Composted Poultry Litter as an Amendment for Substrates With High Wood Content ©[1]

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Whole tree (WT) and clean chip residual (CCR) are potential new nursery substrates that are by-products of the forestry industry containing high wood content. Initial immobilization of nitrogen is one limitation of these new substrates; however the addition of composted poultry litter (CPL) to substrates containing high wood content could balance initial nitrogen immobilization and provide an inexpensive fertilizer source for growers. This study evaluated the growth of five woody nursery crops being grown in WT, CCR, and pine bark (PB) with the addition of CPL or peat as a substrate amendment. Results indicate that woody nursery crops can be grown successfully in WT and CCR substrates (6 : 1, v/v) with CPL. Use of CPL in WT and CCR substrates provides an alternative to traditional PB plus peat-based combinations in container plant production while providing poultry producers an environmentally sound means of waste disposal.

INTRODUCTION

Pine bark (PB) and PB plus peat combinations are the predominant substrate components for container plant production in the southeastern United States of America (Boyer et al., 2008). Reduced forestry production in the United States of America paired with the increased use of PB as a fuel source is reducing the availability of PB. The growing concern over the future availability of PB, high shipping costs associated with peat and the argument that peat is a relatively non-renewable resource, has led researchers to explore alternatives to these two commonly used substrate components (Boyer et al., 2008; Fain et al., 2008).

Whole tree substrate (WT) consists of entire pine trees (*Pinus taeda* L.) which are harvested from pine plantations at the thinning stage and chipped whole and later ground into smaller sizes based upon crop specification (Boyer et al., 2008). The WT substrate is made up of wood, bark, limbs, needles, cones, and is used fresh after grinding. Studies suggest WT can be used successfully in production of greenhouse crops (Fain et al., 2008).

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Mobile field equipment is now being used in pine tree harvesting operations which process trees into clean chips for pulp mills, leaving behind a product composed of about 50% wood, 40% bark, and 10% needles (Boyer et al., 2008). This material, referred to as clean chip residual (CCR) is either sold as boiler fuel or spread across the harvesting area. The CCR accounts for about 25% of the total biomass harvested. With millions of acres in the southeast in forestry production, CCR has the potential to provide an economical and sustainable substrate alternative for the nursery industry (Boyer et al., 2008).

The major concern associated with the use of a wood-based substrate is the initial immobilization of nitrogen. Reports indicate that substrates containing high wood content require higher fertilizer applications to achieve similar plant growth as standard substrates (Gruda et al., 2000; Jackson et al., 2006). Use of composted poultry litter (CPL) in these wood-based substrates could balance the initial nitrogen immobilization while providing poultry farmers a new outlet for the growing problem of waste disposal.

One of the problems in modern agricultural operations is the large amount of waste generated by intense animal production in concentrated areas. Historically land application was the preferred method of waste disposal with almost 90% of all poultry litter being applied to agricultural land (Daniel et al., 1995). In areas where poultry production is intense and concentrated, such as in the Southeastern U.S.A., excess manure still exists and limits have been placed on the amount of litter that can be spread on agricultural land, leaving poultry producers in need of new, economical ways to safely dispose of this waste.

Nutrients present in poultry manure can provide an economical alternative to costly inorganic fertilizers and soil amendments. Fuel costs associated with importing peat are decreasing grower's profit margins (Fain et al., 2007). As fuel costs increase fertilizer becomes more expensive. Fertilizer prices rise with the cost of natural gas which is the primary raw material used to produce ammonium nitrate (Wen-yuan, 2007). National composite fertilizer prices increased 113% between 2000 and 2007 due to increases in nitrogen costs. During this 7-year period the price of ammonium nitrate, the main source of nitrogen in fertilizer production, increased 130% and the price of urea, the primary solid nitrogen fertilizer used in the U.S.A. rose 127% (Wen-yuan, 2007). The USDA Economic Research Service reported a 20% rise in national fertilizer prices in 2007 and is forecasting an additional 18% increase by the end of 2008. As fertilizer prices continue to rise, it is important to search for cost-saving alternatives to conventional fertilizers. Poultry litter has higher concentrations of nutrients than other animal wastes, is relatively dry (easily mixed with substrates), and is totally collectable (Stephenson et al., 1990). Adding CPL to PB, WT, or CCR substrate could provide the nursery industry with a valuable substrate component and a low-cost nutrient supplement while providing poultry producers with a suitable means of waste disposal.

