A Comparison of *WholeTree* and Chipped Pine Log Substrate Components in the Production of Greenhouse Grown Annuals[1]

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Abstract

WholeTree (WT) and chipped pine logs (CPL) are potential new sustainable greenhouse substrate components made by milling chipped pine trees and/or pine logs (*Pinus taeda* L.). Two experiments were conducted to evaluate the growth of *Catharanthus roseus* L. 'Grape Cooler' and *Impatiens walleriana* Hook.f. 'Dazzler Apricot' in 1:1 (v:v) WT:peat (WTP) and 1:1 (v:v) CPL:peat (CPLP), and to compare physical properties of those substrates. In Experiment 1 WTP had 76.8% container capacity (CC) and 96.4% total porosity (TP) while CPLP had 72.4% CC and 90% TP; air space (AS) and bulk density (BD) were similar. In Experiment 2 there were no differences in physical properties. In Experiment 1 EC peaked at 14 days after potting (DAP) and decreased through the remainder of the study. At 0 DAP pH ranged from 4.2–4.3 and increased to a range of 6.4 to 6.8 at 42 DAP. This trend was similar in Experiment 2, except that EC peaked at 7 DAP. In impatiens, plants were similar in Experiment 1 but those grown in WTP in Experiment 2 had bloom counts of 37.3 compared to 27.9 for plants grown in CPLP. With vinca, in Experiment 1 plants grown in CPLP had a dry weight of 7.3 g as compared to 6.9 g for plants grown in WTP, but there were no differences in Experiment 2. Results indicate that growers could use CPL and/or WT interchangeably, depending on available resources.

Index words: alternative substrate, greenhouse production, wood chips, wood fiber, peat, media, annuals.

Species used in this study: *Catharanthus roseus* L. 'Grape Cooler'; *Impatiens walleriana* Hook.f. 'Dazzler Apricot'.

Significance to the Nursery Industry

In recent years, wood-based alternative substrate components have been introduced to growers as viable, renewable alternatives to peat in greenhouse production, including chipped pine logs (CPL) and *WholeTree* (WT). CPL is obtained by chipping and grinding a pine log that has been delimbed; WT is obtained by chipping and grinding all aboveground portions of a pine tree. Availability of WT and CPL to growers may be different regionally; results indicate that growers can use WT and CPL interchangeably as a substrate component in equal volumes with peat.

Introduction

Research into wood-based alternative substrates has been going on for decades (3, 11, 12, 13, 15, 16). While American research into wood fiber alternatives declined in the 1990s, European researchers continued to investigate wood fiber as an alternative for the diminishing peat supply. In 1999, Gumy listed seven well-known wood fiber products marketed in Europe: Culti-Fibre®, Pietal®, Torbo®, Torbella®, Bio-Culta®, Horti-Fibre®, and Toresa®. (9). That same year, over 253,000 m^3 (331,000 yd^3) of wood-fiber products was marketed annually in Germany (9). Toresa® is a wood fiber product comprised primarily of spruce (*Picea spp.*) and is available in Switzerland. Self-described by the company as self-impregnated wood borne from live, peeled coniferous wood, Toresa® is a widely marketed substrate with over seven different blends available to date. Fibralur® is another wood fiber alternative substrate, available in Spain, and is derived from carrying out a thermal-mechanical treatment on wood chips. Tomatoes grown in Fibralur® were similar in fruit yield as compared to those grown in perlite mixes (14). Gruda and Schnitzler (8) reported that the physical properties of wood-fiber based substrates were similar to peat with the exception of water retention. Recently, U.S. research has turned once again to wood fiber substrates when Boyer et al. (2), Fain et al. (4, 5, 6), and Wright and Browder (17) expanded upon earlier work by Laiche and Nash (12). Previous work by Laiche and Nash (12) compared milled pine bark, pine bark with a considerable amount of wood (PBW), and pine tree chips (PTC). Because the material in the study was chipped and not milled, PBW and PTC substrate physical properties were not conducive to plant growth.

