The Landscape Performance of Annual Bedding Plants Grown in Pine Tree Substrate

Robert D. Wright[1,2], Brian E. Jackson[1,3], Michael C. Barnes[1,4], and Jake F. Browder[1,5]

ADDITIONAL INDEX WORDS. **container substrates, fertilization, landscape establishment, media, nutrition, wood fiber, WoodGro™**

SUMMARY. **The objective of this study was to evaluate the landscape performance of annual bedding plants grown in a ground pine tree substrate (PTS) produced from loblolly pine trees (*Pinus taeda*) or in ground pine bark (PB) when transplanted into the landscape and grown at three different fertilizer rates. Begonia (*Begonia ×semperflorens-cultorum*) 'Cocktail Vodka', coleus (*Solenostemen scutellarioides*) 'Kingswood Torch', impatiens (*Impatiens walleriana*) 'Dazzler White', marigold (*Tagetes erecta*) 'Bonanza Yellow', petunia (*Petunia ×hybrid*) 'Wave Purple', salvia (*Salvia splendens*) 'Red Hot Sally', and vinca (*Catharanthus roseus*) 'Cooler Pink' were evaluated in 2005, and begonia 'Cocktail Whiskey', marigold 'Inca Gold', salvia 'Red Hot Sally', and vinca 'Cooler Pink' were evaluated in 2006 and 2007. Landscape fertilizer rates were 1 lb/1000 ft^2 nitrogen (N) in 2005 and 0, 1, and 2 lb/1000 ft^2 N in 2006 and 2007. Visual observations throughout each year indicated that all species, whether grown in PTS or PB, had comparable foliage quality in the landscape trial beds during the growing period. With few exceptions, dry weight and plant size for all species increased with increasing fertilizer additions, regardless of the substrate in which the plants were grown. For the unfertilized treatment, when comparing plant dry weight between PB and PTS for each species and for each year (eight comparisons), PTS-grown plant dry weight was less than PB-grown plants in three out of the eight comparisons. However, there were fewer differences in plant dry weight between PTS- and PB-grown plants when fertilizer was applied (PTS-grown plants were smaller than PB-grown plants in only 2 of the 16 comparisons: four species, two fertilizer rates, and 2 years), indicating that N immobilization may be somewhat of an issue, but not to the extent expected. Therefore, the utilization of PTS as a substrate for the production of landscape annuals may be acceptable in the context of landscape performance.**

Pine bark (PB) and peatmoss are the two most common substrate components currently used for horticultural crop production in the southeastern United States. The availability and cost of PB remain unpredictable due to reduced forestry production and its increased use as fuel and landscape mulch (Lu et al., 2006). The cost of peat substrates continues to rise due to transportation costs and growing environmental concerns over the mining of peat bogs in Canada and Europe. Therefore, alternative substrates for container production of horticultural crops are important. The use of agricultural waste and other composted materials as a replacement for PB and peat is not a new concept; however, factors such as transportation costs, consistency and reproducibility of product, disease and insect infestation, and availability of composted materials represent concerns for growers (Gouin, 1989; Jackson et al., 2005).

Alternative substrates grown from wood and wood-based products have been investigated as suitable substrates or substrate components in nursery and greenhouse crop production. European research in this area has resulted in numerous successful commercialized wood substrates (Gerber et al., 1999; Grantzau, 1991; Gruda and Schnitzler, 2003; Muro et al., 2005; Penningsfeld, 1992). In addition, Prasad and Fietje (1989) and Worrall (1981) reported successful growth of foliage plants grown in substrates containing wood when compared with plants grown in peat and PB substrates. Annual and herbaceous plants including geranium (*Pelargonium ×hortorum*), petunia (*Petunia grandiflora*), impatiens, carnation (*Dianthus caryophyllus*), and chrysanthemum (*Dendranthema ×grandiflorum*) have been grown in wood-based substrates (Bragg et al., 1993; Hicklenton, 1983; Starck and Lukaszuk, 1991). More recently, a pine tree substrate has been developed (WoodGro™; WoodGro, Blacksburg, VA) from ground whole loblolly pine logs to successfully produce a wide range of nursery and greenhouse crops (Jackson et al., 2008; Wright and Browder, 2005; Wright et al., 2006, 2008). Pine tree substrate (PTS) derived from entire ground trees (bark, wood, branches, and needles) has also been evaluated as a container substrate or substrate component to produce vinca (Fain et al., 2008).

