This is the fourth article in a six-part series highlighting various horticultural uses of pine trees, pine bark and associated products as well as data from substrate science research trials. Read part one here [https://bit.ly/substrates1], part two here [https://bit.ly/substrates2] and part three here [http://bit.ly/substrates3].

The marriage of bark and wood

Understand how pine bark amended with pine wood affects substrate pH and physical properties.

STORY AND PHOTOS BY **DR. BRIAN E. JACKSON**

Bark and wood: reunited at last. For decades we have relied on pine bark (or fir bark on the West Coast) substrates to produce most of our container-grown outdoor nursery crops. For a variety of reasons, the use of wood materials as components in bark and peat substrates has increased over the past 15 years. As we discuss more about bark and wood as substrate materials, let's first discuss some terms associated with different materials regarding substrates. Bark, the outside protective layer of trees, is different structurally and chemically than sapwood (functioning wood closest to the bark) and heartwood (nonfunctioning wood in the center of trees) as illustrated in **Figure 1.** Bark, a by-product of the forestry industry, has been the backbone of nursery substrates for decades and it remains as the primary material of choice. The inner portion of a tree, the wood, is often referred to even more specifically as "white wood" when describing the brightly colored pieces that can be seen in substrates. Many folks have gone to great efforts to limit the amount of white wood present in bark mixes as a result of growers refusing bark shipments upon delivery or not being pleased when some wood can be seen in bark inventories **(Fig. 2A-C).** Bark processors/producers across the U.S. work tirelessly to get as much of the white wood as possible out during the processing, aging and handling of the bark substrates, but to remove it all is close to impossible. Some processors have invested in specialized extraction devices to remove strips of inner bark (cambium), limbs, larger chunks of wood or other foreign debris **(Fig. 2D)** while other processors even have hand-picking stations where larger pieces of white wood are removed.

White wood and fertility

We have been taught to believe that fresh wood, even in small quantities, can cause fertility issues and rapidly decompose in containers leading to poor crop growth. The basis for this caution stems from decades of evidence that when incorporated into mineral/field soils, wood will rob nitrogen from the surrounding soil as it is being decomposed. One big difference in field production and container production with soilless substrates is the amount, type and frequency of fertility that is applied to container crops and the ability growers have to compensate additional nitrogen if/when needed. There is little scientific evidence to suggest that a small percent of white wood in bark substrates will do anything to negatively affect fertility and crop growth. What we have learned over the course of many years of research on bark and wood substrates is that perception is not always reality (maybe rarely so) regarding white wood in bark being bad. Bottom line, the presence of white particles in bark should not be concerning to growers as it relates to substrate fertility, toxicity or decomposition. If anything, the white wood found in bark may have an effect on the physical properties of the overall mix which could present some issues. If, for example, large pieces of white wood are present in bark substrates **(Fig. 2C)** this could cause water to channel through the container and greatly reduce the container water holding capacity.

In 2013, researchers at North Carolina State University conducted a survey of pine bark substrates from suppliers across North Carolina. A total of 24 products were analyzed for physical, chemical and hydrological properties and of those 12 were identified as the most common products used by nursery growers. After analyzing the physical properties of those 12 samples, the white wood was removed (handpicked with tweezers) and the volume and mass of wood from each sample was determined **(Fig. 3A).** The physical properties of those 12 wood-free bark

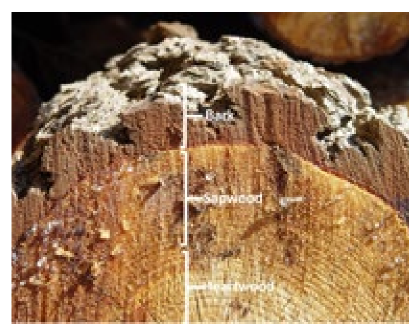

Figure 1: Cross section of a pine tree illustrating the distinctive zones of bark, sapwood and heartwood regions of a tree.

Figure 2: White wood in nursery bark substrates is not an uncommon sight [A-C] despite mechanisms in place at bark processors/suppliers to remove as much of the material as possible such as this cambium/bark extractor [D].

Figure 3: Twelve pine bark substrates acquired from multiple suppliers that have had the white wood hand-extracted to determine percent (A) and grouping of 8 samples of the extracted white wood showing variation in particle size.

samples were analyzed again to determine if any changes had occurred in the physical properties. What we discovered is that the percent (volume) of white wood found in those 12 commercial bark substrates ranged from 22% to 2.5%. We concluded that the main effect seen on physical properties (air and water) was not correlated to the percent wood in the bark but instead it was the size and shape of the wood particles that made the biggest difference in substrate properties. **Figure 3B** shows the difference in wood particle sizes that were extracted from some of the bark samples. A closer look at six of those bark samples we analyzed can be seen in **Figure 4.** Sample 1, which had 22% white wood, showed a significant change in air space and water holding when the wood was removed. Sample 3, which had 14% wood, showed very little change in air and water properties when the wood was removed compared to Sample 4, which had half as much wood (7.5%) yet showed significantly higher reduction in air space (-8.0%) and increase in water holding. Bottom line, the presence of white wood in bark only affects air, water, and drainage properties if the size of the wood is very different than the bark.

