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Scientia Horticulturae 93 (2002) 311–320

SCIENTIA HORTICULTURAE

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Development of compost-based media for containerized perennials☆

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Accepted 16 August 2001

Abstract

Growth of Bolivian sunset (*Gloxinia sylvatica* (HBK) Wiehler), Brazilian plume (*Justicia carnea* Lindl.), and golden globe (*Lysimachia congestiflora*) transplants was evaluated in media containing 25, 50, 75, or 100% compost (derived from biosolids and yard trimmings) as compared to commercial peat-based media. Compost-based media had higher pH, EC, bulk density, particle density and total porosity as compared to peat-based media. The effects of media composition on plant growth and development varied with each species tested. *Gloxinia* generally were smaller with reduced flower development when grown in compost-based media as compared to peat-based media. However, regardless of media composition, plants were of high visual color and quality. *Justicia* were similar in size or smaller when grown in compost-based media as compared to peat-based media but flower development was unaffected. However, the visual color and quality of the plants suffered when plants were grown in compost alone. Growth indexes of *Lysimachia* were similar among media or slightly reduced by 12%. Although, flower development was reduced by 16% in the second trial, plants were still acceptable in terms of visual color and quality, regardless of media composition.

Keywords: Biosolids; Subtropical plant production; *Gloxinia sylvatica* (HBK) Wiehler; *Justicia carnea* Lindl.; *Lysimachia congestiflora*

1. Introduction

Increased commercial interest has been directed towards developing complete or partial alternatives for peat utilized in traditional potting media within ornamental industries.

☆ Florida Agricultural Experiment Station, Journal Series No. R-07908.

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PII: S0304-4238(01)00340-5

Both environmental and economical implications of peat usage have resulted in the development of new substrate substitutes worldwide. Public and private composting facilities have increased over the past decade within the United States (Glenn, 1999) due to enhanced recycling efforts, mandated state and even county regulations on restrictions of disposing organic wastes, including biosolids into existing landfill, and alternative disposal systems being too expensive. Over the past decade, compost facilities have also dramatically improved their compost products to a degree that is acceptable both in terms of quality, quantity, and economical feasibility to various horticultural enterprises. Fitzpatrick (2001) has reviewed and cited numerous investigations illustrating the beneficial effect of compost utilization in greenhouse and nursery crop production systems. Wilson et al. (2001) specifically addressed the utilization of compost for herbaceous subtropical perennial species and reported that growth of cat whiskers (*Orthosiphon stamineus*) and angelonia (*Angelonia angustifolia* Benth.) was reduced when grown in peat or coir-based media amended with high rates of compost (75 or 100%), but not at lower rates (25 or 50%). The objective of this investigation was to develop a compost-based media using a perlite/vermiculite mix suitable for containerized perennial production.

2. Materials and methods

2.1. Plant material and media composition

Plugs of Bolivian sunset (*Gloxinia sylvatica* (HBK) Wiehler) (approximately 5 cm tall), Brazilian plume (*Justicia carnea* Lindl.) (approximately 8 cm tall), and golden globe (*Lysimachia congestiflora*) (approximately 4 cm tall) (Hatchett Creek Farms, Gainesville, FL) were transplanted into 4.5 l cylindrical, plastic pots filled with organic-waste compost amended with a 25, 50, or 75% (by volume) 1:1 vermiculite:perlite mixture (medium grade). Compost was generated by the Solid Waste Authority of Palm Beach County, FL, using a 1:1 ratio (w:w) of biosolids and yard trimmings (screened to 1.3 cm). Materials were composted for 18 days in an agitated bed system, stockpiled, and then re-screened to 1.3 cm. Additional pots were filled with 100% commercial soilless mix (0% compost, peat-based) consisting of 70% peat, 20% perlite, and 10% vermiculite (Fafard mix No. 2, Apopka, FL). All plants were topdressed at a standard rate of 15 g per pot of 15N-3.9P-10K Osmocote Plus® (The Scotts, Marysville, OH) and treated with a 1% granular systemic insecticide (Marathon™; Olympic Horticultural Products™, Bradenton, FL) at a standard rate of 0.37 g/l and a broad spectrum systemic fungicide (Banrot) at a standard rate of 12.9 g/l (Scotts, Marysville, OH). Plants were inspected daily and hand-watered as needed (3–4 times/week). Trial 1 was initiated on 3 February 2000 and replicated as Trial 2 on 24 April 2000. Average minimum and maximum temperatures in the greenhouse were 16.8 and 35.3 °C (Trial 1) and 20.6 and 38.1 °C (Trial 2), respectively.