Understanding the survival and landscape performance of plants grown in PTS is important before PTS can be used for landscape bedding plant production. Previous research describing the post-transplant survival and performance of annual plants grown in a wood-based substrate has not, to our knowledge, been reported. It is well established that wood particles incorporated into the soil (Bollen and Lu, 1957; Lunt and Clark, 1959) or as part of a container substrate (Gruda and Schnitzler, 1999; Jackson et al., 2008; Maas and Adamson, 1972;

The research report herein was partially supported by the Virginia Agricultural Council and by the Virginia Nursery and Landscape Association.

[1]Department of Horticulture, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

[2]Professor.

[3]Graduate Teaching Assistant.

[4]Research Technician.

[5]Research Associate.

[6]Corresponding author. E-mail: wrightr@vt.edu

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
48.8243	lb/1000 ft^2	kg·ha^{-1}	0.0205
0.5933	lb/yard^3	kg·m^{-3}	1.6856
28.3495	oz	g	0.0353
0.9464	qt	L	1.0567
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

Wright et al., 2008) may cause N immobilization and require extra N applications for growth comparable to a fully composted organic material such as PB or peatmoss. The N deficiency caused by the incorporation of wood into soil could present a problem regarding planting PTS-grown plants into the landscape. However, this deficiency can likely be overcome with appropriate fertilizer applications. Therefore, the objective of this study was to evaluate the landscape performance of annual bedding plants grown in PTS or PB when transplanted into the landscape and grown at different fertilized rates.

Materials and methods

2005 Study. On 27 Mar. 2005, begonia 'Cocktail Vodka', coleus 'Kingswood Torch', impatiens 'Dazzler White', marigold 'Bonanza Yellow', petunia 'Wave Purple', salvia 'Red Hot Sally', and vinca 'Cooler Pink' plugs (144-plug tray) were potted into 3-qt plastic containers containing PB or PTS. The PTS substrate was produced by further grinding coarse (1 × 1 × 0.5 inch) pine chips with a hammer mill (Meadows Mills, North Wilkesboro, NC) passing through a 3/16-inch screen and incorporated with 1 lb/yard^3 of calcium sulfate ($CaSO_4$). PB was preplant-amended with 1 lb/yard^3 of $CaSO_4$ and 6 lb/yard^3 dolomitic lime, resulting in a pH of around 6.2. PTS was not amended with lime because of its inherently high pH, which was around 6.4 for this study. Plants were fertilized with 15 g of surface-applied controlled-release 15N–3.9P–10K (Osmocote Plus 15–9–12, 9-month release; O.M. Scott Horticulture Products, Marysville, OH) per container. Plants were glasshouse grown in Blacksburg, VA, with an average temperature of 26 °C day/22 °C night and were hand-watered as needed. On 17 May, 12 plants of visually equal size per treatment were transplanted into a Groseclose silt loam soil (clayey, mixed, mesic Typic Hapludults, pH 7.1) at the Urban Horticulture Center (UHC; Blacksburg, VA). An extensive root system was present on the surface of each root ball, which was not disturbed at planting. Plants were fertilized with 1 lb/1000 ft^2 N with 12N–2.6P–6.6K (Harrell's 12–6–8; Harrell's Fertilizer, Sylacauga, AL), mulched with 2 inches of hardwood bark mulch and were irrigated as needed with drip irrigation. Plants were grown until 1 Nov. 2005 when visual shoot and root growth observations were made in respect to general plant top size, foliage color, and root size.

Fig. 1. (A) Petunia 'Wave Purple' (2005), grown in pine bark (PB, left) or pine tree substrate (PTS, right), were visually the same in landscape beds. Plant size and plant quality of marigold 'Inca Gold' (B) and vinca 'Cooler Pink', (C) whether grown in PB or PTS, were indistinguishable after growing in landscape trial beds (2006). Plants were greenhouse-grown in PB or PTS and were subsequently grown in the landscape. For marigold (B) and vinca (C), the PB- and PTS-grown plants were randomized within each block (fertilizer rate).

