Changes in Physical Properties of a Pine Tree Substrate in Containers Over Time©

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The objective of this work was to determine and compare the changes in physical properties and substrate shrinkage of a pine tree substrate (PTS) to a traditional peat substrate in fallow containers over time under fertigated greenhouse conditions. Pine tree substrates were produced from loblolly pine trees (*Pinus taeda* L.) that were chipped, and hammer milled with different screen sizes. Substrates used in this study included peat-lite (PL), PTS produced with a 2.38-mm (3⁄32-in.) screen (PTS1), and a PTS produced with a 4.76-mm (3⁄16-in.) screen (PTS2). Containers were filled with the individual substrates, fertilized weekly with 300 ppm N, and maintained under greenhouse conditions for 14 weeks. Initial and final substrate physical properties and substrate shrinkage were determined to evaluate and compare changes in the substrates that occur over time. Initial and final air space (AS) was higher in both PTSs compared to PL and container capacity (CC) of PTS1 was equal to PL initially and at the end of the experiment. The initial and final CC of PTS2 was lower than PL. Substrate shrinkage was not different between PL and PTS1, but greater than shrinkage with the coarser PTS2.

INTRODUCTION

Substrate chemical properties can be maintained or changed by fertilizing or by adding other chemical drenches, but physical properties of container substrates have to be optimal from the beginning because they are impossible to change during production. For container-grown plants, it is important that a substrate maintain stability (structure) and a balance between air space (AS) and container capacity (CC) during production so that growing conditions remain favorable for plant growth. It is believed that physical properties of substrates initially considered appropriate for plant growth may deteriorate/change over time in containers due to several processes (Allaire-Lueng et al., 1999).Changes include AS reduction due to settling and segregation of particles of variable sizes (Bures, 1993), shrinkage of the substrate (Bruckner, 1997), and organic matter decomposition and physical breakdown of particles (Nash and Laiche, 1981).

Interest in using wood-based substrates has increased in recent years as potential replacement materials for peat and pine bark for greenhouse and nursery crop production. As the use of wood substrates increases, further evaluation of their management requirements and stability during crop production is needed. Recently, pine tree substrates (PTS) have been developed and researched in the Southeastern United States for nursery and greenhouse crop production (Fain et al, 2008, Jackson and Wright, 2008; Jackson et al., 2008; Wright and Browder, 2005). Researchers have shown that PTS can be constructed to produce a wide range of physical properties including AS and CC that are similar to commercial peat substrates (Jackson and Wright, 2008; Saunders et al., 2006).

Shrinkage of wood substrates in containers has been reported to range from 36% volume loss over 15 months (Fischer et al., 1993) to 50% volume loss over 51 weeks (Meinken and Fischer, 1997) during crop production. The wood substrates used in these reports were wood fiber (so named due to their manufacturing process and physical properties) and were derived from a mixture of various tree species; primarily spruce (*Picea abies* L.). Jackson and Wright (2008) and Jackson et al. (2008) report no significant visual substrate shrinkage or decomposition of PTS during greenhouse and nursery crop production and Fain et al. (2008) reported less shrinkage of a PTS than a peat substrate during a 5-week greenhouse trial. The change in physical properties [total porosity (TP), AS, and CC] of PTS during crop production have not been reported, and need to be addressed before large-scale production and use of this substrate begins. Determination of the changes in substrate physical properties in containers over time (during or at the end of crop production) is difficult to measure and rarely reported in the literature due to the absence of a generally accepted and official measurement procedure (Bilderback et al., 2005).