Four replications of each mixture were evaluated initially for major physical media components (Inbar et al., 1993) consisting of percent moisture, bulk density (BD), particle density (PD), air-filled porosity (AFP), and total porosity (TP). Percent moisture was determined by oven-drying media at 105 °C for 24 h and weighing before and after. The AFP was determined in 500 ml pots (11.43 cm tall with collar) using the Wolverhampton submersion method of measuring the volume of drainage water in relation to the substrate volume (Bragg and Chambers, 1988). Standard drying procedures were then used after volume displacement methods to determine BD, PD, and TP (see Niedziela and Nelson, 1992, for equations).

Three samples from each medium were collected to determine chemical and nutrient composition. A saturated media extract was prepared for each mixture. Electrical conductivity (EC) was measured with a YSI Model 35 conductance meter (Yellow Springs Instrument, Yellowstone, OH). pH was then measured with an Orion Model 520A meter (Orion Research, Boston, MA).

Compost samples were oven-dried for 2 days at 60 °C and ground to a powder with a ball mill prior to combustion (Nelson and Sommers, 1996). Total carbon (C) and nitrogen (N) concentrations were determined by a CNS analyzer (Carlo-Erba Na-1500; BICO, Burbank, CA). Water soluble NO_3-N and NH_4-N were analyzed colorimetrically on an autoanalyzer (Alpkem: OI Analytical, Wilsonville, OR). Water saturated extracts of the media (25 g; dry weight equivalent compost mix with distilled water) were prepared and allowed to equilibrate prior to centrifuging for 15 min. The supernatent was collected, filtered through Whatman filter paper (No. 42), and analyzed for NO_3-N and NH_4-N colorimetrically with an autosampler.

The Environmental Protection Agency (EPA) method 3050 (USEPA, 1998) was used to determine total phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), boron (B), molybdenum (Mo), cadmium (Cd), lead (Pb), nickel (Ni), and aluminum (Al). An acid digestion procedure was used to prepare the samples for analysis by inductively coupled argon plasma spectroscopy (ICP) (Model 61E, Thermo Jarrell Ash Corp, Franklin, MA). Ground tissue was digested in nitric acid then treated with hydrogen peroxide (30%). The sample was then refluxed with nitric acid, filtered through Whatman filter paper (No. 41), and diluted to 100 ml for analyses.

2.2. Plant growth and development

Stem length, leaf greenness, dry weight, and flower number were measured after 10 weeks. Stem length was measured from the soil level to the shoot apex of the primary stem. Leaf greenness was measured on the 4th, 5th, and 6th leaf from the apex of each plant using an SPAD-502 chlorophyll meter (Spectrum Technologies, Plainfield, IL). Shoots were severed at the crown and roots were manually washed prior to oven drying for 1 week at 50 °C. For Lysimachia, a growth index was calculated by averaging the shoot width + width/length.

2.3. Experimental design and statistical analysis

A randomized complete block experimental design was used for each experiment. The experiment was repeated once and designated as Trial 1 and Trial 2. Treatments (0, 25, 50, 75, 100% compost) were replicated five times. All data within each experiment were subjected to an analysis of variance (ANOVA). Individual orthogonal contrasts of treatments vs. control (0% compost, peat-based media) were partitioned from the main effects of treatments.

3. Results

3.1. Chemical and physical properties of compost- and peat-based media

The pH and EC of compost-based media were significantly higher than that of peat-based media (Table 1). The pH of compost treatments averaged 0.7–0.9 units higher than the control (peat-based media). Regardless of the rate of perlite/vermiculite mix (25, 50, or 75%) in the compost, the pH values remained high, ranging from 6.8 to 7.0. The 100% compost media had 3.5 times greater EC than peat-based media. The EC remained higher than that of peat-based media when the compost was amended with 25 or 50% perlite/vermiculite mix, but was similar to that of peat-based media when 75% of the compost-based media consisted of the perlite/vermiculite mix.

Percent moisture was not different among 100% compost- and peat-based media. However, amending compost with perlite/vermiculite mix (25, 50, or 75%) decreased the percent moisture as compared with the peat-based media (Table 1). Bulk density and particle density were higher in the compost-based media than the peat-based media, regardless of the proportion of compost (25, 50, 75, and 100%) in the media (Table 1). AFP was not different among media (Table 1).