2006 Study. Another experiment was conducted in 2006 with the following species: begonia ‘Cocktail Whiskey’, marigold ‘Inca Gold’, salvia ‘Red Hot Sally’, and periwinkle ‘Cooler Pink’. Plants were transplanted as above on 10 Apr. 2006 into 3-qt containers filled with PTS or PB and were fertilized with 200 $mg \cdot L^{-1}$ of 20N–4.4P–16.6K (Jack’s 20–10–20; J.R. Peters, Allentown, PA) peat-lite fertilizer in the irrigation water. On 5 June 2006, plants were transplanted into ground beds at the UHC on 12-inch centers and were fertilized by topdressing with three different N rates (0, 1, and 2 lb/1000 ft^2) from 12N–2.6P–6.6K fertilizer (Harrell’s Fertilizer). Plants were mulched as above and were irrigated as needed with trickle irrigation. After 10 weeks, growth index (GI) was determined for begonia and vinca on 17 Aug. 2006 by measuring height, widest width, and perpendicular width and dividing the total by 3. The canopy of marigold and salvia had grown together, resulting in the inability to accurately take GI, therefore, GI was not determined for these two species. On 25 Aug. 2006, four samples of the most recently matured leaves from PB- and PTS-grown plants from all four species were harvested and analyzed for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), copper (Cu), manganese (Mn), and zinc (Zn) by Penn State Analytical Testing Laboratory (University Park, PA) and shoots for all replications were severed at the soil surface, dried at 65 °C, and weighed.

2007 Study. An experiment with the same species and similar methodology as in 2006 was conducted in 2007. Plugs were potted in PTS- or PB-filled containers on 8 May and were greenhouse-grown as described above until 11 June when they were transplanted into ground beds at the UHC and fertilized at different rates as above. On 16 Aug., growth parameters were measured and tissue samples were collected.

The greenhouse experimental design for the three experiments was a completely randomized design, with each species grown separately. For landscape evaluations in 2005, each species was planted separately, with plants grown in each substrate planted side-by-side and unreplicated for general observation. In 2006 and 2007, species again were planted separately and substrates were randomized within a fertilizer rate; the fertilizer rate was not replicated, therefore comparisons were made between substrates at each fertilizer rate using least significant difference (LSD; SAS, release 9.1; SAS Institute, Cary, NC). Regression using Sigma Plot (version 9.01; SPSS, Chicago) was conducted to determine fertility responses within species.

There were 10 single-plant replicates per fertilizer treatment for begonia, marigold, and salvia, and eight for vinca in 2006, and eight for all species in 2007.

Results and discussion

Landscape plant quality. Visual observations throughout each year indicated that all species, whether grown in PTS or PB, had comparable foliage growth, foliage color, and flower density in the landscape trial beds during the growing period. Representative pictures taken in 2005 and 2006 are shown in Fig. 1. The foliage canopy of some species, such as petunia in 2005, completely covered the planting rows and fully closed across the ground bed [Fig. 1A

