# Barkitecture

How engineering soilless substrates from pine bark benefits the green industry.

Aerial view of a commercial bark supplier.

This is the third 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) and part two here (https://bit.ly/substrates2).

STORY AND PHOTOS BY
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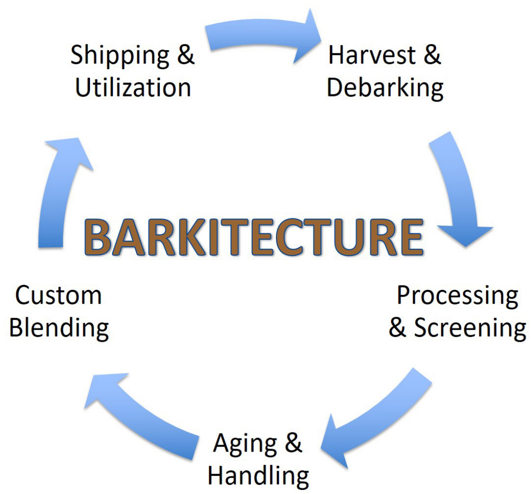
Much like modern architecture, barkitecture is both the process and the product of planning, designing and constructing an end-product, in this example not a building but instead soilless substrates. Specifically, the processing, handling and creation of bark materials into substrates. Container substrates used in the production of horticultural crops have evolved so much over the decades. Manufacturers and researchers have steadily improved the composition, functionality, reliability and consistency of the various substrates that growers around the globe rely so heavily upon to produce their crops. Over the decades substrates have gone from being "stuff in a pot" to being highly functioning and complex materials. Terms often used today by company sales reps, marketing promotions, researchers and even growers to describe the manufacturing of soilless substrates include "crafting," "designing," "formulating," "constructing," "engineering," among others. Substrates are more advanced now than ever before. Let's take a look at where we've been, where we are and where we are going with bark substrates.

**Figure 1:** Barkitecture is the process tree bark undergoes beginning with its removal from the tree, the many steps in processing and handling, followed by the precision blending and product delivery.




## Barkitecture

Barkitecture, a term I coined years ago to encompass the processes involved with constructing bark substrates, is a multi-faceted series of manufacturing steps that take bark from being the skin of a living tree to the contents of a container in which plants grow **(Figure 1)**. While other steps could surely be added to this diagram, the primary ones are represented to illustrate the meticulous steps that bark suppliers (should) go through to produce high-quality substrates. A thorough look through the scientific literature, IPPS (International Plant Propagator's Society) and SNA (Southern Nursery Association) proceedings as well as university and USDA experiment station research bulletins sheds light on the history of bark use in container substrates. As growers began shifting from using mineral soils in containers (yikes!) to using more lightweight and freely draining materials, bark was one of the fist successes. Growers experimented with using bark in the 1950s and '60s with varying levels of success, but it was not until the 1970s that researchers began in-depth work to understand how to reliably use bark in containers to grow plants. Notably, Dr. Frank Pokorny, a professor in the Department of Horticulture at The University of Georgia, was the pioneer of pine bark substrates. Dr. Pokorny worked for a quarter of a century (retired in 1996) on various aspects of processing, handling and using pine bark substrates in nursery crop pro-

**Figure 3:** Bark on pine trees can vary in appearance, thickness, and structure based on age of the tree as well as species of pine (spruce, fir, etc.). These differences will affect the processing and creation of bark into substrate materials.


