From Forest Nursery Notes, Winter 2010

144. A suitable substrate alternative. Jackson, B. E. American Nurseryman 209(9):28-30, 32-33. 2009.

by Dr. Brian E. Jackson

A Suitable Substrate *Alternative*

Researchers in the department of horticulture at Virginia Polytechnic Institute and State University (Virginia Tech), Blacksburg, began grinding pine trees in 2004 to create a new container substrate that is referred to as pine tree substrate (PTS). Having been a member of that research team as a graduate student — and now that I have moved into a research faculty position in the department of horticultural science at North Carolina State University (NCSU), Raleigh — I have brought PTS research to North Carolina.

Continued research has proved that pine tree substrate — rather than pine bark or peat-based substrates — can be an effective component for nursery container plant production.

This research is a totally different approach to container substrate production in that a new material is created for use as a container substrate rather than mining peat (a nonrenewable resource) or using a byproduct of another industry, such as pine or Douglas fir bark. The development of a new substrate for container-grown nursery crops is very timely because the availability of pine and Douglas fir bark is currently unpredictable due to reduced forestry production and their increased use as fuel and landscape mulch.

The interest in these wood-based substrates has precipitated many unanswered questions for nurserymen and scientists across the country. Last year, Dr. Robert D. Wright, Julian and Margaret Gary professor in the department of horticulture at Virginia Tech, and I co-authored an article that detailed PTS research up to that point (see "A New Substrate for Container Crops" in the Aug. 1, 2008, issue of American Nurseryman). In this article, I will report on the current status of PTS research, including a review of what PTS is, plant growth trials, stability during long-term crop production, new methods of substrate construction and storage, patent issues and commercialization efforts.

PTS 101. PTS can be produced from freshly harvested pine trees that are chipped and ground — with or without bark, limbs and needles — in a hammer mill (no difference in plant growth was observed with the inclusion of bark, limbs or needles compared to growing in pine wood only).

Loblolly pine (*Pinus taeda*) has been the most promising and heavily researched pine species for substrate production. Current research has also showed the successful use of eastern white pine (*P. strobus*) as a PTS, which greatly expands the potential of producing PTS further into the northeastern US. The large potential growing area for loblolly pine and eastern white pine means that trees can be grown in close proximity to greenhouse and nursery operations across a large portion of the country, saving on shipping costs of raw products needed for manufacturing and delivering substrates to growers.

Pine trees from forest-thinning operations are normally the source of pine wood chips that are most often used in pulp and

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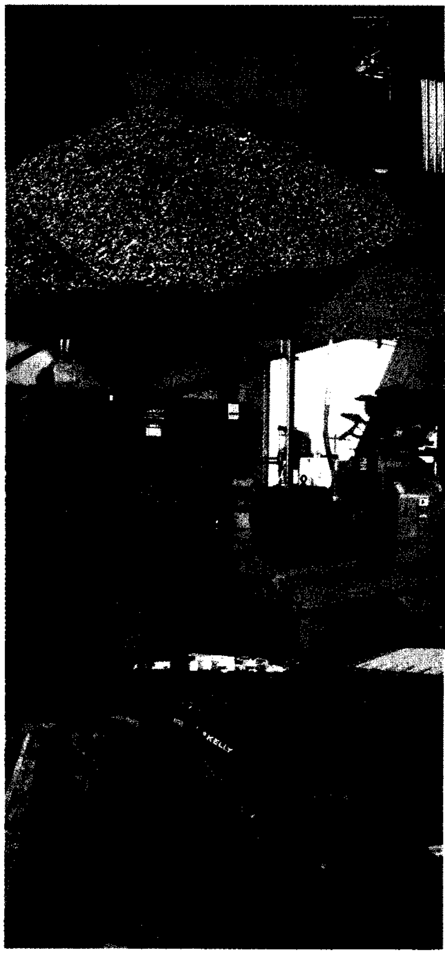

Loblolly pine trees have been harvested and are ready for transport to a processing facility. The pine trees are then chipped and ground in a hammer mill to produce pine tree substrate. The substrate can then be transported, stored or used immediately.