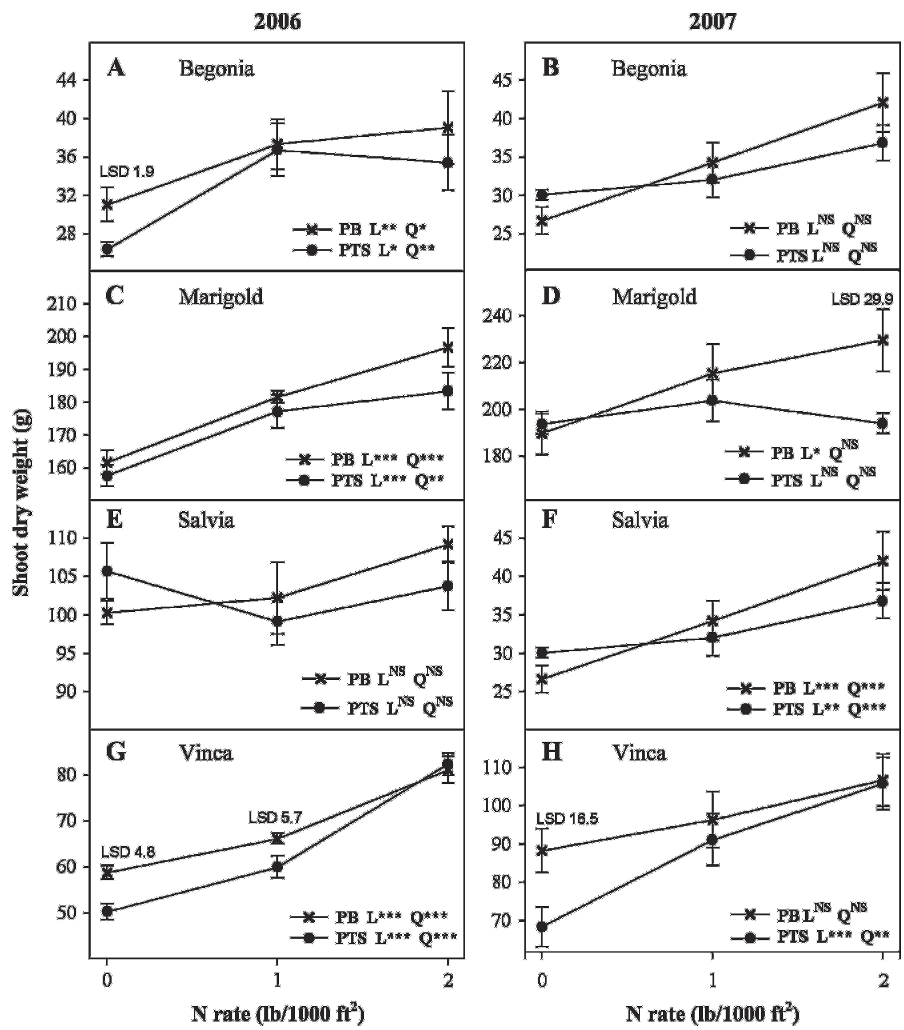

Fig. 2. Shoot dry weight from two experiments (2006 and 2007) with begonia, marigold, salvia, and vinca, greenhouse-grown with pine tree substrate (PTS) or pine bark (PB) and subsequently grown in the landscape at three nitrogen (N) application rates from a 12N–2.6P–6.6K fertilizer (Harrell’s 12–6–8; Harrell’s Fertilizer, Sylacauga, AL). The numbers above treatments indicate least significant difference [LSD ($P \le 0.05$)] between PB and PTS at that fertility level. Vertical bars represent SE of the mean. Linear (L) or quadratic (Q) response for fertilizer rate at *, **, and *, where P = 0.05, 0.01, or 0.001, respectively; 1 lb/1000 ft^2 = 48.8243 $kg \cdot ha^{-1}$, 1 g = 0.0353 oz.**

(petunia, 2005)]. Also, visual observations of excavated PB and PTS root systems for 2005 indicated comparable root proliferation into the surrounding soil whether grown in PB or PTS. In 2006 (Fig. 1B and 1C), visual quality of plants (size and foliage quality) was similar regardless of substrate in which plants were grown.

Landscape plant growth. No growth data were taken on landscape performance for 2005. In 2006 and 2007, dry weight for all species generally increased with increasing fertilizer additions regardless of the substrate in which the plants were grown (Fig. 2). In general, GI followed the same response to fertilizer treatments as dry weight data and because differences in GI between plants grown in the two substrates occurred only once (PB-grown vinca was higher than PTS-grown vinca at the 0 fertilizer rate, 2007), only shoot dry weight data will be shown.

In 2006, for the unfertilized treatment, dry weight was higher for PB-grown begonia (Fig. 2A) and vinca (Fig. 2G). PB-grown vinca dry weight was also higher than for PTS-grown plants at the 1 lb/1000 ft^2 N rate in 2006 and at the unfertilized treatment in 2007 (Fig. 2H). Dry weight of PB-grown marigold was higher in 2007 at the 2 lb/1000 ft^2 N rate, with no differences otherwise for marigold (Fig. 2D). There were no growth differences for salvia (Fig. 2, E and F) between PB- and PTS-grown plants.

The reason that dry weight is higher for PB-grown begonia in 2006 and for vinca in 2006 and 2007 for the unfertilized treatment could be related to N immobilization in PTS (carbon-to-nitrogen ratio is 500:1 for PTS and 50:1 for PB) because differences in dry weight are not present when fertilizer was applied with one exception—vinca at 1 lb/1000 ft^2 in 2006. However, N immobilization would not explain why marigold growth at 2 lb/1000 ft^2 N was higher for PB-grown plants compared with PTS (in 2007), with no difference in dry weight at the 0 rate. Logic would suggest the opposite response, as with begonia and vinca. Overall, there were fewer differences in growth between PTS- and PB-grown plants when fertilizer was applied (1 or 2 lb/1000 ft^2), indicating that N immobilization may be more of an issue in the absence of fertilization. For example, when considering differences in plant dry weight between PB and PTS for all fertility levels, species, and years (24 comparisons), PTS plants were smaller than PB plants five times and three of these occurred at the 0 fertilizer rate [Fig. 2, A, G, and H (begonia, 2006; vinca, 2006, 2007)].