Bark:wood mixes

All of the white wood discussed so far is wood that is unintentionally added to pine bark substrates. Now, let's focus on the practice of adding an engineered wood component to bark mixes as a means of stretching bark supplies, lowering costs or other potential benefits. Researchers in Mississippi first tested the idea of growing nursery crops in bark and fresh wood combinations in the early 1980s, but the

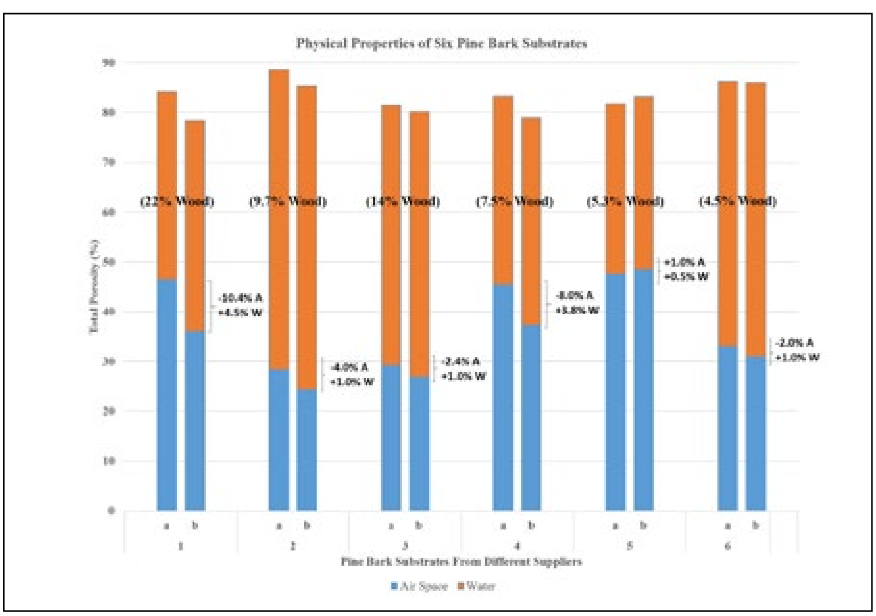

Figure 4: Six pine bark substrates acquired from different suppliers showing the percent white wood found in them and their physical properties assessed before and after the white wood was extracted showing the effect white wood had on those properties.

Figure 5: Processed pine tree substrate blended with aged pine bark at 0, 20, 40, (top row left to right) 60, 80 and 100% (bottom row left to right).

research never changed industry practice. Fast forward to 2004 and the concept was brought back to life as researchers began an aggressive campaign to investigate the potential of incorporating hammer-milled pine wood in bark and peat-based substrates. Since then, we have a better

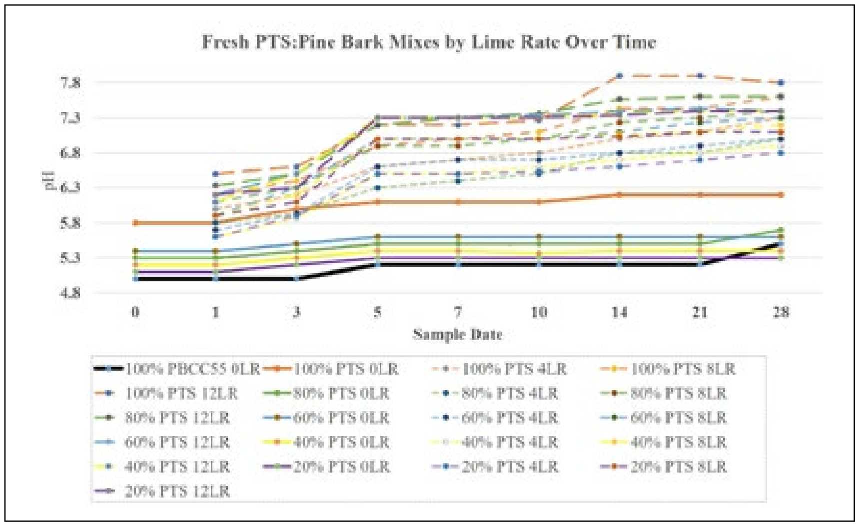

Figure 6: pH response of aged pine bark amended with 20, 40, 60, 80 or 100% pine tree substrate with four limestone rate (LR) additions (0, 4, 8 and 12 lbs/yd3).

understanding of how to properly use wood substrates with bark, with peat, or even alone at 100%. There are several commercial wood products on the market produced in a variety of ways. The greenhouse industry has been more aggressive in adopting new mixes that contain wood products due to the significant cost savings when substituting substrate components like perlite. For the nursery industry, aged pine bark remains abundant and cheap so the switch to wood has not been as advantageous. But that has not stopped some growers from wanting to adopt bark:wood mixes nor have researchers stopped investigating how best wood can be used in nursery production now and even more so in the future.