**Figure 4:** Raw bark removed from freshly harvested trees (A), is delivered from sawmills to bark processers for further grinding (B), sizing and windrowing(C), and screening to create specific substrate products.

duction. He trained numerous students, guided growers and shared his research with the scientific community for decades. As a student myself studying all things substrates, I spent years reading and referencing his many works all the way through graduate school and into my role as a professor at NC State. While at NC State, I was privileged to be mentored by another great scientist who also contributed a tremendous amount of research into pine bark substrates and nursery production, Dr. Ted Bilderback. Arguably one of the all-time best nursery crops extension specialists in the country, Dr. Bilderback took many of the works of Dr. Pokorny to the next level and provided much-needed guidance to bark producers and nursery growers in how to manage bark supplies and manage crops grown in them. In December 2014, I drove to Athens, Georgia, with Dr. Bilderback and another substrate science legend, Dr. Bill Fonteno to visit with Dr. Pokorny. While enjoying pizza and beer, the four of us talked bark for hours and shared decades of stories **(Figure 2)**. I learned during this visit that Dr. Pokorny was a hero beyond the bark piles as well, having served as a captain in the U.S. Air Force during the Korean War. Without doubt, this was and remains, one of the highlights of professional career and I will cherish it forever. Dr. Pokorny died in January 2017 at the young age of 86.

## Bark removal

Over the decades, much as been studied and reported on how bark can be made into substrates. For the purpose of this article we will focus on pine bark, but other barks are used across the United States as well in other parts of the world where pines may not be a common tree species. Just within the genus *Pinus*, there are many variations of bark types. As seen in **Figure 3**, barks are very different based not only on species but also age of the tree as well as location (top or bottom) of a tree. Bark thickness is perhaps the main feature than can alter the processing and eventual use of the material but season of harvest, method of bark removal from harvested logs, as well as other variables can affect bark processing and eventual substrate quality. The decision on how bark is removed from trees (known as debarking) is made at the sawmill without input from the bark processors (those who buy the raw bark from the mills). There are several methods that logging operations or sawmills can potentially use to remove bark from logs including drum debarkers, ring debarkers, cradle debarkers, chain flail debarkers, among others. Each technique can differ in how much white wood is removed from the logs in addition to the bark itself, how much bark is left on the log (called a bole), and how badly the bark is broken or torn during removal. Regardless of debarking

**Figure 2:** Three generations of bark substrate researchers including (from right to left) the Godfather of bark research Dr. Frank Pokorny, Dr. Ted Bilderback, Dr. Brian Jackson, and Dr. Bill Fonteno.

method, once removed from the logs, bark is at that point a byproduct of the sawmill and it is then sold to bark processors (who make substrates), used as fuel, or sold for other purposes.

## Processing

Once on site at a bark processor, the bark can be further processed in a number of different ways. There are no standards or regulations that govern bark producers to subscribe to uniform processing and handling practices, therefore different types and qualities of bark substrates can be made and sold to growers. For example, in North Carolina I have visited most bark processors over the past several years and none of them do the exact same thing or make their bark substrates in the exact same way. Regardless of the small (or large) nuances of processing bark, once it arrives on site in raw form (fresh off the trees) as shown in **Figure 4A**, it is then typically either windrowed (put in piles) as-is for a period of time (months to years) without any grinding or processing, or it is immediately processed (milled/ground) and screened to separate the large nuggets from the smaller particles (fines) as seen in **Figure 4B-C**, before being windrowed for aging as seen in the background of **Figure 4C.** Whether it's the raw bark or screened bark fines that are being windrowed, the purpose of this step is to allow aging to occur which helps stabilize the fresh bark, a process that has been shown to improve the physical and (more so) chemical properties of the bark material. Aging is different than composting, in that aging does not include the addition of a nitrogen source to the bark piles to help cure or stabilize the bark. The difference in aged pine bark and composted pine bark can be substantial as are the handling requirements and some potential regulatory guidelines that must be followed if composting is truly being conducted. Aging is what the large majority of bark processors are doing across the Southeast U.S. During the aging process, the bark piles, which typically should not exceed 12-15 feet in height, are turned periodically to ensure the pile is aging similarly throughout and to prevent over-heating or combustion and anaerobic conditions on the bottom of the pile. It is also common for water

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**Figure 5:** Deconstruction of a nursery bark substrate illustrates the particle size (and shape) range that can be created to yield specific physical and hydrologic properties.

to be added when needed to accelerate the process and facilitate the heating and stabilization of the piles. After the aging process, which can vary in length from a few weeks up to a year in some operations, the bark material is often screened again **(Figure 4D)** to create bark substrates with different physical properties.

