Establishment of Greenhouse-grown *Tagetes patula* and *Petunia ×hybrida* in '*WholeTree*' Substrates

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Abstract

Rising transportation cost of peat moss from Canada or Europe is negatively affecting the profitability of many greenhouse operators. The industry has recognized a need to explore alternatives to peat for greenhouse substrates. The objective of this research was to evaluate processed whole pine (*Pinus taeda*) trees (WT) as an alternative growth substrate for greenhouse crops. Studies were conducted at the Southern Horticultural Laboratory (SHL) in Poplarville, MS, USA and Young's Plant Farm (YPF) in Auburn, AL, USA. Loblolly pine (*Pinus taeda* L.) was harvested from a 10 year old planted pine plantation in south Mississippi. The entire shoot portion of including needles was processed in several stages to pass a 0.48, 0.64, or 0.95 cm screen. The resulting three WT substrates were used alone or mixed with 20% or 50% (by volume) Canadian sphagnum peat moss (peat) and compared to an industry standard mix of 8:1:1 (by volume) peat:vermiculite:perlite (peat-lite). On 14 April 2006 (20 April 2006 for YPF) 15.2 cm containers were filled and four plugs (288 cell) of either marigold (*Tagetes patula* 'Little Hero Yellow') or petunia (*Petunia ×hybrida* 'Dreams Pink') were planted into each container. At 34 days after potting (DAP) there were no differences in flower number for marigold. Petunias grown in peat-lite substrate had over twice the number of flowers than observed on plants grown in other substrates. Leaf chlorophyll content was similar for petunia and marigold among all substrates. Regardless of substrate treatment all marigolds were considered marketable at 34 DAP. At 28 DAP, petunias grown in any 100% WT or 4:1 WT:peat substrate were smaller than plants in any 4:1 WT:peat or the peat-lite substrate. At 28 DAP petunia grown in peat-lite substrate were also larger than those grown in any 4:1 WT:peat substrate however all plants were considered marketable. The results of this experiment indicate that whole tree substrates are a potential alternative to conventional greenhouse substrates especially when combined with peat moss.

INTRODUCTION

Peat moss is the primary component of growth substrates in the production of greenhouse-grown herbaceous annual crops. Rising transportation cost of peat moss from Canada or Europe is negatively affecting the profitability of many greenhouse operators (personal communication). Environmental impacts of peat harvesting have been debated for years in Europe. Barkham (1993) stated that there is no longer a need to use peat for the wide variety of garden, commercial, horticultural and landscape uses for which it has been promoted over the last 30 years. Robertson (1993), reports that despite the proven advantages of peat for the horticultural industry, members of the UK Peat Producers Association (PPA) fully recognized the need to develop alternatives. Robertson stated that members of the PPA produce and market over 100 low-peat or non-peat products. One of the obstacles to the acceptance of some of the alternatives to peat in Europe is the low cost of peat compared to some of the alternatives being marketed (2006, personal communication with Noel Gumy, Intertoresa AG, Switzerland).

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Alternative substrate components have been evaluated in the US for use in greenhouse production. Some substrates have been evaluated as additions to reduce the quantities of peat moss in a given substrate and others as replacements for peat moss. Coconut coir has shown promise as a peat substitute (Evans and Stamps, 1996). However, the high transportation costs from Sri Lanka and Malaysia, and a certain degree of inconsistency in quality (Bragg, 1990) are among the factors that have limited its widespread acceptance. Cotton gin compost, a waste product of the cotton industry, has shown promise as an alternative substrate (Owings, 1993). Evans (2004) demonstrated that geranium (*Pelargonium ×hortorum*) and vinca (*Catharanthus roseus*) when grown in a substrate containing up to 30% processed poultry feather fiber were not significantly different from those grown in 4:1 (by volume) sphagnum peat:perlite. With many, if not all of the alternative substrates that have been evaluated, the biggest obstacle is the availability of a consistent quality product in quantities to sustain the industry into the future.