The objective of this study was to evaluate WT, CCR, and PB with the addition of CPL as a substrate for production of container-grown nursery crops.

MATERIALS AND METHODS

Five species [*Rhododendron* 'Iveryana' (azalea), *Buxus sempervirens* L. (boxwood), *Ilex crenata* Thunb. 'Compacta' (holly), *Loropetalum chinense* Oliv. f. rubrum 'Chang's Ruby' (loropetalum), and *Ternstroemia japonica* [syn. *T. gymnanthera*

Thunb. (cleyera)] were transplanted from cell pack liners (72, 48, 38, 50, and 50 cell pack liners, respectively) into full gallon containers on 31 May 2007, placed in full sun and over-head irrigated as needed. Treatments were nine substrates composed of Whole Tree (WT), clean chip residual (CCR) or pinebark (PB) mixed with either composted poultry litter (CPL) or Peat on a 6 : 1 volume to volume (v/v) basis (Table 1). Treatments included WT and CPL (6 : 1, v/v), CCR and CPL (6 : 1, v/v), PB and CPL (6 : 1, v/v), 100% WT, 100% CCR, 100% PB, WT and Peat (6 : 1, v/v), CCR and Peat (6 : 1, v/v), and PB and Peat (6 : 1, v/v). The WT and CCR used in this study were processed to pass a 0.64 cm (¼ in.) and 0.95 cm (⅜ in.) screen, respectively. Fresh poultry litter used was obtained from Greenville, Alabama and was composted in an in-vessel rotating-drum digester (BMG Organics Inc.) for 2 weeks until temperature fluctuations indicated that the material was fully composted. Nutrient content of CPL based on analysis by Brookeside Laboratories Inc. (New Knoxville, Ohio) was 2.5% nitrogen, 1.4% phosphorous, and 2.3% potassium on a wet-weight (as-is) basis. Each substrate blend was incorporated with 10.9 $kg{\cdot}m^{-3}$ (18 lb/yd^{-3}) of Harrell's 15–6–12 (N–P–K) 8 to 9 mon formulation, 1.2 $kg{\cdot}m^{-3}$ (2 lb/yd^3) gypsum and 0.9 $kg{\cdot}m^{-3}$ (1.5 lb/yd^3) Micromax, Scotts Co. Plants were arranged by species in a randomized complete block design with eight single plant replications. Pour-through extractions were conducted at 7, 15, 30, 60, 90, 120, and 180 days after transplanting (DAT) and analyzed for pH and electrical conductivity. Subjective foliar color ratings were taken at 60 and 120 DAT on a scale of 1 to 5 where 1 = severe chlorosis, 2 = moderate chlorosis, 3 = slight chlorosis, 4 = light green, and 5 = dark green. Growth indices [(height + width1 + width2)/3] were taken at 120 and 340 DAT, and shrinkage measurements (measured in cm from the media surface to the top of the pot) were taken on boxwood at 120 DAT and 340 DAT. Root ratings were taken by rating root coverage of the outer surface of the root ball at 340 DAT on a scale of 1 to 5 with 1 = no visible roots, 2 = 25% of surface covered with roots, 3 = 50% root coverage, 4 = 75% coverage, and 5 = 100% coverage.

RESULTS

Addition of CPL tended to increase pH while peat caused a decline in pH (Table 1). Initial data at 7 DAT showed that pH levels for PB (3.8), CCR (4.7), and WT (5.2) were increased to pH levels of 5.8, 6.7, and 6.9, respectively, when CPL was added to the respective substrates. Conversely, addition of peat tended to lower pH for PB (3.8 to 3.7), CCR (4.7 to 4.2), and WT (5.2 to 4.3). The pH levels for all substrates amended with CPL declined over time; however pH levels at the end of the study were within the desired range (4.5 to 6.5) (SNA, 2007). However, substrates with peat added or 100% WT, CCR, or PB had unacceptable pH levels at 180 DAT (less than 4.5).

Electrical conductivity (EC) levels were initially high in WT, CCR, and PB substrates amended with CPL (1.3, 1.2, and 1.6, respectively). However by 30 DAT all CPL treatments were within the recommended range (0.5 to 1.0 $dS{\cdot}m^{-1}$) (SNA, 2007) with the exception of PB : CPL, which remained slightly higher. At 60 DAT all CPL treatments had acceptable EC levels and remained within an acceptable range for the duration of the study. Substrates amended with peat had slightly higher EC levels than 100% substrates (WT, CCR, and PB), which had desirable EC levels throughout the study. In general, CPL treatments had the highest pH

Table 1. Solution pH and electrical conductivity (EC) of substrates[Z].