Elemental contents of compost samples are reported in Table 2. Levels of measured heavy metals in compost did not exceed EPA standards (USEPA, 1993).

3.2. Growth and development of Gloxinia

Gloxinia grown in media with 50, 75 or 100% compost generally resulted in shorter stem length than *Gloxinia* grown in peat-based media in both trials (Table 3). This correlated with reduced shoot dry weight of plants grown in compost-based media (25, 50, 75 and 100%) as compared to plants grown in peat-based media (Table 3). SPAD readings did not differ among media in either trial (Table 3). Fewer flowers occurred in compost-based media in Trial 1 (Table 3). Flowering did not occur in Trial 2 (Table 3) presumably due to

Table 1
Physical and chemical properties of compost-based media[a]

Media[b]	pH	EC ($dS\ m^{-1}$)	Moisture (%)	Bulk density ($g\ cm^3$)	Particle density ($g\ cm^3$)	AFP (% by volume)	Total porosity (% by volume)
Peat-based mix[c]	6.14	1.53	50.9	0.10	0.20	4.3	57.5
C(25%):PV(75%)	7.00**	1.83 NS[d]	33.5**	0.16**	0.31**	6.4 NS	56.8 NS
C(50%):PV(50%)	6.83**	2.61*	41.9**	0.19**	0.39**	7.0 NS	63.2*
C(75%):PV(25%)	6.80**	4.50**	48.4**	0.22**	0.46**	4.8 NS	69.8**
C(100%)	6.90**	5.4**	51.1 NS	0.23**	0.50**	4.4 NS	72.6**

[a] Comparisons were established between peat-based mix and other individual treatments.
[b] C = compost (yard trimmings:biosolids; 1:1 (w:w) ratio); PV = 1:1 (v:v) ratio of perlite and vermiculite.
[c] A commercial standard potting medium; peat (70%); perlite (20%); vermiculite (10%).
[d] Non-significance.
* Significance at $P < 0.05$.
** Significance at $P < 0.01$.

Table 2
Elemental content of compost (yard trimmings:biosolids; 1:1 (w:w) ratio)

Element	Concentration	Element	Concentration ($\mu g\ g^{-1}$)
C (%)	31.2	Fe	13633
N (%)	2.2	Zn	327
C:N (ratio)	13.9	Cu	200
NH_4 ($\mu g\ g^{-1}$)	11433	Mn	111
NO_3 ($\mu g\ g^{-1}$)	7993	B	28.3
P ($\mu g\ g^{-1}$)	43200	Mo	5.7
K ($\mu g\ g^{-1}$)	3513	Cd	1.0
Ca ($\mu g\ g^{-1}$)	834	Pb	26.7
Mg ($\mu g\ g^{-1}$)	306	Ni	16
		Al	4177

warmer greenhouse temperatures, longer days, and subsequent slower plant growth and development as compared with Trial 1. Despite the suppression of plant growth and delayed flower development associated with compost-based media, plants were still of acceptable quality (Fig. 1A).

3.3. Growth and development of *Justicia*

Justicia grown in compost-based media had similar stem length (with the exception of the 75% compost treatment in Trial 2), root dry weight, shoot:root ratios, and number

Table 3
Plant growth and developmental characteristics of *G. sylvatica*[a]

Media[b]	Stem length (cm)	Chlorophyll (SPAD)	Shoot dry weight (g)	Flowers (No.)[c]
Trial 1				
Peat-based mix[d]	21.1	60.8	23.0	16.2
C(25%):PV(75%)	19.7 NS[e]	61.4 NS	13.7**	8.4*
C(50%):PV(50%)	17.1*	58.6 NS	14.2**	1.2**
C(75%):PV(25%)	14.8**	56.3 NS	13.3**	1.6**
C(100%)	16.9*	60.0 NS	13.0**	1.4**
Trial 2				
Peat-based mix	16.5	55.4	23.8	
C(25%):PV(75%)	15.3 NS	54.9 NS	16.1**	
C(50%):PV(50%)	14.6*	50.5 NS	15.2**	
C(75%):PV(25%)	14.3*	54.5 NS	15.9**	
C(100%)	15.4 NS	52.2 NS	20.9 NS	

[a] Comparisons were established between peat-based mix and other individual treatments.
[b] C = compost (yard trimmings:biosolids; 1:1 (w:w) ratio); PV = 1:1 (v:v) ratio of perlite and vermiculite.
[c] No flowers were at the full-bloom stage in Trial 2.
[d] A commercial standard potting medium; peat (70%); perlite (20%); vermiculite (10%).
[e] Non-significance.
* Significance at $P \leq 0.05$.
** Significance at $P \leq 0.01$.