Some of the more promising alternatives currently used in Europe are those made of wood fiber. Studies by Gruda and Schnitzler (2001) and Gruda et al. (2000) demonstrated the suitability of wood fiber substrates as an alternative for peat-based substrates in cultivation of lettuce seedlings (*Lactuca sativa* var. *capitata*) and tomato transplants (*Lycopersicon lycopersicum*). While not on the market in the United States there are at least seven well-known wood fiber products marketed in Europe (Gumy, 2001). Estimates form Germany in 1999 revealed that over 235,000 m^3 of wood fiber is marketed annually. Laiche and Nash (1986) evaluated whole pine tree chips (needles, twigs, bark and wood) as a primary substrate component in container production of woody ornamentals. Wright and Browder (2005) demonstrated the potential of a substrate composed of wood fiber derived from wood chips of *Pinus taeda*. Boyer et al. (2006) found that container-grown lantana (*Lantana camara*) could be produced in substrates containing from 50% to 100% processed whole pine trees (*Pinus taeda*). What is most promising about the possibility of a substrate made from trees is the availability and sustainability of the raw product over a wide geographic area. Having raw product locally available to the industry could greatly reduce the cost of transportation which is a significant portion of the costs of Canadian sphagnum peat in the US, especially when shipping to the more distant (southern) states. What is most promising about *WholeTree* (WT) compared to other wood fiber products is the fact that it is not a by-product and that it utilizes the entire tree. This would leave virtually no residue in the forest which can amount to 15% – 25% of the total biomass in a typical forest thinning operation. One horticultural advantage of WT substrates is that in the manufacturing process the finished product can be altered and tailored to the required application purposes with respect to physical properties such as particle size and porosity. Because WT is manufactured it can also be produced with a consistent quality over time.

The objective of this research was to evaluate processed whole pine (*Pinus taeda*) tree shoots (*WholeTree*) as an alternative growth substrate for greenhouse-grown herbaceous annual crops.

MATERIALS AND METHODS

Studies were conducted at the Southern Horticultural Laboratory (SHL) in Poplarville, MS, USA and Young's Plant Farm (YPF) in Auburn, AL, USA. Loblolly pine (*Pinus taeda* L.) was harvested from a 10 year old planted pine plantation in south Mississippi. Trees ranged from 15.2 to 20.3 cm in diameter measured at 30.5 cm above ground. The entire shoot portion of the tree including needles was feed through a drum chipper (BC1000XL, Vermeer Inc.). Resulting chips were then further processed using a swinging hammer mill (No. 30, C.S. Bell Co.) to pass a 0.48 (WT1), 0.64 (WT2), or 0.95 (WT3) cm screen. The resulting three WT substrates were used alone or combined with 20% or 50% (by volume) Canadian sphagnum peat moss (peat) and compared to an industry standard mix of 8:1:1 (by volume) peat:vermiculite:perlite (peat-lite). Substrates were amended per m^3 with 4.15 kg dolomitic lime, 0.44 kg Micromax and 3.56 kg

Osmocote 15-9-12 Plus (15N-3.9P-10K, 3-4 month formulation, The O.M. Scotts Co.). On 14 April 2006 (20 April 2006 for YPF) 15.2 cm containers (AZF 0600, ITML Horticultural Products Inc.) were filled with substrates to the top edge of the container and 4 plugs (288 cell) of either marigold (*Tagetes patula* 'Little Hero Yellow') or petunia (*Petunia ×hybrida* 'Dreams Pink') were planted into each container.

Containers were placed on a greenhouse bench and watered as needed. All treatments received supplemental liquid fertilization weekly for three weeks at 200 ppm nitrogen the first week and 300 ppm thereafter using Peters 20-10-20 (20N-4.3P-16.7K, The O.M. Scotts Co.). Substrate air space, container capacity, and total porosity were determined following procedures described by Bilderback et al. (1982). Substrate bulk density ($g \cdot cm^{-3}$) was determined from 347.5 cm^3 samples dried in a 105°C forced air oven for 48h. At 28 (petunia) or 34 (marigold) days after potting (DAP) all plants were measured for growth index [(height + width + perpendicular width) ÷ 3], leaf greenness (SPAD 502 Chlorophyll Meter, Minolta Camera Co., Ramsey, NJ) and flower number. Roots were visually inspected and rated on a scale of 0 to 5 with 0 indicating no roots present at the container substrate interface and 5 indicating roots visible at all portions of the container substrate interface. Substrate shrinkage was recorded as the distance from the top of the container to the substrate surface. Recently matured leaves were sampled from four replications of each substrate for petunia plants (Mills and Jones, 1996). Petunia foliar samples from YPF were analyzed for N, P, K, Ca, Mg, S, B, Fe, Mn, Cu, and Zn. Foliar N was determined by combustion analysis using a 1500 N analyzer (Carlo Erba, Milan, Italy). Remaining nutrients were determined by microwave digestion with inductively coupled plasma-emission spectrometry (ICP) (Thermo Jarrel Ash, Offenbach, Germany). At 28 DAP the shoots of petunia plants at YPF were removed, and the substrate including roots was placed in a sealed polyethylene bag and transported to a laboratory to analyze for substrate pH, electrical conductivity and nutrients (NO_3-N, NH_4-N, P, K, Ca, Mg, SO_4-S, Fe, Mn, B, Cu, Zn, Mo, Na, and Al). Each treatment was replicated eight times (four at YPF) in a randomized complete block design.