## Screening

Screening bark into size fractions or classes, can enable barkitects (processors) to construct very specific substrates that are suitable for propagation, 5-gallon containers, or 50-gallon containers. These particle fractions, as seen in **Figure 5**, are what determine water holding and air properties as well as drainage profiles and longevity in larger containers. The finer particles increase water retention while coarser particles increase air porosity and aid in drainage. As researchers, we often "deconstruct" bark substrates by sieving apart the size fractions to better understand what the components in the mix are as well as what percentages they are in which often are clues to assist in diagnosing substrate-related production problems. Research has also shown the ability to deconstruct and then reconstruct substrates of various particle shapes and sizes with materials such as wood (to be addressed in the next three articles of this series), or other materials.


**Figure 6:** Amendments to bark substrates can include sand (A), nutrient packages, fire ant treatment, and others amendments desired by growers (B), limestone for pH adjustment (C), and wood fiber/products (D).

## The final product

Bark processors (suppliers) often offer a line of products for growers but most can also create specific mixes based on grower requests. Bark suppliers also offer a broad range of amendments and additives that can be blended with the bark to meet grower specs. One of the more common — traditional, I should say — amendments is sand **(Figure 6A)**. Coarse or fine sand is often requested by growers at percentages of 8-12% with the idea that the added weight improves (decreases) pot blow-over on the nursery and aids in water retention and distribution in the substrate. However, as a side note most all research has shown that sand can be more often a problem than a solution to a problem, not to mention the added freight costs due to weight. Other common amendments to

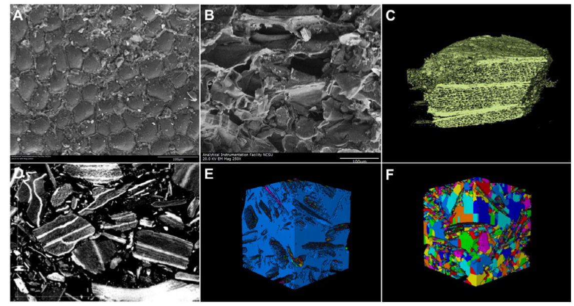

**Figure 7:** Researchers use advanced tools and technologies to study bark properties including scanning electron imaging (A-B) and X-ray microtomography (C-F).

bark substrates are controlled release fertilizers, lime for pH adjustment, micronutrients, fire ant treatment, etc. **(Figure 6B-C)**. Some growers request these ingredients and have their bark mixes delivered ready to use, while other growers prefer to purchase un-amended bark and add all amendments themselves prior to use. Ironically, one of the newer bark amendments is pine wood components **(Figure 6D)**. I say "ironically" because for decades, growers did not want any white wood in their bark substrates as it was believed that white wood would rob nitrogen and degrade rapidly leading to deficient plants and other production-related problems. Research in the past 15 years however has shown these issues to not be as severe as once thought and wood products are now being used in higher percentages with success. This topic will be discussed in future articles.

## The future of substrates

Researchers in the Horticultural Substrates Laboratory at NC State University are actively working with bark suppliers to address current issues and also (more importantly) future opportunities of bark and bark substrates. New technologies are enabling us to see and understand the structure and properties of bark like never before. The use of scanning electron microscopy (old technology) with X-ray tomography now allows us to not only see particles and their surfaces **(Figure 7A-D)** but also to see the spaces created by the substrate matrix **(Figure 7E-F)**. The majority of a substrate is comprised of pores, hence the porosity we always talk about that is filled with either air or water. The ability to see inside of substrates in an undisturbed way allows us to see, among other things, how pores fit together, how water moves through these pores (and the container), how roots navigate and penetrate substrate particles and pores, how machine processing of bark changes the surfaces and shapes of particles, etc. The adoption of these and other new technologies is what drives the evolution of future substrates and what hopefully will continue to improve substrate performance and crop efficiency. NM

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