Annual Crop Growth in Substrates Amended With Sweetgum, Hickory, and Red Cedar©

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Peat has served as an industry standard for greenhouse substrates for over 50 years. Its continued availability, inert characteristics, as well as its ability to stay relatively pathogen-free have all contributed to its success in the horticulture industry. However, due to increased harvesting restrictions, as well as increased shipping costs, the future availability of peat is a largely unknown factor in greenhouse production. Our study evaluated three possible alternative substrates for greenhouse use, including sweetgum (SG), hickory (H), and eastern red cedar (RC). Three greenhouse annual crops (petunia, impatiens, and vinca) were planted in varying ratios of these three wood species mixed with peat. Plants grown with SG and H as amendments did not perform as well as plants in a grower's standard [peat : perlite (3 : 1, v/v)] mix with respect to flower number, growth indices, and plant dry weight. However, plants grown in RC tended to be equivalent to those grown in a peat 75 : perlite 25 (v/v) grower's standard. Data showed that greenhouse producers could amend their standard greenhouse substrate with up to 50% RC with little to no differences in plant growth and overall plant quality.

INTRODUCTION

For the past 40 to 50 years, peat and pine bark have served as industry standards for substrates in the greenhouse and nursery industries because of several inherit qualities; both are readily available and generally pathogen-free. However, due to numerous projected changes, the future availability of these two media is questionable. Peat supplies are decreasing due to increased harvesting regulations, along with increases in fuel costs for the shipping of peat from Canada. This has caused growers to seek alternative greenhouse substrates with equivalent physical characteristics (Greg Young, pers. commun.). Therefore, development of alternative substrates has been a major focus of research efforts.

Hardwoods and hardwood barks have both been evaluated as alternative substrate amendments (Self, 1975; Kenna and Whitcomb, 1985; Broussard et al., 1999). In 1975, results were obtained showing that the best growth of two azalea species was from "pine shavings followed by cedar shavings" (Self, 1975). Kenna and Whitcomb (1985) evaluated hardwood chips of both post oak (*Quercus stellata*

Wangh.) and Siberian elm (*Ulmus pumila* L.) as amendments of container media. *Pyracantha* and *Liquidambar formosana* were the two species used in the study. Addition of Micromax tended to increase height of pyracantha and sweetgum in the elm chips, but not in the oak chips. More importantly, the authors noted that both species grew as well in the hardwood-amended substrates as in the traditional pine bark substrate. Hardwood bark was explored as a possible alternative by Broussard et al. in 1999. They concluded that substrates amended with up to 25% hardwood bark could be used successfully in the production of numerous woody ornamentals.

Recent research has focused on high wood fiber substrates (Boyer et al., 2009; Fain et al., 2008; Jackson et al., 2010). This research has mainly focused on substrates composed of whole pine trees, chipped pine logs, and residual material left on the forest floor after harvesting at pine plantations. Currently, forestry owners are inquiring about the possibility of utilizing low value trees as alternative substrates. Among these are sweetgum (SG) (*Liquidambar styraciflua* L.), hickory (H) (*Carya* spp. Nutt.), and eastern red cedar (RC) (*Juniperus virginiana* L.).

Recent research has evaluated the use of RC in the containerized production of two tree species (Griffin, 2009). Chinese pistache (*Pistacia chinensis*) and Indian-cherry (*Frangula caroliniana*) were potted into one of 24 substrate combinations containing pine bark and varying volumetric ratios of RC. Four fertilizer regimes were evaluated [N at 0.81 $kg{\cdot}m^{-3}$ control release fertilizer (CRF), 1.6 $kg{\cdot}m^{-3}$ CRF, 0.4 $kg{\cdot}m^{-3}$ urea (46-0-0), or no fertilizer at all]. Chinese pistache height was similar to the 100% pine-bark treatment for the substrates amended with 5%, 20%, and 40% red cedar, but less height was seen in substrates amended with 10% and 80% red cedar. Similarly, shoot dry weight was less in the 10% and 80% cedar-amended substrates than in the 100% pine-bark standard, but all the other treatments (5%, 20%, and 40% cedar-amended substrates) performed equally as well as the standard mix. The author reported no problems with substrate shrinkage or visible nutrient deficiencies.