RESULTS AND DISCUSSION

There were no differences in total porosity between the substrates containing WT and the peat-lite substrate (Table 1). Container capacity (CC) was highest for the peat-lite substrate at 67.4% when compared to any of the 100% WT or 4:1 WT:peat substrates. There was no difference in CC between the peat-lite and any of the 1:1 WT:peat substrates. Airspace (AS) was highest for the 100% WT3 substrate at over twice that of the peat-lite substrate. Bulk density was greatest for all of the 100% WT substrates and decreased with the addition of peat. The peat-lite substrate had the lowest bulk density at one half that of the WT1 substrate. AS was greatest and CC lowest for the WT3 substrate, this was expected due to the larger screen opening on the hammer mill during processing. There were no differences in substrate shrinkage between the substrates for marigold, however the peat-lite substrate had significantly more shrinkage with the petunias than any of the 100% WT or 4:1 WT:peat substrates (Table 2).

At 34 DAP there were no differences in flower number for marigold (Table 2). Petunias grown in peat-lite substrate had over twice the number of flowers than observed on plants grown in other substrates. Leaf chlorophyll content was similar for petunia, and marigold among all substrates with the exception that marigold plants grown in peat-lite substrate at the SHL locations had higher leaf chlorophyll content than any other substrate. At 34 DAP there were slight differences in growth index of marigold plants, however it should be noted that regardless of substrate treatment all were considered marketable. The results with marigold were comparable to those reported by Saunders et al. (2006), where marigold grown in ground pine chips (*Pinus taeda*) had similar shoot dry weight to those grown in a peat-lite substrate. At 28 DAP, petunias grown in any 100% WT or 4:1 WT:peat substrate were significantly smaller than plants in any 4:1 WT:peat or the peat-lite substrate. At 28 DAP petunia grown in peat-lite substrate were also larger than those grown in any 1:1 WT:peat substrate, however all these plants were considered marketable. There were no differences in root ratings (RR) with any species among treatments with the exception marigold grown in the 0.48 cm 100% WT substrate at the YPF location, where slightly lower RR than all other substrates were observed.

Analysis of petunia tissue nutrient content revealed that there were no significant differences in foliar N between substrates (Table 3); however all were below reported sufficiency ranges (Mills and Jones, 1996). Tissue P and K were below sufficiency ranges for the peat-lite substrate while P and K for all other substrates were within sufficiency ranges. Petunia tissue Mg and Fe content was lower for all 100% WT and all 4:1 WT:peat when compared to peat-lite and with Fe below the sufficiency range. Substrate analysis for petunia indicated that the pH was higher than the recommended range of 5.4 – 6.2 for petunia (Argo and Fisher, 2002) for all substrates except the peat-lite which was at the upper limit of that range at a pH of 6.18 (data not shown). At 28 DAP all substrates had a similar electrical conductivity ranging from 0.41 – 0.56 dS/cm an expected range for a controlled release only fertilizer regime.

CONCLUSIONS

The results of this experiment indicate that WT substrates in whole or in part are a potential alternative to peat moss in greenhouse substrates. Although there were no differences in tissue N concentration with petunias for any substrate at 28 DAP, they were all below the published sufficiency range (Mills and Jones, 1996) and it is possible a nitrogen sink in the WT substrates early in the crop cycle could explain some of the differences in final growth. Although there were no visual signs of foliar deficiency, tissue Fe content did appear to be affected by substrate pH. The much higher than recommended pH for all substrates containing WT most likely contributed to the lack of performance petunia exhibited in these substrates when compared to the peat-lite substrate. All marigold plants were considered marketable at 34 DAP regardless of substrate used. Another area of concern was the difference in physical properties of the substrates tested. Future research should focus on developing and testing WT substrates with physical properties more similar to standard greenhouse substrates as well as addressing the possible N immobilization that is likely occurring with the WT substrates.