Wright and Browder (18) reported that CPL obtained by chipping and grinding a loblolly pine log (*Pinus taeda* L.) without limbs could be a potential new greenhouse substrate. *Tagetes erecta* Big. 'Inca Gold' grown in 75:25 CPL:peat had similar dry weights to those grown in 100% peat. A later report indicated a need for additional fertilizer in the production of greenhouse annuals in CPL obtained by chipping and grinding a loblolly pine log (18). Also in 2008, Jackson et al. (10) reported that physical properties similar to those of peat could be attained in CPL when hammer-milled using a 0.24 cm (0.09 in) screen.

Another wood-fiber alternative for greenhouse producers is clean chip residual (CCR). A by-product of the forestry industry, CCR is the material left over after pine trees are processed into clean chips (used for making paper products and boiler fuel) and is approximately 50% wood, 40% bark, and 10% needles (1). Growth indices and shoot dry weights for ageratum (*Ageratum houstonianum* Mill. 'Blue Hawaii') grown in CCR-based substrates were similar to those grown in standard pine bark mixes (2). Ageratum leaf chlorophyll content in plants grown in CCR-based substrates was similar or greater than that of plants grown in standard mixes. Re-

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sults (2) were consistent with results reported by Wright and Browder (18), Wright et al. (19), Fain et al. (5) and Jackson et al. (10) where annuals grown in wood fiber substrates have similar growth to plants grown in a standard mix.

WholeTree (WT) is another wood fiber alternative substrate component created from entire pine trees harvested at the thinning stage. All above ground portions of the tree (wood, bark, and needles) are chipped and ground to crop specifications; thus, WT consists of approximately 80% wood, 15% bark, and 5% needles. Fain et al. (4, 5) reported that WT substrates derived from three different pine species (*Pinus taeda* L., *Pinus elliotti* Engelm., and *Pinus palustris* Mill.) have potential as an alternative source for producing short-term horticultural crops. Studies also indicate that with adequate starter nutrient charge, WT serves as an acceptable substrate component for replacing the majority of peat in greenhouse production of petunia (*Petunia* ×*hybrida* Vilm.) and marigold (*Tagetes patula* L.) (6). Petunia dry weight was greatest for any substrate containing peat with a 7-3-10 starter fertilizer rate of 2.37 $kg{\cdot}m^{-3}$ (4 $lb{\cdot}yd^{-3}$) or greater, except petunia grown in WT at 3.56 $kg{\cdot}m^{-3}$ (6 $lb{\cdot}yd^{-3}$) had shoot dry weights as high as any other treatment. Marigold dry weights were similar for WT at the 2.37 $kg{\cdot}m^{-3}$ (4 $lb{\cdot}yd^{-3}$) starter fertilizer rate and for all treatments containing peat except 4 WT:1 peat with no starter fertilizer (6).

Independent studies comparing CPL and WT to peat-lite mixes are similar; however, a comparison of the two substrate components has not yet been reported. This research was conducted to compare the physical properties as well as plant response of two annual species to both substrate components in order to characterize differences, if any, between WT and CPL.