While RC has been evaluated as a substrate amendment in woody ornamental production, no efforts have been made to evaluate it as a greenhouse substrate component. Therefore, the objective of this study was to determine if greenhouse growers could amend their standard substrates with up to 50% SG, H, or RC, without reducing the quality of three annual greenhouse crops.

MATERIALS AND METHODS

Both SG (average caliper = 12.6 cm; 4.97 in.) and H (average caliper = 13.0 cm; 5.10 in.) were harvested from the forest on 16 Feb. 2009, and RC (average caliper = 12.6 cm; 4.95 in.) was cut on 17 Feb. 2009. All trees were de-limbed at the time of cutting. The SG, H, and RC were chipped through a Vermeer BC1400XL chipper on 19 Feb. 2009 and stored in large plastic containers (208.2 L) with lids, until grinding through a 0.6 cm (0.25 in.) screen in a swinging hammer-mill (No. 30; C.S. Bell, Tifton, Ohio) on 7 May 2009. Fresh whole tree (WT) chips were obtained from Young's Plant Farm (Auburn, Alabama) on 7 May 2009.

Nine treatments were evaluated in this study including a grower's standard (GS) control consisting of 75 peat : 25 perlite (v/v). Remaining substrate treatments consisted of 75 : 25 (v/v) and 50 : 50 (v/v) ratios of the different substrates (Table 1). All substrates were amended prior to planting with 1.98 $kg{\cdot}m^{-3}$ (4 lb/yd^3) 15-9-12 (N-

P-K) OsmocotePlus CRF (3–4 month) (The Scotts Company, Marysville, Ohio) and 2.48 kg·m^{-3} (5 lb/yd^3) dolomitic limestone. AquaGro-L® wetting agent (Aquatrols, Paulsboro, New Jersey) was incorporated at mixing at a rate of 124.01 g·m^{-3} (4 oz/yd^3).

Table 1. Substrate treatments evaluated.

Substrate ratios	
75 : 25 (v/v)	50 : 50 (v/v)
P* : PE (control)	
P : SG	P : SG
P : H	P : H
P : RC	P : RC
P : WT	P : WT

*Abbreviations: Peat (P), perlite (PE), sweetgum (SG), hickory (H), eastern redcedar (RC), and fresh whole tree chips (WT).

Three species were used in this study, which was initiated on 8 May 2009 at the Auburn Alabama Paterson Greenhouse Complex at Auburn University. 'Dreams Sky Blue' petunia (*Petunia* Juss. 'Dreams Sky Blue'), 'Cooler Peppermint' vinca (*Catharanthus roseus* (L.) G.Don 'Cooler Peppermint'), and 'Super Elfin Salmon' impatiens (*Impatiens walleriana* Hook.f. 'Super Elfin Salmon') were planted into 1.21-L containers with two plugs (from 288 plug flat) per pot. Plants were placed on greenhouse benches and watered by hand as necessary. The experimental design was a randomized complete block design with eight single-pot replications per treatment. Each species was treated as its own experiment. Data were analyzed using Tukey's Honestly Significant Difference test (p0.05) in a statistical software package (SAS Institute version 9.1.3, Cary, North Carolina).