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paper production, but pines of any age can be harvested and processed into a substrate. It is even likely that pine plantations could be specifically planted and harvested for substrate production — in other words, nurseries could conceivably grow their own substrate. No composting of PTS is necessary, and the trees can be literally harvested one day and used to pot plants the next day after grinding.

Plant growth trials. The successful production of numerous woody and herbaceous perennial species using PTS, as well as the need for additional fertilizer during crop production compared to plants grown in pine bark or peat-based substrates, was reported in our article last year. In addition to comparable shoot growth of plants grown in PTS, one main observation is the prolific root growth that is often greater in PTS-grown plants than in plants grown in bark or peat. It is believed that the higher percentage of air space in PTS is the reason for the accelerated root growth. The improved and accelerated root growth is considered an advantage of PTS-grown plants, especially when potted and grown in larger containers or transplanted in the landscape.

Long-term growth studies show excellent results when arborvitae liners were potted and grown in 3-gallon containers for one year, then stepped up to 15-gallon containers and grown for two additional years before being planted into the landscape for further post-transplant evaluation. Arborvitae plants grown in PTS for a total of three years were of equal size and quality as plants grown in pine bark.

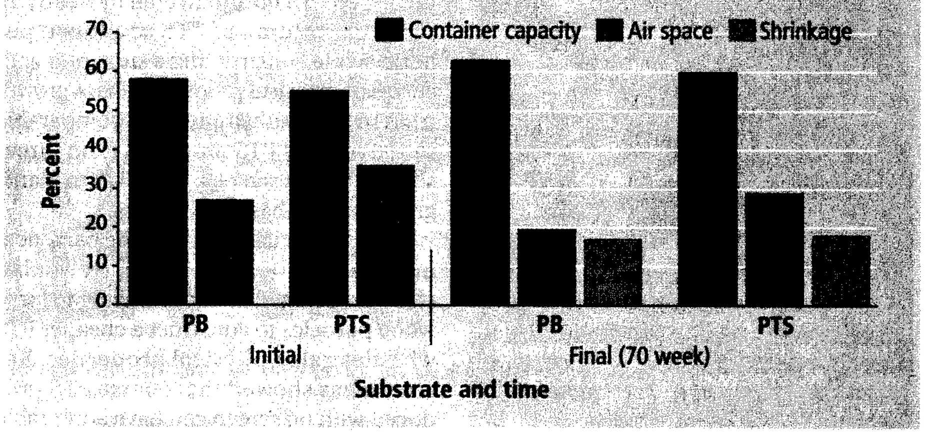
In addition to our research and plant growth trials, several nurseries in the Mid-Atlantic region have trialed large PTS (produced with no hammer mill screen) in their operations with very positive results and no reports of plant growth differences compared to plants grown in pine bark (when properly fertilized and irrigated as needed).

PTS stability during long-term crop production. A major concern for growers has been the stability of PTS during long-term crop production. To address this concern, a two-year study with 5-gallon containers of PTS and pine bark was conducted under outdoor nursery conditions. The physical properties, including container capacity and air space of PTS and pine bark, were within recommended ranges at the beginning of this study, with PTS having 55 percent container capacity and 36 percent air space.

After two growing seasons (70 weeks), physical properties were determined again and are shown in the graph below. After 70 weeks, PTS had a container capacity of 60 percent compared to 64 percent for pine bark, while air space was at 29 percent for PTS and 20 percent for pine bark. As expected, due to decomposition of both substrates, container capacity increased over time while air space decreased. The really significant observation was that after 70 weeks, substrate shrinkage in the contain-

Pine tree substrate vs. pine bark

Pine tree substrate (PTS) can have similar water-holding capacities as traditional pine bark (PB), while providing much higher air-space percentages. After 70 weeks, both water-holding and air-space percentages in PTS are in desired ranges. Also significant is the similar amount of substrate in containers after 70 weeks with PTS and PB.