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Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

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Tables

Table 1. Physical properties of substrates.[z]

Substrates[y]	Air space	Container capacity	Total porosity	Bulk density
		(% vol)		(g · cm $^{-3}$)
WholeTree #1 (WT1)	37.7	44.9	82.6	0.136
WholeTree #2 (WT2)	35.6	50.7	86.3	0.130
WholeTree #3 (WT3)	47.9	33.3	81.2	0.144
4:1 (by vol) WT1:Peat	33.2	59.4	92.6	0.134
4:1 (by vol) WT2:Peat	32.3	58.9	91.3	0.127
4:1 (by vol) WT3:Peat	39.2	50.0	89.2	0.138
1:1 (by vol) WT1:Peat	23.9	67.3	91.1	0.102
1:1 (by vol) WT2:Peat	27.5	63.7	91.3	0.107
1:1 (by vol) WT3:Peat	24.7	64.6	89.3	0.114
8:1:1 (by vol) Peat:Verm:Perlite	19.9	67.4	87.2	0.082
HSD[x]	*7.0*	*8.8*	*7.2*	*0.007*

[z] Analysis performed using the NCSU porometer.
[y] Processed whole pine trees ground to pass a 0.48 (WT1), 0.64 (WT2), or 0.95 (WT3) cm screen.
[z] Tukey's Honest Significant Difference (α≤0.05, n=4).

Table 2. Effects of '*WholeTree*' substrates on growth of *Tagetes patula* 'Little Hero Yellow' and *Petunia* ×*hybrida* 'Dreams Pink'.

	SPAD[y]		Flower #		Growth index[x] (cm)		Root rating[w]		Shrinkage
Substrates[u]	SHL[t]	YPF	SHL	YPF	SHL	YPF	SHL	YPF	(cm)
			Tagetes patula 'Little Hero Yellow'						
WholeTree #1 (WT1)	41.3	42.2	13.7	9.8	18.6	21.9	3.8	3.6	2.1
WholeTree #2 (WT2)	41.1	42.8	15.0	12.0	18.0	23.3	3.5	3.9	1.9
WholeTree #3 (WT3)	42.3	42.1	12.2	11.0	18.3	21.1	3.5	3.9	1.4
4:1 (by vol) WT1:Peat	42.8	45.4	13.0	8.8	19.5	23.7	3.8	3.6	2.1
4:1 (by vol) WT2:Peat	41.9	47.3	14.2	10.8	20.1	24.8	3.8	3.9	2.2
4:1 (by vol) WT3:Peat	43.8	45.3	14.8	10.5	19.7	25.0	3.8	3.9	1.8
1:1 (by vol) WT1:Peat	42.8	45.8	14.2	10.5	20.1	24.8	4.2	4.0	2.4
1:1 (by vol) WT2:Peat	46.2	45.9	15.2	10.5	21.7	24.7	4.1	4.0	2.3
1:1 (by vol) WT3:Peat	43.7	45.8	14.3	10.8	22.5	25.3	4.0	4.0	2.1
8:1:1 (by vol) Peat:Verm:Perlite	49.6	46.7	15.3	14.0	22.7	27.3	3.9	4.3	2.3
HSD[s]	*4.2*	5.8	*5.5*	*5.2*	*2.3*	*3.8*	*0.6*	0.6	*0.5*
			Petunia ×*hybrida* 'Dreams Pink'						
WholeTree #1 (WT1)	41.1	34.0	1.7	3.3	17.2	19.9	3.3	2.5	1.2
WholeTree #2 (WT2)	42.0	39.4	0.3	1.8	15.6	16.9	3.3	2.1	1.1
WholeTree #3 (WT3)	45.8	37.0	0.3	1.5	15.1	18.1	3.9	2.0	1.0
4:1 (by vol) WT1:Peat	43.2	35.3	2.1	3.3	18.0	22.3	4.0	2.8	1.2
4:1 (by vol) WT2:Peat	41.0	35.7	0.6	2.8	18.5	22.5	3.6	2.6	1.4
4:1 (by vol) WT3:Peat	43.5	38.1	1.4	1.5	19.9	19.0	4.1	2.4	1.1
1:1 (by vol) WT1:Peat	43.0	39.3	4.4	5.5	24.2	26.9	3.6	3.6	1.6
1:1 (by vol) WT2:Peat	41.2	38.3	4.4	4.5	23.8	24.0	3.8	2.6	1.6
1:1 (by vol) WT3:Peat	43.4	39.0	5.9	7.5	23.8	28.4	4.1	3.0	1.4
8:1:1 (by vol) Peat:Verm:Perlite	44.0	39.8	13.0	14.0	30.8	34.0	3.8	3.9	1.9
HSD[s]	*7.0*	6.4	*4.7*	*6.0*	*3.8*	*5.3*	*1.2*	1.7	*0.5*