Growth indices [(height + width1 + width2)/3] (cm) were measured at termination (n = 8). Flower number was also evaluated at termination, where only open blooms and blooms showing color were counted towards the total number on each plant (n = 8). Plant dry weights (PDW) were determined after samples were dried at 170 °F for 72 h (n = 4). Root growth and general health was assessed at study termination on a scale from 1–5, where 1 was assigned to plants with less than 20% root ball coverage, and 5 was assigned to plants with between 80%–100% root ball coverage (n = 8). Pour-through leachates were obtained from 'Super Elfin Salmon' impatiens at 1, 15, 30, and 45 days after planting (DAP) in order to determine substrate pH and electrical conductivity (EC) (n = 4) (Wright, 1986). Physical properties [substrate air space (AS), water holding capacity (WHC), total porosity (TP)] were determined using the North Carolina State University porometer method (n = 3) (Fonteno et al., 1995). Bulk density (BD) was determined from 347.5 cm^3 samples dried in a 105 °C (221 °F) forced air oven for 48 h (n = 3).

RESULTS AND DISCUSSION

Growth Indices. Petunias in the following treatments were similar in size to those in the GS (26.7), 75 P : 25 WT (26.1), 75 P :25 H (24.9), 75 P : 25 RC (26.1), 50 P : 50 WT (26.4), and 50 P : 50 RC (26.3) (Table 1). Both substrate treatments containing SG [75 P : 25 SG (23.2) and 50 P : 50 SG (22.2)] as well as the 50 P : 50 H (18.1) treatment had less growth than that exhibited in the GS. With impatiens, the only 75 : 25 (v/v) treatment not similar to the GS (22.4) was 75 P : 25 H (18.5). When the alternative substrate volume was increased from 25% to 50%, only the treatments containing WT and RC [50 P : 50 WT (21.1) and 50 P : 50 RC (21.8)] remained similar in growth to the impatiens grown in the GS. Vinca growth in the GS (25.6) was similar to three treatments: 75 P : 25 WT (24.0), 75 P : 25 RC (25.6), and 50 P : 50 RC (25.1). These results were similar to those seen in a previous study with eastern redcedar as an amendment in woody tree production (Griffin, 2009). In that study, no differences were observed in height of Chinese pistache in a substrate amended with 40% RC. In the current study, vinca growth indices in SG and H were less than the growth indices of vinca in the GS.

Flower Number. Petunia flower number for all treatments were similar to the GS, with the exception of the 50 P : 50 H treatment (5.4) (Table 1). With impatiens, treatments with RC and WT were similar to the GS (70.3) (both v/v ratios of each), while treatments with H and SG had less flowers. Only two treatments [75 P : 25 RC (27.8) and 50 P : 50 RC (21.6)] were similar to the GS (27.3) with respect to flower number in vinca. Other treatments, including those with WT, H, and SG had fewer flowers than the GS.

Plant Dry Weight. Petunia plant dry weight (PDW) in 75 P : 25 WT (13.4 g) and 75 P : 25 RC (14.4 g), as well as in 50 P : 50 WT (12.3 g) and 50 P : 50 RC (13.3 g) were similar to PDW of plants in the GS (13.2 g) (Table 1). The 75 P : 25 H (10.3 g) treatment was the only treatment from any containing H or SG to be similar to the GS. For impatiens and vinca, the substrate treatments containing RC were the only treatments similar to the GS. The PDW of plants in treatments containing H and SG had the least mass of all.

Root Growth. Root ratings were similar for all treatments compared to the GS (7.4) with respect to petunia (Table 1). For impatiens and vinca, all treatments containing 25% of the alternative substrate material were observed to have similar root ratings to the GS (6.4 for impatiens; 7.1 for vinca). The only two treatments in both plant species to have dissimilar root ratings to the GS were 50 P : 50 SG (1.9 for impatiens; 4.4 for vinca) and 50 P : 50 H (1.5 for impatiens; 3.9 for vinca).

