PART 3

FIGURE 1. Processing of inventory bark for the long-term pine bark aging study.

Pine Bark Handling and Aging

Effects on Substrate Chemical Properties

The third installment of a three-part series highlights the changes in the physical, hydrologic and chemical properties of pine bark over 12 months of managed aging focuses on the effects on substrate chemical properties.

By Laura E. Kaderabek, Dr. Brian E. Jackson and Dr. Bill Fonteno

Although much research has been conducted on irrigation and fertilization of substrates, little research exists regarding their chemical properties. Understanding the chemical properties of substrates is important in terms of fertilization and nutrient retention in container crop production. The main factor that distinguishes fertilization management of substrates used for container grown plants is the limited volume of the substrate in the container, which may result in a lower pH buffering capacity (ability to resist shifts in substrate pH), and limited nutrient reserves when compared to field/mineral soils.

The objective of this research was to investigate and quantify changes in some of the chemical properties of pine bark during 12 months of managed aging to better understand and utilize pine bark at various degrees of age and stability. Understanding the nutrient holding capacities of bark of different ages may assist growers in improving fertilizer use efficiency, especially when combined with the physical and hydrologic properties of pine bark substrates that were discussed in the previous two articles of this series (see the June and July 2017 issues).

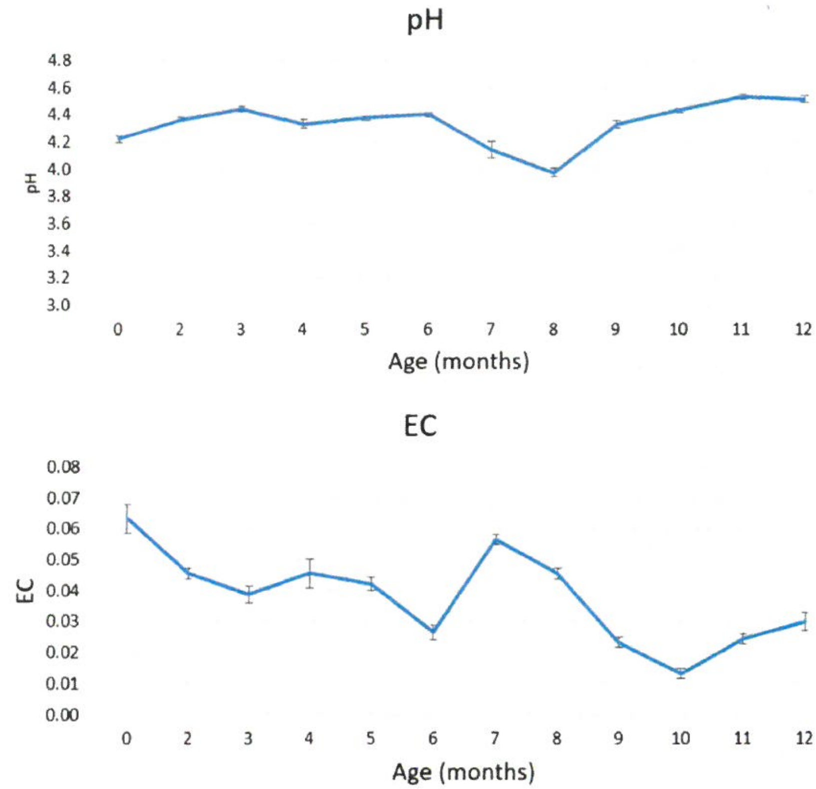

FIGURE 2. pH and EC of processed pine bark at 0, 3, 6, 9 and 12 months of aging.