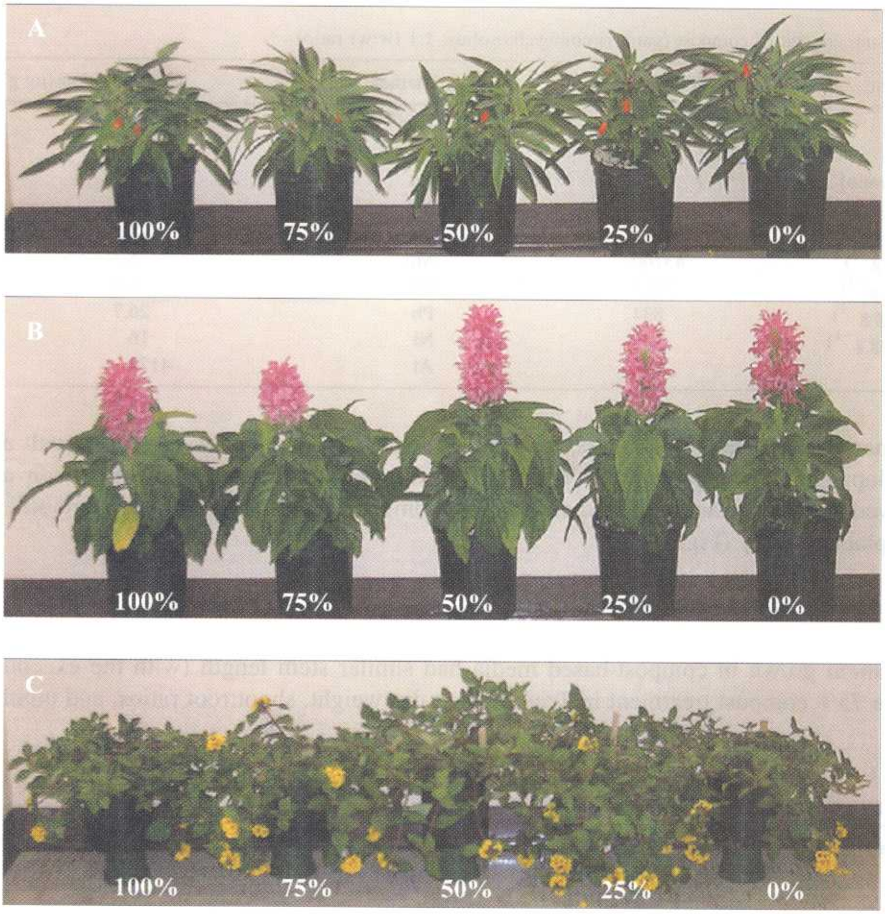

Fig. 1. Effects of compost amended media on growth of *Gloxinia* (A), *Justicia* (B), and *Lysmachia* (C) 10 weeks after transplanting (Trial 1). 100% = yard trimmings/biosolids compost (C); 75% = C(75%):PV(25%) (PV = 1:1 (v:v) ratio of perlite and vermiculite); 50% = C(50%):PV (50%); 25% = C(25%):PV(75%); 0% = a commercial soilless mix.

of flower buds than the peat-based media in either trial (Table 4). Plants grown in compost-based media had similar or lower shoot weights (Trial 1 and 2, respectively) than did plants grown in peat-based media. Leaf SPAD readings of plants grown in 25 or 50% compost-based media were similar to that of peat-based media. When plants were grown in 100% compost, SPAD readings were significantly lower as compared to plants grown in peat-based media in both trials (Table 4), thereby decreasing their visual quality (Fig. 1B).