pH and EC. Throughout the experiment, pH levels remained within the BMP recommended range (4.5–6.5) for all treatments at all testing dates with only two exceptions at 30 DAP [50 P : 50 SG (6.6) and 50 P : 50 H (6.7)] (Table 2) (Yeager et al., 2007). The only testing date where pH was similar for 50 P : 50 H (4.9) compared to the GS (5.2) was at 1 DAP. At 14, 30, and 45 DAP, 50 P : 50 H had higher pH levels (6.2, 6.7, and 6.4, respectively) than the GS (5.6, 6.2, and 5.9, respectively). The pH values for 50 P : 50 SG tended to be higher than those for the GS, except at 14 DAP, where the values were similar. Substrate pH values for treatments consisting of 75 P : 25 RC were similar to those of the GS at all testing dates. By the end of the study, treatments with higher percentages of RC tended to have slightly higher pH values than the GS. At 30 and 45 DAP, pH values for 50 P : 50 RC treatments (6.5 and 6.3, respectively) were higher than those for the GS control (6.2 and 5.9, respectively). Treatments containing WT had similar pH values to the GS at each testing date.

Table 1. Effect of substrate on growth indices[z], flower number[y], dry weight[x], and root ratings[w] at termination (47 DAP[v]) of three greenhouse annuals.

	Growth indices			Flower number			Dry weight (g)			Root ratings		
Substrate	Petunia	Impatiens	Vinca	Petunia	Impatiens	Vinca	Petunia	Impatiens	Vinca	Petunia	Impatiens	Vinca
75:25 Peat:Perlite	26.7 a[u]	22.4 a	25.6 a	10.8 ab	70.3 a	27.3 a	13.2 ab	7.8 a	11.6 a	7.4 ab	6.4 ab	7.1 a
75:25 Peat:Wholetree	26.1 ab	21.0 ab	24.0 ab	9.8 abc	53.6 ab	18.0 bc	13.4 ab	4.9 bcd	9.3 bc	8.8 a	6.1 ab	7.4 a
75:25 Peat:Sweetgum	23.2 bc	19.3 ab	20.3 c	9.3 abc	45.1 b	8.6 de	7.6 cd	3.7 cd	7.3 d	7.9 ab	4.5 b	6.5 ab
75:25 Peat:Hickory	24.9 abc	18.5b	20.0 c	11.0 ab	38.1 bc	11.0 de	10.3 bc	3.3 de	6.5 d	8.3 a	4.9 b	5.9 abc
75:25 Peat:Redcedar	26.1 ab	21.9 a	25.6 a	8.3 abc	52.8 ab	27.8 a	14.4 a	5.8 abc	10.9 ab	6.0 b	6.1 ab	6.8 a
50:50 Peat:Wholetree	26.4 ab	21.1 ab	23.2 b	12.3 a	55.5 ab	14.9 cd	12.3 ab	4.5 bcd	8.5 cd	8.6 a	6.8 ab	7.0 a
50:50 Peat:Sweetgum	22.2 c	14.4 c	16.2 d	7.1 bc	18.4 c	6.1 e	7.3 cd	1.1 f	3.1 e	8.8 a	1.9 c	4.4 bc
50:50 Peat:Hickory	18.1 d	13.6 c	14.4 d	5.4 c	16.7 c	6.0 e	5.1 d	1.3 ef	2.3 e	7.3 ab	1.5 c	3.9 c
50:50 Peat:Redcedar	26.3 ab	21.8 a	25.1 ab	9.0 abc	58.6 ab	21.6 ab	13.3 ab	6.6 ab	10.0 abc	8.6 a	7.4 a	7.1 a

[z]Growth index = [(height + width1 + width2) / 3].

[y]Flower number recorded as number of flowers with open blooms and blooms showing color.

[x]Dry weights (g) determined by drying the above-soil portion of the plant in a 76.7°C (170.0°F) forced air oven for 72 hours.

[w]Root growth assessed at study termination (45 days after planting) on 1-5 scale (1 - less than 20% root ball coverage, 5 - between 80–100% root ball coverage).

[v]DAP = days after planting.

[u]Means within column followed by the same letter are not significantly different based on Tukey's Honestly Significant Difference test at $\alpha = 0.05$ (n = 8 for flower number and growth indices; n = 4 for dry weight.

Table 2. Substrate effects on pH and electrical conductivity (EC)[z] in impatiens.