[z] Days after potting.
[y] Leaf chlorophyll content determined using a SPAD-502 chlorophyll meter (ave. of 4 leaves per rep).
[x] Growth index = [(height + width + perpendicular width) / 3].
[w] Root rating 0-5 scale, where 0= no roots visible at substrate container interface and 5= roots present in all portions of substrate container interface.
[u] Processed whole pine trees ground to pass a 0.48 (WT1), 0.64 (WT2), or 0.95 (WT3) cm screen.
[t] SHL – Southern Horticulture Laboratory, Poplarville, MS, USA or YPF – Youngs Plant Farm, Auburn, AL, USA.
[s] Tukey's Honest Significant Difference (α≤0.05, n=4).

Table 3. Tissue nutrient content of *Petunia ×hybrid* 'Dreams Pink' grown in '*WholeTree*' substrates 28 days after potting.

	Tissue nutrient content[z]													
	Macro (%)						Micro (ppm)							
Substrates	N	P	K	Ca	Mg	S	B	Fe	Mn	Cu	Zn	Mo	Na	Al
WholeTree #1 (WT1)	2.76	0.38	4.48	1.03	0.44	0.25	37.2	56.2	73.5	8.8	61.8	1.5	1924	20.9
WholeTree #2 (WT2)	3.19	0.39	4.49	1.14	0.50	0.15	42.1	56.7	98.3	7.8	42.4	2.1	1819	33.6
WholeTree #3 (WT3)	3.62	0.43	4.57	0.81	0.39	0.23	48.3	52.6	97.5	8.2	57.6	1.5	1856	20.0
4:1 WT1:Peat	3.44	0.44	4.88	0.95	0.53	0.33	36.4	57.1	74.9	9.3	73.6	1.7	1854	20.5
4:1 WT2:Peat	2.71	0.49	3.96	0.98	0.53	0.32	38.7	64.3	72.9	9.2	66	2.8	1742	25.7
4:1 WT3:Peat	2.82	0.46	3.75	0.84	0.46	0.26	36.1	57.7	81.3	9.0	50.5	3.1	1389	45.1
1:1 WT1:Peat	3.03	0.43	3.22	1.07	0.65	0.35	31.1	72.1	71.4	7.7	54.8	2.5	1558	24.7
1:1 WT2:Peat	3.08	0.41	2.83	0.99	0.61	0.27	35.7	58.3	90.3	7.4	40.8	2.7	1761	25.8
1:1 WT3:Peat	3.19	0.50	4.49	1.30	0.82	0.44	39.3	77.4	145.5	5.4	59.4	1.1	1818	9.6
8:1:1 Peat:Verm:Perlite	3.24	0.36	2.69	1.42	0.95	0.40	38.2	83.2	206.5	5.1	45	0.8	2469	9.2
HSD[y]	*1.27*	*0.22*	*2.01*	*0.51*	*0.32*	*0.28*	*11.9*	*21.6*	*61.8*	*4.1*	*34.7*	*1.1*	*1151*	*35.3*
Sufficiency range[x]	*3.9-7.6*	*0.47-0.93*	*3.13-6.65*	*1.2-2.8*	*0.36-1.37*	*0.33-0.80*	*18-43*	*84-168*	*44-177*	*3.0-19*	*33-85*	*0.19-0.46*	*3067-10896*	*50-92*

[z] Tissue analysis performed on 30 recently mature leaves per plant.
[y] Tukey's Honest Significant Difference (α≤0.05, n=4).
[x] Sufficiency ranges as published by Mills and Jones 1996.