The reason why N immobilization may not have reduced growth for PTS-grown plants to the extent expected at the 0 fertilizer rate may be that plant roots quickly explored the surrounding mineral soil from which they have equal access to soil nutrients after transplanting. In cases in the literature (Bollen and Lu, 1957; Lunt and Clark, 1959) where N immobilization and N deficiencies were reported, they are associated with wood-incorporated soil, where wood decomposition and microbial immobilization of N would compete with plants for N. In our case, the soil surrounding the newly planted root ball had not been amended with PTS (high carbon-to-nitrogen ratio), and N immobilization would occur primarily within the root ball and not in the area around the root ball where roots proliferate.

Plant tissue levels. Only in three cases for all species for the 2-years did tissue N levels increase with increasing fertilizer (marigold, 2006; vinca 2006, 2007). Differences with other nutrients over fertilizer rate was even less frequent and in only in one case were the tissue N levels different between plants grown in PTS vs. PB—vinca for PTS in 2007. An example of these data are included for marigold from 2006 (Table 1). Tissue data from other plant genera and years are not shown because such data would not present information pertinent to the overall interpretation of the results. For the most part, N tissue levels ranged from 3% to 4%, P from 0.3% to 0.6%, and K from 2.5% to 4%. These levels are within normal ranges for these species (Mills and Jones, 1996). Differences in micronutrient (Fe, Cu, Mn, and Zn) tissue levels were inconsistent, following no pattern relating to substrate, species, or fertilizer treatment (Data not shown). It is unclear why there were only limited differences in tissue nutrients in response to fertilizer rates given the

Table 1. Marigold leaf tissue levels taken on 25 Aug. 2006 of plants grown in pine tree substrate (PTS) or pine bark (PB) and subsequently grown for 3 mo. in the landscape and fertilized at three nitrogen (N) rates from Harrell's 12N–2.7P–6.6K fertilizer[z].

Nitrogen rate (lb/1000 ft^2)[y]	Tissue nutrient content (%)[x]				
PB	N	P	K	Ca	Mg
0	3.18	0.57	4.04	4.64	0.59
1	3.14	0.48	4.23	4.31	0.53
2	3.61	0.52	4.24	3.92	0.53
Significance[vw]	L*	NS	NS	L**	NS
	Q**	NS	NS	Q*	NS
PTS[u]					
0	3.35	0.46	3.83	4.26	0.51
1	3.03	0.42	4.08	3.91	0.45
2	NS	0.45	4.00	4.44	0.52
Significance[vw]	NS	NS	NS	NS	NS
	Q**	NS	NS	NS	NS
			LSD (0.05)[t]		
0	0.2632	0.0808*	0.3326	0.4676	0.0658*
1	0.5276	0.0746	0.4871	0.6814	0.1089
2	0.2519	0.0968	0.4300	0.7548	0.1103

[z]Harrell's 12–6–8 (Harrell's Fertilizer, Sylacauga, AL).
[y]1 lb/1000 ft^2 = 48.8243 $kg\cdot ha^{-1}$.
[x]N = nitrogen, P = phosphorus, K = potassium, Ca = calcium, Mg = magnesium.
[w]NS or significant at $P \le 0.05(*)$, 0.01(**), or 0.001(***).
[v]L = linear, Q = quadratic.
[u]PTS produced from 12- to 15-year-old loblolly pine trees harvested at ground level, delimbed, chipped, and hammer milled to pass through a 3/16-inch (4.8 mm) screen.
[t]Least significant difference at $P \le 0.05$. Values followed by asterisk indicate significance between substrates at that particular fertilizer rate.

general increase in plant growth with increasing fertilizer levels. One possible explanation could be that the larger plant size at the higher fertilizer rates compared with the smaller plant at the lower fertilizer rate could result in a nutrient concentrations being equal due to a dilution effect even though more N, for example, was absorbed at the higher fertilizer rates. This hypothesis could not be tested because tissue levels were determined on recently matured leaves and not on the whole plant. Soil testing of these plots showed levels of P, K, Ca, and Mg to be in the medium to high range of fertility before fertilizer applications in 2007. Previous cropping of the plots did not include differential fertilizer rates and the soil type was uniform throughout the plot.