3.4. Growth and development of Lysimachia

Plants grown in compost-based media had similar stem length and leaf SPAD readings than plants grown in peat-based media in both trials (Table 5). In Trial 1, shoot dry weights

Table 4
Plant growth and developmental characteristics of *J. carnea*[a]

Media[b]	Stem length (cm)	Chlorophyll (SPAD)	Shoot dry weight (g)	Root dry weight (g)	Shoot:root (ratio)	Flowers (No.)
Trial 1						
Peat-based mix[c]	24.6	50.6	17.7	9.6	2.0	8.4
C(25%):PV(75%)	22.8 NS[d]	47.0 NS	14.9 NS	9.0 NS	1.7 NS	5.8 NS
C(50%):PV(50%)	22.1 NS	46.2 NS	17.9 NS	8.4 NS	2.2 NS	6.6 NS
C(75%):PV(25%)	23.0 NS	45.5 NS	17.7 NS	9.8 NS	2.1 NS	7.6 NS
C(100%)	22.6 NS	39.9**	14.9 NS	8.1 NS	2.4 NS	6.4 NS
Trial 2						
Peat-based mix	18.1	45.5	27.1	5.0	6.0	9.6
C(25%):PV(75%)	14.8 NS	45.2 NS	22.0**	4.2 NS	6.2 NS	10.0 NS
C(50%):PV(50%)	15.4 NS	39.4 NS	23.3*	4.5 NS	5.2 NS	9.0 NS
C(75%):PV(25%)	13.6*	34.9**	20.1**	3.5 NS	6.3 NS	11.0 NS
C(100%)	21.6 NS	25.3**	21.3**	4.6 NS	4.7 NS	8.8 NS

[a] Comparisons were established between peat-based mix and other individual treatments.
[b] C = compost (yard trimmings:biosolids; 1:1 (w:w) ratio); PV = 1:1 (v:v) ratio of perlite and vermiculite.
[c] A commercial standard potting medium; peat (70%); perlite (20%); vermiculite (10%).
[d] Non-significance.
* Significance at $P \leq 0.05$.
** Significance at $P \leq 0.01$.

Table 5
Plant growth and developmental characteristics of *L. congestiflora*[a]

Media[b]	Stem length (cm)	Chlorophyll (SPAD)	Shoot dry weight (g)	Growth index (cm^3)	Flowers (No.)
Trial 1					
Peat-based mix[c]	30.4	41.9	19.7	43.9	24.8
C(25%):PV(75%)	26.4 NS[d]	42.3 NS	18.8 NS	42.7 NS	22.6 NS
C(50%):PV(50%)	27.8 NS	44.4 NS	18.7 NS	42.9 NS	27.8 NS
C(75%):PV(25%)	33.2 NS	44.3 NS	20.5 NS	42.5 NS	21.0 NS
C(100%)	31.5 NS	45.4 NS	17.3*	43.2 NS	21.2 NS
Trial 2					
Peat-based mix	31.5	44.6	30.5	44.5	91.4
C(25%):PV(75%)	31.0 NS	47.1 NS	23.5**	41.0**	66.2**
C(50%):PV(50%)	32.0 NS	49.9 NS	26.1**	40.9**	77.8*
C(75%):PV(25%)	32.4 NS	46.2 NS	27.5*	41.0**	73.4**
C(100%)	28.9 NS	49.1 NS	25.6**	39.4**	77.0*

[a] Comparisons were established between peat-based mix and other individual treatments.
[b] C = compost (yard trimmings:biosolids; 1:1 (w:w) ratio); PV = 1:1 (v:v) ratio of perlite and vermiculite.
[c] A commercial standard potting medium; peat (70%); perlite (20%); vermiculite (10%).
[d] Non-significance.
* Significance at $P \leq 0.05$.
** Significance at $P \leq 0.01$.

of plants grown in compost-based media were similar to that of plants grown in peat-based media, with the exception that plants grown in 100% compost had a lower shoot dry weight than plants grown in peat-based mix. In Trial 2, plants grown in compost-based media had less shoot dry weight than plants grown in peat-based media, regardless of compost proportion. The growth index and flower number of plants grown in compost-based media were either similar (Trial 1) or less than (Trial 2) plants grown in peat-based media (Table 5). Regardless of media composition, all plants were considered of marketable quality (Fig. 1C).

4. Discussion

These results support our previous observations (Wilson et al., 2001) and extend our knowledge on the ability to use compost in containerized plant production. Depending on the plant species, compost alone or compost amended at rates of 50% or less (by volume) provided an adequate substitute for peat in media for containerized production of *Gloxinia*, *Justicia*, and *Lysimachia*. Fitzpatrick (2001) reviewed and cited numerous investigations illustrating the beneficial effect of compost utilization in ornamental and nursery crop production systems. Also cited were deleterious growth responses, particularly in containerized media with high compost contents due to excess soluble salts, phytotoxicity, or compaction. At a minimum, neutral plant growth and developmental responses associated with compost amended media are advantageous over using peat-based soilless mixes due to the escalating costs of peat, lack of inexpensive media alternatives, and inexpensive, readily available, horticultural grade, compost.