Sampling

Fresh, longleaf pine bark (within days of being removed from freshly harvested trees) was hammer-milled to pass through a ½-inch screen (see Figure 1) and placed in three piles of approximately 250 cubic yards each, with dimensions of approximately 55 by 33 by 10.5 feet. These were treated as replications. Piles were sampled initially, then turned every four to six weeks using a front-end loader, and subsequently sampled after turning for a period of 12 months. At each sample date, subsamples were taken from different locations on each pile to account for variation within the pile and to reduce possible errors due to stratification of constituents and conditions within the piles. These subsamples were combined into one representative sample per pile, and tested for the following properties.

pH, electrical conductivity and pH buffering capacity

pH is very important for assimilation of major nutritional elements. Pine bark is highly acidic, with a pH range generally between 3.8 to 4.5. Several sources disagree whether the pH goes up or down slightly with decomposition, which may be due to the fact that pH may decrease if the piles have gone under anaerobic conditions during the decomposition process. Other researchers have found no changes in pine bark pH based on age, while some have indicated that there may be an increase in pH when the bark has a higher percentage of fine particles.

For our study, pH and electrical conductivity (EC) were measured each month within 48 hours after sampling using the 1:1 (1 pine bark : 1 water) dilution method. In this trial we observed that pH increased slightly over the course of 12 months from 4.2 to 4.5, with a significant increase occurring after month 3. This general increase in pH over the aging process could be a result of the particle size distribution shifting to a higher percent of fine particles over time, or as a result of monthly turning, which promotes aerobic decomposition, which tends to result in a slight increase in pH. We found no differences in EC among bark of any of the ages, with values ranging from 0.01 to 0.06 mS (see Figure 2).

Additionally, the pH buffering capacity of pine bark samples of 0, 3, 6, 9 and 12 months of age were determined by titration. Two sets of samples were measured: one that contained an "as-is" particle size distribution with a range of fine and coarse particles, and another where particles were screened to 2.00 mm or less. We found no differences in age for either the screened or unscreened (2.00 mm or less) samples, with values of approximately 2.0 mmol kg^{-1} for fresh bark, and values of approximately 1.6 mmol kg^{-1} for bark aged 12 months. If pine bark is managed differently (higher/larger pile sizes, less frequent turning, and so on), these chemical properties could be different from what we observed.

Cation exchange capacity

Cation exchange capacity (CEC) is a term used to describe the attraction of cations in a substrate to negatively charged sites on substrate particles, and indicates the ability of a substrate to retain the mineral elements supplied by fertilization. Many nutrients required by plants are positively charged, and are attracted by these negatively charged sites. The CEC of horticultural substrates, which are composed primarily of organic matter, is highly pH dependent. Most substrates possess negative permanently and/or temporarily charged surfaces, and surface charge properties of substrates have a great effect on the chemical reactions taking place in the rhizosphere (area of soil directly around the plant roots), and on the

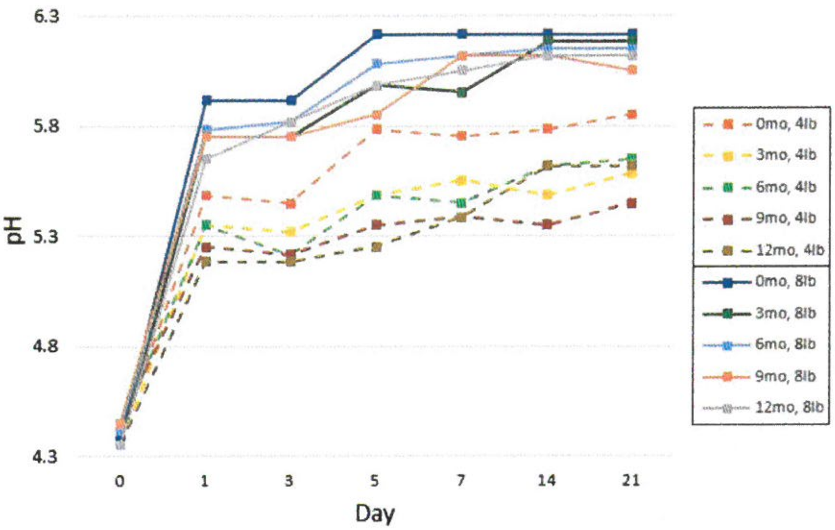

Figure 3. Lime incubation results for pine bark aged 0, 3, 6, 9 and 12 months, amended with 4 and 8 lbs yd3. pH was measured before liming, and 1, 3, 5, 7, 14 and 21 days after lime amendment.