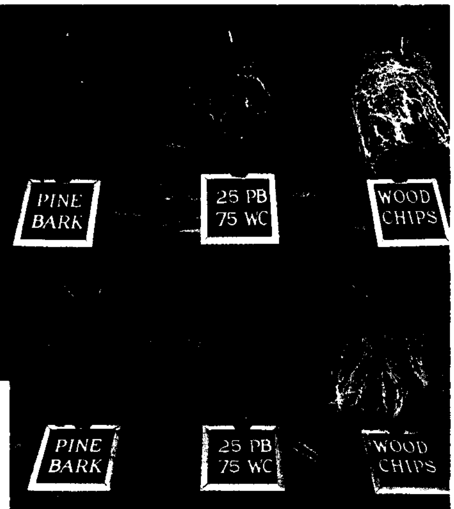


Conceivably, pine trees can be harvested one day then processed into a substrate and potted the next day because no aging or composting of the materials is necessary.

ers was similar for both pine bark and PTS — both around 17 percent. The similarity in shrinkage, despite known higher rates of decomposition in PTS, was due to the increased root volume of the PTS-grown plants, which fills the void left by the decaying wood particles.

Method of PTS construction. One advantage of PTS is that physical properties, such as particle size, can be easily altered to meet the needs of particular plants and container sizes by the degree of grinding in the hammer mill. The degree of grinding is controlled by the screen size with which the hammer mill is fitted. Screens with larger holes produce PTS with more coarse particles, and screens with smaller holes produce PTS with finer particles. However, the increased grinding time required to produce a PTS with a particle size fine enough to possess physical properties similar to peat moss or aged pine bark may be cost-prohibitive due to energy and labor costs associated with grinding.

Studies have showed that the output of PTS produced in a hammer mill with no screen in place would be about 76 kilograms per horsepower-hour (kg/hp-hr) compared to only 16 kg/hp-hr for a hammer mill fitted with a three-sixteenth-inch screen. The lower output for producing a smaller-particle PTS would also likely require a more expensive hammer mill designed to move material (coarse pine chips) through a smaller screen.



One-gallon Japanese holly — grown for one year in either 100 percent pine bark, 75 percent pine tree substrate (PTS) or 100 percent PTS — all show healthy root systems, often with the most root growth occurring in the wood substrates.

Three-gallon arborvitae were grown from liners in pine tree substrate (PTS), then stepped up to 15-gallon containers and grown for two additional years in PTS.

More economical and practical methods of constructing PTS needed to be explored, so studies were conducted over the past three years that involved mixing and amending different wood particles and other materials together to produce a cheaper substrate that still had desirable physical properties. Research has showed that small and large wood particle sizes can be produced separately (separate screens), then mixed in various proportions to construct a substrate with desirable physical properties while reducing processing costs, such as energy and time. More than 50 combinations of wood particle sizes have been mixed and tested.

One of the more cost- and time-effective substrate blends was derived from large PTS (produced with no hammer mill screen). It was mixed with approximately 50 percent PTS that was produced with a three-sixteenth-inch screen to yield a substrate with approximately 45 percent water-holding capacity, which is comparable to many bark mixes. This blending method increased PTS output overall by nearly 50 percent (volume of PTS produced per hour) while constructing a substrate with adequate physical properties. Plant growth trials in these substrates were comparable to 100 percent PTS produced from three-sixteenth-inch screens, as well as to plants grown in peat-based substrates.

Other materials, such as pine bark, peat moss, compost and sand, were also closely evaluated as amendments to large wood particles to construct a cheaper PTS with desirable physical properties. Research has showed that coarse PTS produced with no screen can have acceptable container capacities (above the recommended 45 percent) when constructed or mixed in any of the following ways:

- amended with 10 percent sand;
- mixed with 25 percent peat moss; or
- hammered with 25 percent aged pine bark with the wood chips in the hammer mill.