	7 DAT[Y]		30 DAT		60 DAT		120 DAT		180 DAT	
Treatment	pH	EC (dS/m)	pH	EC (dS/m)	pH	EC (dS/m)	pH	EC (dS/m)	pH	EC (dS/m)
WT[X] : CPL[W] (6 : 1, v/v)	6.9 a[S]	1.3 a	6.6 a	0.3 e	6.3 a	0.4 b	5.9 a	0.3 a	5.3 b	0.24 a
CCR[V] : CPL (6 : 1, v/v)	6.7 b	1.2 a	6.4 b	0.5 cde	5.9 a	0.8 a	6.0 a	0.2 a	5.8 a	0.15 bc
PB[U] : CPL (6 : 1, v/v)	5.8 c	1.6 a	5.6 c	1.2 a	5.5 b	0.5 ab	5.2 ab	0.2 a	4.9 b	0.13 c
WT (100%)	5.2 d	0.4 b	4.9 d	0.4 de	5.1 c	0.4 b	3.8 c	0.3 a	3.4 c	0.2 ab
CCR (100%)	4.7 e	0.4 b	4.6 e	0.8 b	4.6 ed	0.6 ab	4.5 bc	0.3 a	3.4 c	0.18 abc
PB (100%)	3.8 g	0.4 b	3.8 g	0.7 bc	4.3 e	0.5 ab	3.5 c	0.2 a	3.3 c	0.21 ab
WT : P[T] (6 : 1, v/v)	4.3 f	0.6 b	4.4 f	0.4 de	4.7 d	0.4 b	4.6 bc	0.2 a	3.5 c	0.2 abc
CCR : P (6 : 1 v/v)	4.2 f	0.6 b	4.3 f	0.6 bcd	4.4 ed	0.5 b	3.7 c	0.2 a	3.7 c	0.18 abc
PB : P (6 : 1, v/v)	3.7 h	0.6 b	3.7 g	0.8 b	4.3 e	0.4 b	3.8 c	0.3 a	3.5 c	0.19 abc

[Z]pH and EC of solution obtained by the pour-through method.
[Y]Days after transplanting.;
[X]WT = Whole tree.
[W]CPL = Composted poultry litter.
[V]CCR = Clean chip residual.
[U]PB = Pinebark
[S]Means separated within column by Duncan's Multiple Range Test at $P = 0.05$.

and the highest EC throughout the study. The pH levels of substrates amended with CPL were more desirable than 100% WT, CCR, and PB or substrates containing peat, which remained very acidic throughout the study. While high EC levels may be a concern for more sensitive crops, the majority of woody nursery crops would not be affected by the EC levels exhibited in CPL treatments, which peaked at 1.6 and declined quickly.

Growth indices data [(height + width1 + width2)/3] at 120 DAT indicated that hollies were larger when grown in 100% WT, CCR, or PB (Table 2). At 340 DAT the hollies grown in 100% WT, CCR, or PB, as well as CCR : Peat grew the largest; however growth was statistically similar to all other treatments except WT : CPL and PB : Peat, which were smaller (Table 2). At 120 DAT, boxwood grown in CCR : CPL were larger than plants in all other substrates. This trend continued at 340 DAT. The least growth in boxwood occurred in substrates containing 100% PB or PB : Peat, which may be a result of low pH levels. *Loropetalum* were larger in substrates containing 100% CCR or CCR : Peat at 120 and 340 DAT while the least growth occurred in WT : CPL. Azaleas grown in substrates containing 100% CCR were the largest at 120 DAT; however, by 340 DAT growth indices of plants grown in 100% CCR were statistically similar to WT : Peat and CCR : Peat. No differences were observed in the growth of cleyera in any substrate throughout the study.

Foliar color ratings (FCR) were similar among all treatments in holly and boxwood at 60 and 120 DAT (Table 3). *Loropetalum* FCR were highest in 100% CCR at 60 DAT; however by 120 DAT, 100% WT received the highest ratings. Azaleas grown in WT : Peat received the highest FCR at both 60 and 120 DAT. Azaleas had the poorest FCR in treatments containing CPL, possibly due to higher pH levels. Cleyera FCR were similar for plants grown in 100% WT, CCR, or PB and CCR : Peat, and this trend continued at 120 DAT.