MATERIALS AND METHODS

The substrates used in this experiment were (1) PTS produced with a 2.38-mm (3⁄32-in.) screen (PTS1); (2) PTS produced with a 4.76-mm (3⁄16-in.) screen (PTS2); and (3) a mix composed of peat and perlite (4 : 1, v/v; peat-lite – PL). The PTSs selected for this experiment were chosen based on their range of physical properties (Jackson and Wright, 2008). Pine tree substrates were produced from 12-year-old loblolly pine trees [approximately 25-cm (10-in.) in basal diameter] that were harvested at ground level, delimbed on 9 Apr. 2007 in Blackstone VA, and chipped with bark intact on 8 Aug. 2007 with a Bandit Chipper (Model 200, Bandit Industries, Inc. Remus, Michigan).Wood chips were then hammer milled on 8 Aug. 2007 to pass through either the 2.38-mm (3⁄32-in.) or 4.76-mm (3⁄16-in.) screens. Peat-lite substrate was pre-plant amended with dolomitic lime at a rate of 3.6 $kg \cdot m^{-3}$ (6.0 lb/yd^3) and calcium sulfate ($CaSO_4$) at a rate of 0.6 $kg \cdot m^{-3}$ (1.0 lb/yd^3). Neither PTS1 or PTS2 were amended with lime due to the relatively inherent high pH (~6.0) of freshly ground pine wood, but both PTSs were amended with 0.6 $kg \cdot m^{-3}$ (1.0 lb/yd^3) $CaSO_4$ which has been observed to improve growth of herbaceous species (data not shown).

Samples of all substrates were collected on 14 Aug. 2007.Substrate samples in the amount of 25-L (7-gal) were force-air-dried for 2 days then bagged and dry-stored for 14 weeks. Plastic containers measuring 12 cm tall × 15 cm wide (4.8 inch × 6.0 inch) were filled with PL, PTS1, and PTS2 on 14 Aug. 2007 and placed fallow on a greenhouse bench. Six replications of each substrate were fertilized with 300 ppm N made from Peters 20N–4.4P–6.6K Peal-Lite Special (The Scotts Co., Marysville, Ohio) containing 12% nitrate (NO_3-N) and 8% ammonium (NH_4-N) until 12 Nov. 2007 (96 days after potting; DAP). Containers were irrigated once weekly with 500 mL of fertilizer solution. Substrate shrinkage (cm) was determined by measuring the difference in substrate height (from the top of the containers to the substrate surface) at 1 DAP, following the first irrigation, and again at 96 DAP. At 96 DAP, two containers of each substrate were combined for physical property determination (n = 3).

Physical properties (TP, AS, and CC) were determined on 10 Dec. 2007 on three replicate samples of each substrate from the initial dry-stored bagged samples and from the fallow samples fertilized in containers for 14 weeks, using the North Carolina State University Porometer Method (Fonteno et al. 1995). Determination of physical properties of undisturbed substrate-filled containers was not conducted in this study. Analysis of the substrates that were in containers for 14 weeks were determined as an indicator of how the breakdown/decomposition of the materials changed physical properties over time compared with how they were initially (at potting). The objective of this study was to determine and compare the changes in physical properties (including substrate shrinkage) of a pine tree substrate to a traditional peat substrate after 14 weeks in fallow containers under fertigated greenhouse conditions.

RESULTS

Physical Properties: Initial. Total porosity was higher in both PTSs compared to PL, and were within, or higher than, the upper limit of the recommended range of (50% to 85%; Yeager et al., 2007; Table 1). Air space was high in both PTSs and within the recommended range (10% to 30%; Table 1).Peat-lite had the lowest percentage AS (15%) but was within the recommended range. Container capacity values for PTS1 were equal to PL and the PTS1 values were higher than the PTS2 values. This is likely due to the higher percentage of fine particles in PTS1 (data not shown) compared to PTS2 which are known to hold water thereby increasing CC.

Physical Properties: Final. Total porosity increased in PL and PTS1 after 14 weeks but did not change in PTS2, and all substrate TP values were above the upper limit of the recommended range (50% to 85%; Table 1). Similar to these results, Allaire-Leung et al. (1999) reported an increase in TP over time in containers of peat, sand, and sawdust (40 : 20 : 40, by volume). Higher than recommended TP values (>85%) have also been previously reported with several commercial wood substrates in Europe, including Cultifiber® (94%), Fibralur® (96%), Hortifiber® (94%), Pietal® (93%), and Toresa® (92% to 97%; Gumy, 2001; Raviv and Leith, 2008). Air space did not change for PTS2, but decreased in PL and PTS1. Air space for all substrates was within the recommended range (10% to 30%) after 14 weeks. Container capacity values were equal in PL and PTS1 and were lowest in PTS2 (Table 1). Container capacity increased in all substrates after 14 weeks and was at or above the suggested range (45% to 65%) at the end of the experiment. Decreased AS and increased CC over time could be due to the settling "nesting" of the particles in a substrate when the finer particles fit between larger particles as described by Bilderback and Lorscheider (1995) or due to substrate decomposition. Over time for PTSs, the changes in physical characteristics were minor and with the exception of TP were substantially the same as those in PL showing that PTS can maintain desirable physical properties over time (14 weeks) under greenhouse growing conditions.