These results demonstrated that landscape annuals, in the context of landscape appeal from a commercial or private garden perspective, whether grown in PB or PTS, are equally acceptable under normal landscape fertilization regimes. However, plants grown in both substrates will benefit from fertilizer applications after transplanting.

Literature cited

Bollen, W.B. and K.C. Lu. 1957. Effect of douglas-fir sawdust mulches and incorporations on soil microbial activities and plant growth. Soil Sci. Soc. Proc. 21: 35–41.

Bragg, N.C., J.A.R. Walker, and E. Stentiford. 1993. The use of composted refuse and sewage as substrate additives for container grown plants. Acta Hort. 342:155–165.

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

Gerber, T., F. Steinbacher, and B. Hauser. 1999. Holzfasersubstrat zur Kultur von *Pelargonium-Zonale*-Hybriden biophysikalische und pflanzenbauliche Untersuchung. J. Appl. Bot. 73:217 221.

Gouin, F.R. 1989. Compost standards for horticultural industries. Biocycle 30:4245, 47–48.

Grantzau, E. 1991. Holzfasersubstrate im Zierpflanzenbau: Eigenschaften und Qualitatsanforderungen. Gartenbau 38:44–47.

Gruda, N. and W.H. Schnitzler. 1999. Influence of wood fiber substrates and nitrogen application rates on the growth of tomato transplants. Adv. Hort. Sci. 13:20–24.

Gruda, N. and W.H. Schnitzler. 2003. Suitability of wood fiber substrate for production of vegetable transplants I. Physical properties of wood fiber substrates. Scientia Hort. 100:309–322.

Hicklenton, P.R. 1983. Flowering, vegetative growth and mineral nutrition of pot chrysanthemums in sawdust and peat-lite media. Scientia Hort. 21:189–197.

Jackson, B.E., A.N. Wright, D.M. Cole, and J.L. Sibley. 2005. Cotton gin compost as a substrate component in container production of nursery crops. J. Environ. Hort. 23:118–122.

Jackson, B.E., R.D. Wright, J.F. Browder, J.R. Harris, and A.X. Niemiera. 2008. Effect of fertilizer rate on growth of azalea and holly in pine bark and pine tree substrates. HortScience 43:1561–1568.

Lu, W., J.L. Sibley, C.H. Gilliam, J.S. Bannon, and Y. Zhang. 2006. Estimation of U.S. bark generation and implications for horticultural industries. J. Environ. Hort. 24:29–34.

Lunt, O.R. and B. Clark. 1959. Horticultural applications for bark and wood fragments. Forest Products J. 9:39a–42a.

Maas, E.F. and R.M. Adamson. 1972. Resistance of sawdusts, peats, and bark to decomposition in the presence of soil and nutrient solution. Soil Sci. Soc. Amer. Proc. 36:769–772.

Mills, H.A. and J.B. Jones, Jr. 1996. Plant analysis handbook II. Micromacro Publishing, Athens, GA.

Muro, J., I. Irigoyen, P. Samitier, P. Mazuela, M.C. Salas, and J. Soler. 2005. Wood fiber growing medium in hydroponic crop. Acta Hort. 697:179–185.

Penningsfeld, F. 1992. Toresa, a new substrate for soilless culture. Proc. Intl. Congr. Soilless Culture. 335–345.

Prasad, M. and G. Fietje. 1989. Evaluation of ground tree fern as a growing medium for ornamental plants. Acta Hort. 238:157–164.

Starck, J.R. and K. Lukaszuk. 1991. Effect of fertilizer nitrogen and potassium upon yield and quality of carnations grown in peat and sawdust. Acta Hort. 294:289–296.

Worrall, R.J. 1981. Comparison of composted hardwood and peat-based media for the production of seedlings, foliage, and flowering plants. Scientia Hort. 15:311–319.

Wright, R.D. and J.F. Browder. 2005. Chipped pine logs: A potential substrate for greenhouse and nursery crops. HortScience 40:1513–1515.

Wright, R.D., B.E. Jackson, J.F. Browder, and J.G. Latimer. 2008. Growth of chrysanthemum in a pine tree substrate requires additional fertilizer. HortTechnology 18:111–115.

Wright, R.D., J.F. Browder, and B.E. Jackson. 2006. Ground pine chips as a substrate for container-grown wood nursery crops. J. Environ. Hort. 24: 181–184.