Materials and Methods

Experiment 1. Fresh 20–25 cm (8–10 in) diameter loblolly pine (*Pinus taeda* L.) trees from a pine plantation in Macon County, AL, were chipped with a Woodsman Model 334 Biomass Chipper (Woodsman, LLC Farwell, MI) and ground with a Williams Crusher Hammer Mill (Meteor Mill #40, Williams Patent Crusher and Pulverizer Co., Inc., St. Louis, MO) to pass a 0.95 cm (0.375 in) screen on January 19, 2009, to produce WT substrate. On the same day loblolly pine trees were cut and delimbed leaving the log and bark portions of the tree, which was then chipped and ground in the same way as the WT chips to produce chipped pine log substrate (CPL). The two substrates were placed in separate 1.78 m^3 (63 ft^3) woven polypropylene bulk bags and placed in the sun. On February 18, 2009, 30 days after the WT and CPL were processed, uniform plugs of vinca (*Catharanthus roseus* L. 'Grape Cooler') and impatiens (*Impatiens walleriana* Hook. f. 'Dazzler Apricot') were transplanted from 144 plug flats into 0.95 liter (1 qt) plastic containers and grown until April 1, 2009, in a twin walled polycarbonate greenhouse in full sun. Plants were grown in a WT:peat substrate (1:1, by vol) (WTP) or CPL:peat substrate (1:1, by vol) (CPLP). Sphagnum peat moss was obtained from SunGro Horticulture (Bellevue, WA). Both substrates were amended with 2.97 $kg{\cdot}m^{-3}$ (5 $lbs{\cdot}yd^{-3}$) crushed dolomitic limestone, 0.89 kg/m^3 (5 $lbs{\cdot}yd^{-3}$) 7-2-10 N-P-K nutrient charge (GreenCare Fertilizers, Kankakee, IL), and 154.7 $mL{\cdot}m^{-3}$ (4 $oz{\cdot}yd^{-3}$) AquaGro®-L (Aquatrols Corporation, Paulsboro, NJ). Plants were placed on a greenhouse bench and hand watered as needed. Plants were liquid fed beginning 10 days after potting (DAP) utilizing a 250 ppm N 20-10-20 N-P_2O_5-K_2O fertilizer every other watering (GreenCare Fertilizers Kankakee, IL). Data loggers were installed to capture actual greenhouse temperatures at 30 min intervals for the duration of the study. Greenhouse temperature daily average highs and lows were 29/21C (85/70F).

Substrate physical properties including bulk density (BD), air space (AS), container capacity (CC), and total porosity (TP) were determined for WTP and CPLP using the North Carolina State University Porometer Method (7). Particle size distribution was also determined for WTP and CPLP by passing a 100 g air-dried sample through 12.5, 9.5, 6.35, 3.35, 2.36, 2.0, 1.4, 1.0, 0.5, 0.25, and 0.11 mm sieves with particles passing the 0.11 mm sieve collected in a pan. Sieves were shaken for 3 min with a Ro-Tap sieve shaker [278 oscillations/min, 159 taps/min (Ro-Tap RX-29; W.S. Tyler, Mentor, OH)]. Leachates were collected using the Virginia Tech Extraction Method (17) and analyzed for pH and electrical conductivity ($dS{\cdot}cm^{-1}$) (EC) at 0, 7, 14, 21, 28, 35, and 42 DAP. Termination data, at 42 DAP, included final plant growth indices [(height + height + width / 3)] and substrate shrinkage measured from the top of the container to the substrate surface, final bloom counts, plant shoot dry weights, and root ratings based on a 1 to 5 scale. The scale rated roots with 1 indicating less than 20 percent of the substrate interface with roots present, 2 indicating 20 to 40 percent of the substrate interface with roots present, 3 indicating 40 to 60 percent of the substrate interface with roots present, 4 indicating 60 to 80 percent of the substrate interface with roots present, and 5 indicating roots visible at more than 80 percent of the container substrate interface.

Plants were arranged in a randomized complete block design with twelve blocks and three samples per block per treatment. Each species was set up as a separate experiment, with a total of 72 total pots per species. Data were subjected to t-test ($P = 0.05$) using SAS (Version 9.1; SAS Institute, Cary, NC).

Experiment 2. Experiment 2 was conducted similarly with the following exceptions. The WT and CPL material used in Experiment 2 was collected from the same bulk bags utilized in Experiment 1, and sphagnum peat moss was obtained from Lambert Peat Moss, Inc. (Riviere-Ouelle, Quebec, Canada). Plugs were planted on June 12, 2009, and the experiment was terminated on August 3, 2009. Greenhouse temperature daily average highs and lows were 31/23C (88/74F).

Results and Discussion

Experiment 1. There were particle size differences in only three sieve sizes (1.0–2.0 mm, 0.5–1.0 mm, and 0.25–0.5 mm) (Table 1). Particle size distribution data was grouped into texture sizes (> 3.2 mm being coarse, > 0.5–3.2 mm being medium, and < 0.5 mm being fine). For CPLP, 76.51% of particles were in the medium texture range, compared to 70.51% of the WTP; conversely, 24.88% of the WTP particles were fine textured, compared to only 19.57% of the CPLP. The greater percentage of fine particles present in WTP is likely due to the needles and small twigs on the WT when milled; however, these differences in particle size distribution did not translate into any differences in AS, CC, TP, or BD (Table 2).

