table 2. Initial substrate pH, electrical conductivity (EC), air-filled porosity (AFP), container capacity (CC), moisture content (MC), and total pore space of the pine bark/sedge peat/sand substrate (BSS), Metro-mix 500 (MM), Pro-mix GSX (PM), or a 60% biosolid substrate (SYT) (n = 3).

Substrate	pH	EC ($dS\cdot m^{-1}$)	AFP (%)	MC (%)	CC (%)	Total pore space (%)
BSS	5.8 b[z]	0.79 b	22 a	30 c	39 c	52 b
MM	5.1 b	0.70 b	19 b	34 b	47 b	52 b
PM	5.6 b	0.71 b	23 a	45 a	69 a	67 a
SYT	7.1 a	2.75 a	15 c	38 b	42 b	53 b
Suggested standards[y]	5.8–6.2	2.0–3.5	5–30	20–60	10–80	38–94

[z]Mean separation within columns by Duncan's multiple range test at $P \le 0.05$.
[y]Suggested standards based on recommendations from Warncke and Krauskopf (1983) and Fonteno (1996).

Table 3. Final substrate electrical conductivity (EC) for pentas, crossandra, philodendron, and areca palm plants grown in a pine bark/sedge peat/sand substrate (BSS), Metro-mix 500 (MM), Pro-mix GSX (PM), or a 60% biosolid substrate (SYT). Plants were watered using subirrigation or overhead irrigation. The suggested standard EC range of 2.0 to 3.5 $dS·m^{-1}$ is based on recommendations from Warncke and Krauskopf (1983). Values were averaged for the three irrigation frequencies (n = 120).

	EC ($dS·m^{-1}$)			
Substrate	Pentas (5 weeks)[z]	Crossandra (9 weeks)	Philodendron (11 weeks)	Areca palm (28 weeks)
		Subirrigated		
BSS	0.51 b[y]	0.69 b	0.74 b	6.53 a
MM	0.63 b	0.75 b	0.94 b	5.68 a
PM	0.53 b	0.64 b	0.65 b	6.28 a
SYT	2.18 a	2.49 a	2.41 a	5.60 a
		Overhead		
BSS	0.42 b	0.53 b	0.72 b	2.20 b
MM	0.53 b	0.58 b	0.79 b	2.10 b
PM	0.44 b	0.57 b	0.76 b	2.00 b
SYT	2.91 a	2.90 a	2.54 a	2.86 b
Significance				
Irrigation	NS	NS	NS	*
Substrate	*	*	*	NS
Irrigation × substrate	NS	NS	NS	NS
Frequency	NS	NS	NS	NS
Frequency × irrigation	NS	NS	NS	NS
Frequency × substrate	NS	NS	NS	NS
Frequency × irrigation × substrate	NS	NS	NS	NS

[z]The number in parenthesis indicates the number of weeks after transplanting when the plants were harvested.
[y]Mean separation within columns by Duncan's multiple range test $P \leq 0.05$.
[NS,*]Nonsignificant or significant response at $P \leq 0.05$.

subirrigated palm substrates were more than double the concentrations in overhead watered palm substrates (Table 3). Salts also were visible on the surface of all subirrigated palm substrates, but no salts were evident on the surface of the overhead watered substrates or on any of the other substrates of plants grown on the subirrigation benches. Accumulation of salts in the upper half of the substrate is one of the drawbacks of using subirrigation systems (Lieth, 1996). The accumulation of salts in the growing substrate also tends to increase over time (Guttormsen, 1969). Areca palms are sensitive to soluble salts in the growing substrate (Griffith, 1998) and are a rather long-term crop requiring more than twice as many weeks of growing time than the other crops. Warncke and Krauskopf (1983) reported that soluble salt concentrations of 5 to 6 $dS·m^{-1}$ are associated with reduced growth and vigor while concentrations greater than 6 $dS·m^{-1}$ are associated with severe salt injury. However, Yelanich and Biernbaum (1993) demonstrated that when fertilizer input exceeds plant utilization, salts tend to accumulate in subirrigation substrates. If the concentration of applied fertilizer is reduced or if higher leaching fractions are used, no susceptible salt buildup should occur when using subirrigation (Yelanich and Biernbaum, 1993).