Understanding pH

Recent trials have evaluated bark:wood blends as it relates to crafting specific substrates to have unique air and water properties suitable for large containers or potential for fruit crop production in containers. We have also been working to better understand and predict how the pH of bark and wood blends can be adjusted and maintained. We conducted pH trials in the summer of 2019 at the NCSU Horticultural Substrates Laboratory. Our objective was to evaluate the pre-plant substrate pH modification of aged pine bark when blended with hammer-milled pine tree substrate (PTS) at varying percentages and at increasing rates of dolomitic limestone additions. To produce the PTS, logs of freshly harvested 12-year-old de-limbed loblolly pine (*Pinus taeda* L.) trees were shredded in a wood shredder before being further processed in a hammer mill. Two commercial wood fiber products, one disc-refined and one extruded material were also evaluated in this trial. All three wood products were blended with aged pine bark at ratios of 20%, 40%, 60%, 80%, and 100% for a total of 15 substrate blends. Each blend was wetted to 60% moisture content and subsamples were amended with 100 mesh dolomitic limestone at rates of 0, 4, 8 and 12 pounds/yard^3. Samples were incubated in a controlled climate chamber and sampled for pH determination on 0, 1, 3, 5, 7, 10, 14, 21 and 28 days after lime addition. In this article we will only present and discuss data from the PTS blends **(Fig. 5)**.

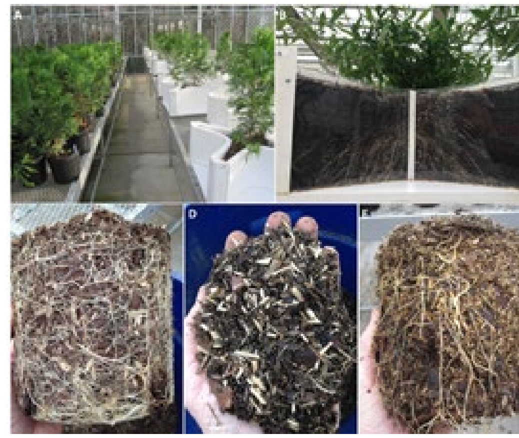

Figure 7: Enhanced root growth and rootball development of woody ornamentals grown in pine bark: pine wood blends is a common observation by growers and researchers.

The pH of 100% pine bark was the lowest, while the pH of 100% PTS with no lime addition started at 5.8 and increased over the four-week study to 6.2 **(Fig. 6).** What is not shown are all lime rates in the 100% pine bark. The PTS treatment with 12 pounds of lime had its pH rise to almost 8.0 by the end of the incubated study. Overall, the pH trends were as expected in that the pH increased as the percent PTS increased (and conversely the percent pine bark decreased). The addition of PTS to pine bark even without lime may establish a pre-plant substrate pH range suitable for some crops. The high pH of fresh pine wood can be attributed to several factors including tree species, age of the tree, location of wood within the tree, site location and soil type trees are grown on and season of tree harvest. The pH comes from the acidic nature of the tree components, in particular the organic acids (acetic, formic, oxalic) and polyphenols present in the wood. Over the past 16 years the pH of fresh PTS has been reported to range from 4.4 to 6.0, a range mostly attributed to the season of tree harvest and age of the tree. It should be noted that the PTS used in this trial was fresh. If the PTS was aged, the pH may change and therefore would change the bark mix pH as well once amended. It is also unknown how different bark sources or supplies may alter the initial pH prior to or immediately after potting or the effect of that fertilizer, irrigation water or plants have on pH shift during crop production.

As a side note, the addition of wood products (PTS or commercial materials) has been noted many times to have an effect on rooting and rootball development of numerous woody and herbaceous crop species **(Fig. 7)**. Research trials aimed at studying and quantifying root growth and development in Horhizotrons have shown that as wood percentage increases, so does the speed of root growth of some propagation material (cuttings) and larger plant material being stepped up to larger containers **(Fig. 7B)**. Much is left to learn about this phenomenon but it appears to be linked to the humidity of the substrate environment that wood fiber materials create as well as the physical nature of the thin wood fibers providing ease-of-passage of roots through the substrate to the container wall.

Remember that some percent of unintentional white wood in pine bark substrates does not pose negative production challenges. And the intentional addition of engineered/processed pine wood to bark offers a range of physical properties that could be crafted to certain crops or container sizes. Keep in mind that substrate pH is naturally higher with wood than bark, so if mixes are made using ratios of bark and wood do not assume that "normal or traditional" lime rates are needed or acceptable. NM

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