There were minor differences in leachate pH and EC in the plant response test (Table 3). For both species, substrate

Table 1. Particle size distribution of *WholeTree* and chipped pine log substrates amended with peat.

	Experiment 1			Experiment 2			Exp. 1 vs. Exp. 2
Sieve opening	**WTP**[z]	**CPLP**[y]		**WTP**	**CPLP**		
(mm)	**(% dry weight)**		**Significance**	**(% dry weight)**		**Significance**	**Significance**
> 6.4	0.80	0.64	NS[x]	13.59	11.80	NS	***
3.2–6.4	3.81a	3.54	NS	8.87	8.90	NS	***
2.0–3.2	21.52	20.84	NS	24.19	26.23	NS	**
1.0–2.0	24.77	28.65	***	39.40	38.85	NS	***
0.5–1.0	24.22	26.74	***	9.04	8.91	NS	***
0.25–0.5	20.06	16.14	***	3.36	3.67	NS	***
0.105–0.25	4.20	2.84	NS	1.13	1.13	NS	***
< 0.105	0.62	0.59	NS	0.43	0.50	NS	NS
Coarse[w]	4.61	4.18	NS	22.46	20.70	NS	NS
Medium	70.51	76.51	**	72.63	73.99	NS	**
Fine	24.88	19.57	**	4.92	5.30	NS	**

[z] 1:1 *WholeTree*:peat.

[y] 1:1 chipped pine logs:peat.

[x] **,*** represent significance when $P \leq 0.01$, or 0.001, respectively. NS denotes no significance using t-test (n = 3).

[w] Particle texture, with particle size > 3.2 mm coarse, > 0.5–3.2 mm medium, and < 0.5 mm fine.

Table 2. Physical properties of *WholeTree* and chipped pine log substrates amended with peat.[z]

	(% volume)						(g·cm^{-3})	
	Air space		**Container capacity**		**Total porosity**		**Bulk density**	
Substrate	**Exp. 1**	**Exp. 2**	**Exp. 1**	**Exp. 2**	**Exp. 1**	**Exp. 2**	**Exp. 1**	**Exp. 2**
WTP[y]	19.6	19.6	76.8	76.8	96.4	96.0	0.12	0.13
CPLP[x]	17.6	17.7	72.4	72.4	90.0	90.0	0.12	0.13
Significance	NS[w]	NS	**	NS	*	NS	NS	NS

[z] Analysis performed using the NCSU porometer.

[y] 1:1 (v:v) *WholeTree*:peat.

[x] 1:1 (v:v) chipped pine logs:peat.

[w] *,** represent significance when $P \leq 0.05$ or 0.01 respectively. NS denotes no significance using t-test (n = 3).

Table 3. Effects of *WholeTree* and chipped pine log substrates amended with peat on pH and electrical conductivity in two greenhouse-grown annuals (Experiment 1).

	0 DAP[z]		**7 DAP**		**14 DAP**		**21 DAP**		**28 DAP**		**35 DAP**		**42 DAP**	
Substrate	**pH**	**EC**[y]	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**
							Catharanthus roseus 'Grape Cooler'							
WTP[x]	4.34	1.82	5.08	1.89	5.40	2.16	6.12	1.09	5.89	1.14	5.98	0.73	6.46	0.69
CPLP[w]	4.24	1.42	5.12	2.05	5.34	2.53	5.74	1.34	5.63	1.30	5.82	0.86	6.44	0.45
Significance	NS[v]	NS	NS	NS	NS	*	**	NS	*	NS	*	NS	NS	NS
							Impatiens walleriana 'Dazzler Apricot'							
WTP	4.34	1.82	5.24	1.91	5.45	1.95	5.90	1.24	6.09	0.84	6.02	0.87	6.82	0.35
CPLP	4.24	1.42	5.16	2.30	5.35	2.37	5.72	1.65	5.97	1.01	5.97	0.76	6.55	0.37
Significance	NS	*	NS	*	*	***	**	*	NS	NS	NS	**	NS	0.37

[z] Days after potting.