4.1. Chemical and physical properties of compost- and peat-based media

The pH values of compost-based media were higher than that of peat-based media but still within an acceptable pH range for optimum plant growth (Fitzpatrick et al., 1998). In addition to increased alkalinity, high soluble salt content also has been associated with compost-based media (Chong and Rinker, 1994; Raymond et al., 1998). In the present experiment, high EC values of media with 75 or 100% compost may have attributed to reduced plant growth, particularly for species such as *Gloxinia*, *Justicia*, and *Lysimachia* that are salt intolerant. High salinity (>3.5 dS m^{-1}) has been reported to be detrimental to seed germination and subsequent seedling growth and development (Bernstein, 1975). Hemphill et al. (1984) reported that media amended with up to 50% compost increased fresh weight of pansy (*Viola tricolor* L.) and snapdragon (*Antirrhinum majus* L.). Raymond et al. (1998) suggest that compost-based substrates be limited to <50% by volume to reduce the potential of risk of high salinity. The desirable source and optimum percent of the compost in the final substrate differ with varying plant species and their salt sensitivity.

Higher bulk and particle densities of the compost-based media as compared with the peat-based medium were attributed to the yard waste (50% by weight) fraction of the compost. The larger particles (sieved to 1.3 cm) of the yard waste fraction of the compost contributed to a higher percent total porosity. Poole et al. (1981) recommended that compost amended media for container-grown foliage crops have a bulk density of 0.30 g cm^3.

4.2. Elemental content of compost

The compost had a low C:N ratio of 13.9. Zucconi et al. (1981) consider composts with C:N ratios greater than 30 immature and unstable which may result in phytotoxicity and subsequent plant injury. Likewise, Hue and Sobieszczyk (1999) reported that compost-derived media with C:N ratios greater than 20 resulted in immobilization of some of the inorganic N, whereas C:N ratios less than 15 resulted in release of inorganic N for subsequent plant uptake. The compost was, therefore, considered stable, mature, and beneficial for subsequent N release and plant availability (Sims, 1995).

The P, K, Ca, Fe, Zn, Cu, B, and Mo content in the compost was higher than that reported for a commercial peat-based media. He et al. (1995) reported that macro- and micro-nutrient contents vary among municipal solid waste (MSW) composts throughout the United States. He et al. (2001) have reviewed literature documenting compost as a significant source of P, K, Ca, Mg and other micro-nutrients.

4.3. Plant growth

Media with high proportions of compost (50% or greater), having higher nutrient content, higher bulk density, and improved porosity, may have more substrate compaction over time, thereby potentially contributing to smaller plants and slower plant development. However, research by Fitzpatrick and Verkade (1991) showed that compost consisting of yard waste and biosolids had the least compaction and resulted in the greatest plant growth as compared to other compost compositions.

The effect of compost on plant growth and development varied with each species tested. *Gloxinia* generally were smaller with reduced flower development when grown in compost-based media as compared to peat-based media. However, regardless of media composition, plants were of high visual color and quality. *Justicia* were similar in size (Trial 1) or smaller (Trial 2) when grown in compost-based media as compared to peat-based media but flower development was unaffected. However, the visual color and quality of the plants suffered when plants were grown in 100% compost. In Trial 1, *Lysimachia* growth and development was similar among media. Although, growth and flower development was reduced in Trial 2, plants were still of acceptable visual color and quality, regardless of media composition.

Justicia root weights did not differ among compost or peat-based media in either trial. However, in each trial for all plant species grown in media with 50% or more compost, roots were more extensive around the circumference of plastic containers rather than evenly distributed throughout the media (visual observation). Perhaps the greater media compaction and/or the higher soluble salts in the media with high proportions of compost may have contributed to poorer root distribution but not less root growth. Subsequently, abnormal root distribution of compost-based media may have attributed to slower plant growth and development. Future research will investigate mechanisms to improve root distribution in compost-based media.

Acknowledgements

The authors gratefully appreciate the technical assistance of Laurie Krumfolz and Dawn Lucas.

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