	1 DAP[y]		14 DAP		30 DAP		45 DAP	
Substrate	pH	EC[x] ($mS \cdot cm^{-1}$)[w]	pH	EC ($mS \cdot cm^{-1}$)	pH	EC ($mS \cdot cm^{-1}$)	pH	EC ($mS \cdot cm^{-1}$)
75:25 Peat:Perlite	5.2 bc[v]	1.2 a	5.6 b	2.4 a	6.2 d	0.9[ns]	5.9 b	0.4[ns]
75:25 Peat:Wholetree	5.2 bc	1.1 ab	5.7 b	1.3 abc	6.2d	0.6	6.1 ab	0.4
75:25 Peat:Sweetgum	5.3 abc	1.0 ab	5.7 b	2.2 ab	6.3cd	0.9	6.1 ab	0.5
75:25 Peat:Hickory	4.9 c	1.2 a	5.7 b	2.0 abc	6.4bcd	0.9	6.3 a	0.3
75:25 Peat:Redcedar	5.4 ab	1.1 ab	5.7 b	1.7 abc	6.3cd	1.0	6.1 ab	0.3
50:50 Peat:Wholetree	5.5 ab	0.8 ab	5.9 ab	1.4 abc	6.4bcd	0.5	6.2 ab	0.3
50:50 Peat:Sweetgum	5.7 a	0.9 ab	6.0 ab	1.0 bc	6.6ab	0.9	6.3 a	0.5
50:50 Peat:Hickory	4.9 c	1.1 ab	6.2 a	0.7 c	6.7a	0.7	6.4 a	0.5
50:50 Peat:Redcedar	5.6 ab	0.7 b	5.9 ab	1.4 abc	6.5abc	0.6	6.3 a	0.4

[z]pH and EC of solution determined using pour-through method on 'Super Elfin Salmon' impatiens.

[y]DAP = days after planting.

[x]EC = electrical conductivity.

[v]Means within column followed by the same letter are not significantly different based on Tukey's Honestly Significant Difference test at $\alpha = 0.05$ (n = 4).

[ns]Means not significantly different.

The recommended range for substrate EC levels is between 0.5 to 1.0 mS·cm^{-1} (Yeager et al., 2007). Substrate EC levels for all treatments were similar to the GS (1.2 mS·cm^{-1}) at 1 DAP except for the 50 P : 50 RC treatment (0.7 mS·cm^{-1}) (Table 1). At 14 DAP, the only treatments dissimilar to the GS (2.4 mS·cm^{-1}) were the 50 : 50 blends of both P : SG (1.0 mS·cm^{-1}) and P : H (0.7 mS·cm^{-1}). All other treatments, including all 75 : 25 blends of P : WT (1.3 mS·cm^{-1}), P : RC (1.7 mS·cm^{-1}), P : SG (2.2 mS·cm^{-1}), and P : H (2.0 mS·cm^{-1}), as well as the 50 : 50 blends of both P : WT (1.4 mS·cm^{-1}) and P : RC (1.4 mS·cm^{-1}) were similar to the GS (2.4 mS·cm^{-1}). By 30 DAP, there were no differences among any substrate EC levels for the remainder of the experiment.