[y] Electrical conductivity ($dS \cdot cm^{-1}$) of substrate solution using the pour-through method.

[x] 1:1 (v:v) *WholeTree*:peat.

[w] 1:1 (v:v) chipped pine logs:peat.

[v] *,**,*** represent significance when $P \leq 0.05$, 0.01, or 0.001, respectively. NS denotes no significance using t-test (n = 8).

Table 4. Effects of *WholeTree* and chipped pine log substrates amended with peat on growth of two greenhouse-grown annuals (Experiment 1).

Substrate	Shrinkage (mm)[z]	GI (cm)[y]	Bloom count[x]	Dry weight (g)[w]	Root rating[v]
			Catharanthus roseus 'Grape Cooler'		
WTP[u]	9.33	20.31	3.50	6.89	3.67
CPLP[t]	11.00	20.14	4.17	7.34	3.22
Significance	NS[s]	NS	NS	*	NS
			Impatiens walleriana 'Dazzler Apricot'		
WTP	11.06	21.58	49.78	5.44	4.50
CPLP	10.50	21.40	51.09	5.13	4.50
Significance	NS	NS	NS	NS	NS

[z] Shrinkage in millimeters measured from the top of the container to the top of the substrate surface.

[y] Growth index in centimeters [(height + width + perpendicular width) / 3].

[x] Bloom counts determined by counting all attached flowers and buds showing color.

[w] Plant shoot dry weight in grams.

[v] Visual root rating on a 1 to 5 scale: 1–20% coverage; 2–40% coverage; 3–60% coverage; 4–80% coverage; 5–100% coverage.

[u] 1:1 (v:v) *WholeTree*:peat.

[t] 1:1 (v:v) chipped pine logs:peat.

[s] *,**,*** represent significance when $P \leq 0.05$, 0.01, or 0.001, respectively. NS denotes no significance using t-test (n = 8).

shrinkage, growth index, root ratings, and bloom count were all similar (Table 4). The only difference in plant response was dry weight: vinca grown in CPLP had a 6.5% greater shoot dry weight than those grown in WTP; however, plant dry weights for impatiens were similar.

Experiment 2. There were no differences in particle size distribution in Experiment 2 (Table 1); however, there was an obvious shift from Experiment 1 to Experiment 2 in particle texture (coarse vs. fine). In Experiment 1, the majority of the particle sizes were medium or fine textured in both substrates. In Experiment 2, the majority of the particle sizes were coarse or medium textured (Table 1). Coarse textured particles made up 22.46% of the dry weight in WTP compared to 20.7% in CPLP. In Experiment 1 these percentages were 4.62 and 4.18%, respectively. Differences in particle size distribution could be attributed to different peat moss sources for Experiment 1 and Experiment 2. The particle size and texture of the peat used in Experiment 2 was coarser than peat used in Experiment 1 (data not shown). However, differences in particle size distribution had no effect on substrate physical properties, as there were no differences in total porosity, air space, container capacity, or bulk density (Table 2) in either experiment. While the peat used in Experiment

Table 5. Effects of *WholeTree* and chipped pine log substrates amended with peat on pH and electrical conductivity in two greenhouse-grown annuals (Experiment 2).

	0 DAP[z]		7 DAP		14 DAP		21 DAP		28 DAP		35 DAP		42 DAP	
Substrate	pH	EC[y]	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC
								Catharanthus roseus 'Grape Cooler'						
WTP[x]	4.85	2.03	5.72	3.54	5.96	2.78	6.48	1.22	6.47	1.78	6.41	0.65	6.21	1.39
CPLP[w]	4.95	1.91	5.59	3.52	5.94	3.18	6.41	1.08	6.69	1.11	6.36	0.93	6.09	1.01
Significance	NS[v]	NS	*	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
								Impatiens walleriana 'Dazzler Apricot'						
WTP	4.85	2.03	5.60	3.65	5.91	3.23	5.89	2.75	6.89	1.45	6.44	1.45	6.46	1.37
CPLP	4.95	1.91	5.67	3.59	5.92	3.23	6.14	2.15	6.64	1.60	6.35	1.29	6.53	1.30
Significance	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS

[z] Days after potting.