Hollies grown in substrates containing CPL had the lowest root ratings, and root ratings were statistically similar among all other treatments (Table 4). Boxwood root ratings were highest in CCR : CPL, and the lowest root rating occurred in substrates containing PB : Peat. Root ratings in loropetalum, azalea, and cleyera were all lowest in WT : CPL; however, all other treatments had root ratings similar to the traditional PB : Peat substrate.

Shrinkage measurements were all similar with the exception of WT : CPL and CCR : CPL, which had more shrinkage than any other treatment at 340 DAT (Table 4) possibly due to further decomposition of the CPL. Interestingly, PB : CPL substrates had the least shrinkage of any treatment, even less than PB : Peat combination (3.6 to 4.3). The high wood substrates (WT and CCR) had more shrinkage in general than treatments containing PB. However, similarities between 100% WT, CCR, and PB indicate that the use of high wood substrates alone does not increase media settling due to wood decomposition.

All substrates exhibited acceptable results with regard to growth indices, and FCR at the completion of the study. All substrates without the addition of CPL had pH levels too low to be considered acceptable (below 4.5). The CPL treatments exhibited more shrinkage than treatments containing peat or no CPL, and further research may be needed to develop the proper volume of CPL to add to container substrates to reduce media settling.

Table 2. Influence of substrate composition on growth indices[Z] at 120 and 340 days after transplanting.

Substrate	Holly		Boxwood		Loropetalum		Azalea		Cleyera	
	120 DAT[T]	340 DAT	120 DAT	340 DAT	120 DAT	340 DAT	120 DAT	340 DAT	120 DAT	340 DAT
WT[Y] : CPL[X] (6 : 1, v/v)	27.0 bcd[S]	32.8 b	15.3 b	25.2 b	34.4 e	39.5 c	20.5 d	29.1 c	20.0 a	31.3 a
CCR[W] : CPL (6 : 1, v/v)	32.3 a	35.8 ab	20.6 a	30.2 a	45.8 bc	46.4 b	19.8 d	31.6 bc	24.7 a	35.6 a
PB[V] : CPL (6 : 1, v/v)	31.1 ab	36.2 ab	17.4 b	23.7 bc	37.3 de	40.7 c	21.1 cd	29.6 c	25.3 a	32.3 a
WT (100%)	28.8 abcd	36.7 a	14.7 cb	21.7 cd	45.1 c	46.4 b	23.0 bcd	33.7 b	25.6 a	35.1 a
CCR (100%)	29.4 abc	37.4 a	14.8 cb	19.2 de	53.3 a	53.2 a	27.3 a	39.4 a	25.6 a	35.9 a
PB (100%)	28.1 bcd	36.2 ab	12.4 c	16.5 e	41.8 cd	43.2 bc	24.8 ab	33.4 b	24.8 a	33.5 a
WT : P[U] (6 : 1, v/v)	26.0 cd	34.5 ab	15.1 bc	20.4 d	41.9 cd	42.6 bc	20.7 d	38.9 a	20.7 a	32.3 a
CCR : P (6 : 1, v/v)	28.3 abcd	36.7 a	14.8 bc	19.5 de	51.2 ab	51.6 a	24.0 bc	37.9 a	24.6 a	32.4 a
PB : P (6 : 1, v/v)	24.7 d	32.8 b	12.5 c	17.0 e	42.6 cd	44.1 bc	20.4 d	31.9 bc	24.2 a	41.0 a

[Z]Growth Indices = [(height + width1 + width2)/3].
[Y]WT = Whole tree.
[X]CPL = Composted poultry litter.
[W]CCR = Clean chip residual.
[V]PB = Pine bark.
[U]P = Peat.
[T]DAT = Days after transplanting.
[S]Means separated using Duncan's Multiple Range Test at $P = 0.05$.

Table 3. Influence of substrate compositition on foliar color ratings[Z] at 60 and 120 DAT[Y].