availability and uptake efficiency of applied cations. Cations in the soil solution such as calcium, magnesium, ammonium-nitrogen and potassium will be attracted to the surface of pine bark particles and exchanged with other cations. High CEC increases pH buffering capacity, which prevents wide variation in pH and availability of nutrients. We measured the CEC of bark samples from 0, 3, 6, 9 and 12 months of aging using a barium chloride ($BaCl_2$) extraction. We found that the CEC of bark increased after month 0 from 76.7 mg L^{-1} to 92.4 mg L^{-1} at month 12. This increase has been reported in other works over the years in fresh versus aged barks.

Lime incubation

Limestone is incorporated into substrates to neutralize the acidity of the substrate solution, increase pH buffering capacity, provide additional calcium and magnesium, and enhance microbial activity within the media. Dolomitic lime increases substrate pH up to a certain point, usually around 6.5, after which additional lime has little or no effect, due to the low solubility of dolomite at pH values above 6.5.

Samples of pine bark from 0, 3, 6, 9 and 12 months of aging were amended with two different lime rates to investigate effects of pine bark age on lime efficacy. Pulverized 100 mesh dolomitic limestone was incorporated at rates of 0, 4 and 8 lbs/yd^3, making for a total of 15 treatments (5 substrates times 3 lime rates).

On 1, 3, 5, 7, 14 and 21 days after limestone amendment pH was measured using the 1:1 extraction method. We found that pH increased rapidly one day after lime addition, with slight increases during days 3 through 5, and a general stabilization for the remainder of the sample days (see Figure 3). Both lime rates had the greatest efficacy on fresh bark at month 0, with no other trends observed for bark age and lime rate.

Plant available nutrients

The elemental composition of pine bark varies according to tree species, age, ecology, soil type and season; but the concentration of elements in bark from the same tree species and geographic region has been found to be fairly stable. It has been reported that milled bark is low in both macro and micro nutrients needed for plant growth, but calcium, potassium, manganese and iron might be present in beneficial qualities, depending on the soil type in which the harvested tree originated. Studies have found that pine bark supplied sufficient amounts of boron, iron, zinc, copper and manganese.

Nutrient analysis for bark samples aged 0, 3, 6, 9 and 12 months were determined by saturated media extract and vacuum filtration. Total concentrations of phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, zinc, copper, boron and sodium were measured. We found a decrease in concentrations of potassium, calcium, magnesium, sulfur, iron, manganese, zinc, copper, boron and sodium; no changes in concentrations of chlorine, nitrogen (inorganic, organic, and urea); and an increase in phosphorus concentrations.

Heavy metal content

One of the concerns related to the use of aged or composted waste products for use as horticultural substrates is the question of regulated elements/heavy metals. Some heavy metals are essential micronutrients for plants at low concentrations, but may be toxic at higher concentrations. The U.S. Environmental Protection Agency has recommendations in place for the maximum permissible levels of arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium and zinc.

For our study, heavy metals were analyzed using a handheld x-ray fluorescence analyzer. The heavy metals we detected with this analysis were lead and zinc for months 4, 5, 6, 9, 10, 11 and 12. Readings were between 6.5 and 9.1 ppm for lead, and 6.3 and 7.2 for zinc.