[y] Electrical conductivity ($dS \cdot cm^{-1}$) of substrate solution using the pour-through method.

[x] 1:1 (v:v) *WholeTree*:peat.

[w] 1:1 (v:v) chipped pine logs:peat.

[v] *represent significance when $P \leq 0.05$. NS denotes no significance using t-test (n = 8).

Table 6. Effects of *WholeTree* and chipped pine log substrates amended with peat on growth of two greenhouse-grown annuals (Experiment 2).

Substrate	Shrinkage (mm)[z]	GI (cm)[y]	Bloom count[x]	Dry weight (g)[w]	Root rating[v]
			Catharanthus roseus 'Grape Cooler'		
WTP[u]	7.95	20.57	14.61	22.07	3.89
CPLP[t]	7.56	19.82	13.06	21.25	3.78
Significance	NS[s]	NS	NS	NS	NS
			Impatiens walleriana 'Dazzler Apricot'		
WTP	9.56	16.95	37.30	8.49	3.22
CPLP	8.78	16.80	27.89	7.77	2.33
Significance	NS	NS	*	NS	*

[z] Shrinkage in millimeters measured from the top of the container to the top of the substrate surface.

[y] Growth index in centimeters [(height + width + perpendicular width) / 3].

[x] Bloom counts determined by counting all attached flowers and buds showing color.

[w] Plant shoot dry weight in grams.

[v] Visual root rating on a 1 to 5 scale: 1–20% coverage; 2–40% coverage; 3–60% coverage; 4–80% coverage; 5–100% coverage.

[u] 1:1 (v:v) *WholeTree*:peat.

[t] 1:1 (v:v) chipped pine logs:peat.

[s] * represents significance when $P \leq 0.05$. NS denotes no significance using t-test ($n = 8$).

2 was a coarser texture, it still contributed to water holding capacity and other physical properties.

In the plant response test, vinca grown in CPLP had a higher pH at 7 and 28 DAP (Table 5). All other pH and EC measurements for vinca in experiment 2 were similar. With impatiens, all pH and EC measurements were similar except for 21 DAP, where plants grown in CPLP had a higher pH than WTP.

Vinca had similar shrinkage, growth index, bloom counts, root ratings, and dry weight in both substrates (Table 6). Impatiens plants grown in WTP had more blooms and greater root ratings than those grown in CPLP. Shrinkage, growth index, leaf greenness, and dry weights were all similar in impatiens.

Results from these experiments indicate that CPL and WT can be used interchangeably. While minor differences in physical properties and plant response did occur, growth indices and leaf greenness were similar in both species, suggesting that plants grown in CPL and WT are equally marketable. Our data supports previous independent findings by Wright and Browder (17) and Jackson, et al. (10) that CPL is an appropriate alternative for container grown annuals, and by Fain et al. (4, 5, 6) that WT is also a suitable alternative. The most interesting results from this study were perhaps the shift in plant dry weights for both species in both substrates from Experiment 1 to Experiment 2. While the only statistical difference in plant growth occurred in vinca dry weight in Experiment 1 and impatiens bloom count and root rating in Experiment 2, the dry weight tripled for vinca from Experiment 1 to Experiment 2, and in impatiens the dry weight nearly doubled from Experiment 1 to Experiment 2. In vinca, bloom counts also tripled from Experiment 1 to Experiment 2. Warmer temperatures, longer day length or the different source of peat in Experiment 2 may be an explanation for these differences; however, another explanation for these differences may be the age of the material. Unpublished work by the authors now suggests that aging wood fiber material may be more conducive to plant growth. In Experiment 1 the material had been aged 30 days; in Experiment 2 the material had been aged 144 days. Further research is needed to investigate the benefits, if any, of aging a wood-fiber substrate component; however, CPL and WT are both viable options for greenhouse growers to extend peat supplies.

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