Physical Properties. The recommended range for container substrate AS percentage is between 10%–20% (by vol) (Jenkins and Jarrell, 1989). Container substrate AS values in this experiment ranged from 5.9% (75 P : 25 SG) to 15.4% (50 P : 50 RC) (data not shown). Only three treatments had container AS values within the recommended range; 50 P : 50 WT (12.3%), 50 P : 50 H (11.3%), and 50 P : 50 RC (15.4%). Given that most container AS percentages were below the recommended range, it follows that substrate WHC percentages would be higher than normal. No treatment fell within the recommended range for WHC (50%–65%), as they were all higher than 65%. Substrate WHC percentages ranged from 74.9% (50 P : 50 WT) to 84.7% (75 P : 25 SG). With only one exception [50 P : 50 WT (74.9%)], all treatments had similar WHC percentages to that of the GS (82.0%). All percent values for TP of substrates were higher than the recommended range (60%–75%) (Jenkins and Jarrell, 1989). Bulk density values for all treatments were less than the recommended range (0.19–1.70 g·cm^{-3}) (Yeager et al., 2007). While all treatments were not similar to the GS (0.15 g·cm^{-3}), all BD values fell within a tight range [from 0.13 g·cm^{-3} (75 P : 25 WT, 75 P : 25 SG, 75 P : 25 RC, and 50 P : 50 WT) to 0.16 g·cm^{-3} (50 P : 50 H)]. The 75 P : 25 SG treatment had one of the lowest BD values (0.13 g·cm^{-3}).

In general, these data show that while physical properties indicated that these substrates were similar, they performed very differently. Throughout the study, treatments with RC as an amendment tended to perform as well as the traditional GS. Plants in treatments with RC also performed equal to or better than plants in WT. Plants grown with SG and H as amendments differed significantly from the GS with respect to growth indices, flower number, and PDW. Given that plants grown in SG and H appeared to be stunted and smaller than those grown in the GS, WT, and RC, they are not recommended as amendments for annual plant production with current greenhouse practices. However, additional studies are in place to determine if different fertility regimes could improve the potential of using H and SG substrates. While results from this study concerning using RC as an amendment in the GH production of three annual crops were promising, additional trials with a greater number of plant species would be necessary before advising growers to make a switch in their own production practices.

LITERATURE CITED

Boyer, C.R., C.H. Gilliam, G.B. Fain, T.V. Gallagher, H.A. Torbert, and **J.L. Sibley.** 2009. Production of woody nursery crops in clean chip residual substrate. J. Environ. Hort. 27:56–62.

Broussard, C., E. Bush, and **A. Owings.** 1999. Effects of hardwood and pine bark on growth response of woody ornamentals. Proc. Southern Nurs. Res. Assn. Conf. 44:73–76.

Fain, G.B., C.H. Gilliam, J.L. Sibley, and **C.R. Boyer.** 2008. WholeTree substrates derived from three species of pine in production of annual vinca. HortTechnology 18:13–17.

Fonteno, W.C., C.T. Hardin, and **J.P. Brewster.** 1995. Procedures for determining physical properties of horticultural substrates using the NCSU porometer. Horticultural Substrates Laboratory, North Carolina State University, Raleigh, North Carolina.

Griffin, J. 2009. Eastern red-cedar (*Juniperus virginiana*) as a substrate component for container production of woody plants. HortScience 44:1131.

Jackson, B.E., R.D. Wright, and **M.C. Barnes.** 2010. Methods of constructing a pine tree substrate from various wood particle sizes, organic amendments, and sand for desired physical properties and plant growth. HortScience 45:103–112.

Jenkins, J.R., and **W.M. Jarrell.** 1989. Predicting physical and chemical properties of container mixtures. HortScience 24:292–295.

Kenna, S.W., and **C.E. Whitcomb.** 1985. Hardwood chips as an alternative medium for container plant production. HortScience 20:867–869.

Self, R.L. 1975. Comparison of cedar, mahogany, and pine shavings in azalea potting mixtures. Proc. Southern Nurs. Assn. Res. Conf. 20:14.

Wright, R.D. 1986. The pour-through nutrient extraction procedure. HortScience 21:227–229.

Yeager, T., T. Bilderback, D. Fare, C.H. Gilliam, J. Lea-Cox, A. Niemiera, J. Ruter, K. Tilt, S. Warren, T. Whitwell, and **R. Wright.** 2007. Best management practices: Guide for producing nursery crops. 2nd ed. Southern Nursery Assn., Atlanta, Georgia.

Young, G. 2010. President, Young's Plant Farm. Auburn, Alabama. Pers. Commun., 18 Feb. 2010