	Holly		Boxwood		Loropetalum		Azalea		Cleyera	
Treatment	60 DAT	120 DAT	60 DAT	120 DAT	60 DAT	120 DAT	60 DAT	120 DAT	60 DAT	120 DAT
WT[X] : CPL[W] (6 : 1, v/v)	4.0 a[S]	4.0 a	3.9 ab	4.0 a	3.1 d	3.8 d	3.4 c	3.6 d	3.7 c	3.6 c
CCR[V] : CPL (6 : 1, v/v)	4.0 a	4.0 a	4.0 a	4.0 a	3.8 bc	4.3 ab	3.5 c	3.8 d	3.8 bc	3.1 d
PB[U] : CPL (6 : 1, v/v)	4.0 a	4.0 a	3.8 ab	4.0 a	3.9 b	4.3 ab	3.9 ab	3.8 d	3.8 bc	3.8 bc
WT (100%)	4.0 a	4.0 a	3.9 ab	4.0 a	3.8 bc	4.5 a	3.9 ab	4.2 bc	4.1 ab	4.4 a
CCR (100%)	4.0 a	4.0 a	3.9 ab	4.0 a	4.4 a	4.1 bc	4.2 a	4.5 ab	4.0 abc	4.0 abc
PB (100%)	4.0 a	4.0 a	3.4 c	4.0 a	3.6 c	3.9 cd	3.9 ab	3.9 cd	4.1 ab	4.1 ab
WT : P[T] (6 : 1, v/v)	4.0 a	4.0 a	3.9 a	4.0 a	3.6 c	4.1 bcd	4.1 a	4.8 a	3.8 bc	3.9 bc
CCR : P (6 : 1, v/v)	4.0 a	4.0 a	3.9 ab	4.0 a	4.3 a	4.1 bcd	3.9 ab	4.2 bc	3.9 abc	3.9 bc
PB : P (6 : 1, v/v)	4.0 a	4.0 a	3.6 bc	4.0 a	3.8 bc	3.4 e	3.9 ab	3.9 cd	4.2 a	4.0 abc

[Z] Foliar color rated on a scale of 1 to 5: 1 = severe chlorosis; 5 = dark green.
[Y]DAT = Days after transplanting.
[X]WT = Whole tree.
[W]CPL = Composted poultry litter.
[V]CCR = Clean chip residual.
[U]PB = Pinebark.
[T] P = Peat moss.
[S] Means separated using Duncan's Multiple Range Test at $P = 0.05$.

Table 4. Influence of substrate composition on root rating[Z] and shrinkage[Y].

	Root ratings					Shrinkage	
Treatment	Holly	Boxwood	Loropetalum	Azalea	Cleyera	120 DAT[S]	340 DAT
WT[X] : CPL[W] (6 : 1, v/v)	3.1 b[R]	2.8 bc	2.2 d	1.3 e	2.3 c	5.7 a	7.35 a
CCR[V] : CPL (6 : 1, v/v)	3.7 b	3.8 a	2.6 c	2.2 d	3.1 bc	4.9 b	6.5 b
PB[U] : CPL (6 : 1, v/v)	3.6 b	3.1 b	3.3 b	2.3 d	3.8 bc	3.1 e	3.6 e
WT (100%)	4.6 a	2.4 c	3.6 ab	3.4 c	4.2 a	3.7 cd	4.5 cd
CCR (100%)	4.8 a	2.7 bc	3.9 a	4.3 ab	4.0 ab	4.0 c	4.5 cd
PB (100%)	4.6 a	1.6 d	3.6 ab	4.1 b	3.3 b	3.4 de	4.1 de
WT : P[T] (6 : 1, v/v)	4.3 a	2.3 c	3.4 ab	4.1 b	3.2 bc	4.1 c	4.8 c
CCR : P (6 : 1, v/v)	4.7 a	1.8 d	3.6 ab	4.6 a	3.6 ab	3.7 cd	4.3 cd
PB : P (6 : 1, v/v)	4.3 a	1.4 d	2.9 c	3.8 b	4.0 ab	3.7 cd	4.3 cd

[Z]Root rating scale of 1 to 5: 1 = very poor root system; 5 = very strong root system.
[Y]Shrinkage = measure (cm) from media surface to the top of pot.
[X]WT = Whole tree.
[W]CPL = Composted poultry litter.
[V]CCR = Clean chip residual.
[U]PB = Pinebark.
[T]P = Peat.
[S]DAT = Days after transplanting.
[R]Means separated using Duncan's Multiple Range Test at $P = 0.05$.

DISCUSSION

Similarities amongst substrates in this study amended with peat or CPL indicate that CPL could be an economically viable and sustainable substrate amendment for container plant production. While growth differences occurred with individual species throughout the study, at the end of the study all five species grown in high-wood substrates had growth equal to or larger than plants grown in the PB : peat commercial standard substrate. Use of CPL in container production could balance initial nitrogen immobilization which is often a concern when using substrates with high wood content. As PB supplies decline and fertilizer prices continue to increase, growers must look to the future for economically sustainable substrates. These results show high wood substrates with or without CPL (depending on crop) have potential to address future industry needs.

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