Conclusions

Because substrates have different physical and chemical properties, it is important to adjust production conditions to optimize the benefits of a particular substrate. Substrates suitable for overhead irrigation may not produce similar results when used with subirrigation systems. Subirrigation appears to be a viable method for growing pentas, crossandra, and pentas. In this study, greatest pentas, crossandra, and philodendron shoot dry weight was in pots filled with PM that were subirrigated daily, but greatest areca palm shoot dry weight was in pots filled with MM or SYT that were watered overhead daily. Subirrigation probably has the potential to be used to grow areca palm plants as long as fertilization rates are adjusted or periodic leaching occurs to avoid the potential for salt buildup in the substrate.

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Susceptibility of *Lantana* Cultivars to *Orthezia insignis*

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ADDITIONAL INDEX WORDS. Hemiptera, Ortheziidae, insect pest resistance

SUMMARY. The greenhouse orthezia (*Orthezia insignis*) is a serious and widespread pest of cultivated lantanas (*Lantana* sp.) in warmer regions of the world. Forty species and cultivars of lantanas were screened for their relative susceptibility to this insect pest. Results showed that two Florida native lantanas, pineland lantana (*L. depressa*) and buttonsage (*L. involucrata*), were highly susceptible to infestation, with trailing lantana (*L. montevidensis*) and its cultivars and hybrids being somewhat less susceptible. Shrub lantana (*L. camara*) and its cultivars and hybrids were the least susceptible to greenhouse orthezia infestation, but some of these varieties are rather unattractive as landscape ornamentals and can become serious weeds.

The greenhouse orthezia, a damaging insect pest, is native to Central America and South America (Booth et al., 1995) but is now pantropical in distribution. It is usually found in greenhouses in temperate parts of the world but in warmer locations such as Florida and southern California, it is commonly found infesting plants in the landscape.

The greenhouse orthezia is unusual in that long, posteriorly oriented white waxy filaments are secreted on females. These filaments typically extend twice the length of the body (Essig, 1926). The structure that the filaments form, called the ovisac, houses eggs produced by females. Nymphs hatching from the eggs crawl through a posterior opening on the ovisac onto the host plant. Like aphids, reproduction is parthenogenetic (Epila, 1986). The greenhouse orthezia is a sucking insect that feeds on plant sap. Honeydew secreted by the feeding insects supports the growth of sooty mold, which renders plants unsightly and reduces photosynthetic efficiency.

The host range of the greenhouse orthezia is extensive and it has been reported feeding on species within 34 families (Ben-Dov et al., 2000). It is considered to be a very damaging and even lethal pest of some lantanas. Management of the greenhouse orthezia is generally accomplished by application of botanical oils (Hussain et al., 1996) or by release and augmentation of ladybird beetle (*Decadomius bahamicus* and *Hyperaspis pantherina*) predators (Bennett and Gordon, 1991, Booth et al., 1995). The purpose of this study was to determine if genetic resistance to the greenhouse orthezia exists among the numerous cultivars of lantanas grown as ornamentals in the United States.

Materials and methods

Rooted cuttings of 21 cultivars and/or species of lantana were potted into 2.8-L (0.75-gal) plastic containers using a 5 pine bark: 4 sedge peat : 1 sand substrate on 18 Apr. 1999. This substrate was amended with dolomitic limestone at 7.1 $kg \cdot m^{-3}$ (12 lb/yard^3) and Micromax (Scotts Co., Marysville, Ohio) at 890 $g \cdot m^{-3}$ (1.5 lb/yard^3). All pots received 22 g (0.7 oz) of Osmocote Plus 15N–3.9P–10K (Scotts Co., Marysville, Ohio) every 6 months. A second experiment containing 20 additional cultivars, plus *L. involucrata* as a repetition from the first experiment, was similarly set up on 2 Sept. 1999.

All plants were grown in a full sun nursery in Davie, Fla. (maximum photosynthetic photon flux = 1900 $\mu m \cdot m^{-2} \cdot s^{-1}$), where they received about 2 cm (0.8 inch) of water daily from overhead irrigation, plus natural rainfall. Ten replicate plants of each cultivar were arranged in a randomized complete-block design. Within 2 months of planting, all blocks of lantanas showed signs of infestation with

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Florida Agriculture Experiment Station journal series R-07676. The cost of publishing this paper was defrayed in part by payment of page charges. Under postal regulations, this paper must therefore be marked *advertisement* solely to indicate this fact.

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