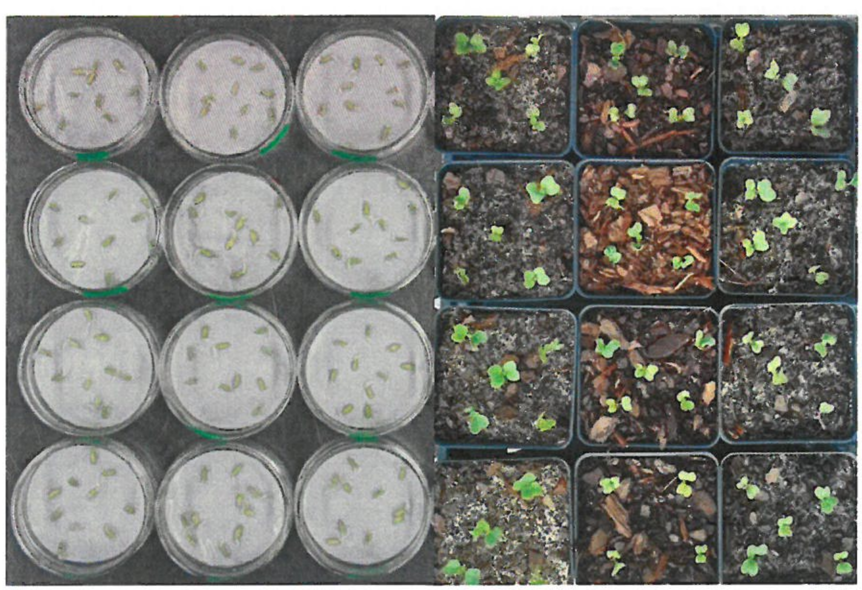

Figure 4. Phytotoxicity assays of different bark ages to determine seedling/germination success.

The frequency and concentrations of heavy metal detection did not appear to increase with age, and readings were not much higher than the accepted limit of 5 ppm for lead and zinc.

Phytotoxicity assays

To detect phytotoxic substances in materials used for substrates, germination tests are frequently used to investigate delay of germination of seeds, such as cucumber. Loblolly, slash and longleaf pine, the prominent pine species used for pine bark substrates over much of the eastern U.S., are considered to be non-phytotoxic and may be used without aging or composting with no phytotoxic effects. At each month of sampling, we tested for seedling toxicity using a cucumber germination assay from pine bark extracts; and at 0, 3, 6, 9 and 12 months of aging a seedling (radish, tomato and marigold) survival assay was conducted following the Mulch and Soil Council protocols (see Figure 4).

We found no differences in the cucumber germination assays, with all months between 99 to 100 percent germination. The Mulch and Soil Council assay did not show any differences in seedling survival for any of the species in either the 100 percent pine bark or 50:50 pine bark/sand mix, except for tomato in 100 percent pine bark at month 0, which had a lower germination rate.

Conclusions

Data from this long-term study provided many new insights and previously unreported information on the properties of pine bark at specific ages of a year-long aging process. Many of the chemical properties of bark managed under these conditions appeared to show no differences between age, or a general stabilization beginning at three months of aging, as shown by a decrease in the C:N ratio and lime efficacy at month 3, and an increase in pH and CEC at three months of aging. No trends based on age were observed for EC, pH buffering capacity, heavy metal analysis or phytotoxicity assays. In general, the nutrient content decreased over the aging process, presumably due to nutrent leaching over time due to rain events.

It is important to note that the results from our study cannot be applied or assumed for other bark suppliers or all bark supplies. Different bark suppliers have different methods of processing their bark, different methods to turn/handle their materials, have space limitations, supply and demand issues, and so on, that can influence the end-product. Bark that is handled and treated differently may yield different end products that can be used successfully, but may not be identical to our findings.

However, understanding potential differences is not only important in producing consistent materials, but it is key to understanding how to utilize bark of specific ages, and predicting how they may perform as a container substrate. This study also illustrates the importance of establishing a good relationship with the bark supplier and frequently checking bark supplies to ensure product consistency. We advise all bark consumers to visit their bark supplier, ask questions and make it a habit to check their bark for consistency and quality.

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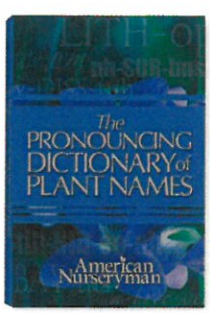

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