Substrate Shrinkage. Shrinkage after 14 weeks was lowest in PTS2 (7%) followed by PL (12%), and PTS1 (13%; Table 1). Less shrinkage with PTS2 is likely due to the larger particle size compared to PTS1 which agrees with observations by Wang (1994) who reported less shrinkage of a coarse particle substrate derived from kenaf wood compared to a smaller particle kenaf substrate. Conversely, the increased shrinkage observed in PL and PTS1 is likely due to their high percentage of small particles (Table 1). Shrinkage is due to either breakdown

Table 1. Initial and final (after 14 weeks in containers fertilized weekly with 300 ppm N) physical properties and shrinkage of peat-lite (PL) and pine tree substrates (PTS).[z]

	Total porosity[y] (% vol)			Air space[x] (% vol)			Container capacity[w] (% vol)			Substrate shrinkage[v] (%)
Substrate	Initial	Final	LSD	Initial	Final	LSD	Initial	Final	LSD	
PL[u]	80.6 b[t]	85.9 b	3.5[s]	15.0 c	13.0 c	1.9	65.6 a	72.9 a	4.8	11.9 a
PTS1[r]	86.7 a	90.0 a	2.4	22.1 b	18.0 b	1.5	64.6 a	72.0 a	3.0	12.7 a
PTS2[r]	84.9 a	89.4 a	4.7	30.2 a	24.7 a	7.9	54.6 b	64.9 b	4.8	6.8 b
Range[q]	50–85	—		10–30	—		45–65	—		—

[z] Data were collected from three samples per substrate and represented as means. Analysis performed using the North Carolina State University Porometer method (Fonteno et al., 1995).

[y] Total porosity is equal to container capacity + air space.

[x] Air space is the volume of water drained from the sample ÷ volume of the sample.

[w] Container capacity is (wet weight – oven dry weight) ÷ volume of the sample.

[v] Shrinkage = substrate height in container at 1 day after potting (DAP) - substrate height at 96 DAP.

[u] PL composed of 80% peat moss / 20% perlite (v/v).

[t] Means separated within columns (initial and final) by Duncan's multiple range test, $P \leq 0.05$.

[s] Means were separated within rows between initial and final substrate properties by least significance difference (LSD) at $P \leq 0.05$.

[r] PTS produced from 12-year-old loblolly pine trees harvested at ground level, delimbed, chipped, and hammer-milled to pass through 2.38-mm ($^3/_{32}$-in.; PTS1) or 4.76-mm ($^3/_{16}$-in.; PTS2) screens.

[q] Suggested range for container substrates = Best Management Practices recommended sufficiency ranges for physical properties of substrates used in general container production (Yeager et al., 2007).

(microbial decomposition) of the substrate or by substrate settling and compression caused by gravity and water movement through the substrate during irrigations (Fonteno et al., 1981).

DISCUSSION

These results indicate that physical alterations of PTS do not lead to the deterioration of their structure under fertilized greenhouse conditions, as believed based on generally accepted knowledge of wood decomposition, but rather maintain desirable characteristics (little evidence of physical changes) over time similar to a traditional peat substrate. It is also advantageous to be able to grind PTS to various particle sizes to achieve desired physical properties (AS and CC) which excludes the need for additional amendments (perlite, vermiculite, PB, etc.) that are required for commercial peat substrates to achieve desired physical properties.

It is understood that organic materials decompose during long-term crop production cycles which can drastically change physical properties of the substrates in containers. Preliminary results from other studies by these authors suggest that larger wood particles [i.e., 9.5-, 16-, or 20-mm (3⁄8-, 5⁄8-, or 1-in.) particles produced with larger hammer mill screens] take longer to breakdown and loose structure in containers, therefore, their addition to finer PTS may extend stability in containers during long-term (18 to 24 months) nursery production in place of adding mineral aggregates (perlite, pumice, coarse sand, pea gravel, calcined clay) for long-term stability which is currently recommended (Bilderback et al., 2005).

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