Testing of these PTS mixes showed equal growth of azalea and spirea after one growing season compared to plants grown in 100 percent pine bark. The benefits of a PTS constructed by amending wood chips with 25 percent pine bark, compost or peat moss include:

- reduction of PTS production costs;
- improved physical and chemical properties of a coarse PTS; and
- the creation of a dark-colored PTS similar to traditional substrates, which may be a criterion that some growers or manufacturers want because of consumer preference or expectation.

One factor to be considered when processing wood for use as a container substrate is the type of equipment used for processing, or grinding, wood chips. Hammer mills appear to be the best choice for this task, but mills can vary considerably between brands (hp, air-handling devices, motor rpm, hammer tip speed), which will affect the amount of wood that can be processed. A second factor that can affect PTS production rates is the moisture-content percentage of the wood at the time of grinding. The moisture content of freshly harvested pine trees is normally between 50 percent and 55 percent, and the amount of moisture in wood chips directly influences the processing rate (reduction of particle size in a hammer mill), with higher moisture increasing grinding time and decreasing PTS output from the hammer mill.

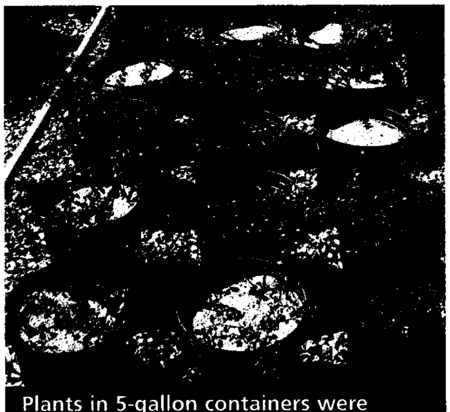
Another important advantage of manufacturing a more coarsely ground PTS is that the extra fertilizer required for PTS — compared to pine bark or peat moss — will be reduced. Other work conducted by our research team has showed that the addition of peat moss and pine bark to PTS reduces substrate microbial activity and nitrogen immobilization. This work also showed that microbial activity and nitrogen immobilization in PTS are reduced when PTS particle size increases. As a result of recent industry trends for the production of large woody plants in large containers (greater than 15 gallons for more than two years), production of PTS comprising larger particles would decay less rapidly and facilitate substrate stability over these long production periods.

Previous research showed that hardwood tree species were unsuitable for use

A hammer mill can be fitted with different-sized screens to grind coarse wood chips into any particle size to produce a substrate with physical characteristics similar to pine bark or peat-based mixes.

as a container substrate due to how quickly they decompose and shrink during crop production — a result of the low lignin content in hardwoods. The substrates produced in these studies — conducted in 2006 — were processed with three-sixteenth-inch hammer mill screens to produce small particles that accelerated their decomposition (small particles decompose quickly) in containers and negatively affected plant growth.

Based on the more current methods of substrate construction (grinding wood to have large particles and amending with other materials for fine particles), it is believed that hardwood species could be viable for use as a substrate component. This is especially true if, for example, hardwood chips are used as 25 percent, 50 percent or even 75 percent replacement/amendment to pine or Douglas fir bark. Some growers in the US have already had success with hardwood substrates. More research with hardwood species is currently underway.



Plants in 5-gallon containers were evaluated for two growing seasons (70 weeks) when grown in pine bark or pine tree substrate under fertilized outdoor nursery conditions to monitor changes in physical properties and substrate shrinkage.

Methods of pine tree and PTS storage. A three-year study evaluating PTS and the age and storage of pine trees was conducted to determine if there were any potential effects of substrate age on plant growth and substrate quality. Initial results indicate that PTS produced from freshly harvested pine trees and then stored in piles outdoors or in large bags indoors (under a covered shed) for up to one year had a drop in pH, but, when adjusted, no plant growth differences were observed compared to plants grown in PTS that was produced from freshly harvested trees and had never been stored.

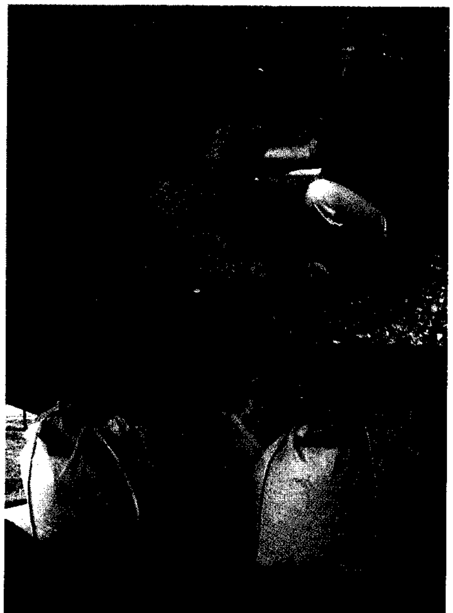
The changes that occur in substrate pH over time during storage have to be monitored and adjusted (increased) before growing plants (only woody and herbaceous perennial species tested so far). As mentioned, no pH modification is needed for PTS produced from freshly harvested trees (and never stored) due to the inherently high pH of pine wood (between 5.8 and 6.2). Initial results also show that pine trees (logs) harvested and stored outdoors in piles for up to one year can be chipped and ground to produce PTS without any negative effects on plant growth, but only when attention is paid to adjusting pH levels for proper plant growth.

Patent issues and commercialization efforts. The process of grinding wood — regardless of wood or tree species — for the specific purpose of using the material as a substrate for plant growth is a process that is patented by Virginia Tech. There has been much discussion in the industry about how this patent will prevent substrate companies and/or individual growers from developing nursery substrates using wood chips or other wood-based materials without approval from — and royalties paid to — Virginia Tech.

One of the major claims of the patent is that a wood substrate must have at least 0.5 percent of the wood chip particles be a size of 0.05 millimeters (mm) or less. Based on previously reported data, as well as my most recent unpublished data, to have this amount of fine particles would require wood chips to be ground in a three-thirty-seconds of an inch or less hammer mill screen. Current research shows that it is uneconomical and impractical to grind wood this finely, hence the addition of other materials, such as pine bark, peat or sand, that provide the much-needed water-holding capabilities of a substrate. It is for this similar reason that sawdust is excluded from the patent because it does not have the amount and size of fine particles needed. Therefore, based on research results, if a wood substrate is produced that contains 0.5 percent of its volume in particles 0.05 mm or less, the patent is applicable, and appropriate actions should be taken to respect the patent and its potential licensing requirements.

Conversely, if a wood substrate derived from any species is produced with larger screens (particles) and constructed using current methods partially outlined in this article, it is extremely doubtful that the substrate will have the particle range outlined by the patent. To be certain, it is suggested that a particle-size distribution analysis be conducted to determine these percentages on wood substrates, or contact the appropriate sources to seek clarification.

As a result of grower interest in PTS — and wood substrates in general — trials are underway with a number of growers to further test PTS on a wide range of nursery and greenhouse crops. Substrate producers have also recently begun producing and trialing various mixes and formulations of PTS, as well as other wood substrates derived from various tree species. It is my goal to offer assistance



Research has showed that pine tree substrate can be made from freshly harvested pine trees and stored either in uncovered piles outdoors or in bags indoors.

and collaboration to these companies to evaluate PTS for commercial production, marketing and use in crop production. If a grower — or a consortium of several growers — is interested in evaluating PTS, it is feasible to purchase a hammer mill and produce PTS for themselves where pine trees are available.

In addition to myself here at NCSU, there are researchers at other universities working with pine and other wood substrates who have contributed greatly to the development and utilization of these alternative substrates. The ultimate goal is to provide growers with viable alternative substrate options to reduce costs without sacrificing crop quality.

The author wishes to acknowledge Dr. Robert D. Wright at Virginia Tech for beginning this PTS project in 2004 and for guiding much of the research reported in this article. The author also wishes to express appreciation to the following groups for supporting this research and commercialization efforts: American Floral Endowment, Virginia Agricultural Council, Virginia Nursery & Landscape Association and numerous nurseries in the Mid-Atlantic region.

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