Applications of Biochar for Arboriculture

By Chris Fields-Johnson and Chelsi Abbott

Learning Objectives

- Learn the components of the soil and where biochar fits
- Understand what biochar is, how it is made, and ways to select good biochar
- Learn the benefits of using biochar in the landscape and the locations in which biochar would be most effective
- Review methods in which biochar can be used in the landscape

CEUs: A, U, M, T, Bs, Bm

An estimated 80 percent of aboveground issues in trees are caused by issues below ground, namely problems related to roots and soil. This has led to an increased interest in the care of belowground features, particularly to overcome soil compaction and fill materials lacking organic matter. The soil has three components which may be influenced:

- Chemical/nutritional component
- Biological component
- Physical component

The chemical component consists of macro- and micronutrients in the soil, such as nitrogen, phosphorous, potassium, iron, magnesium, etc., as well as the soil's pH level and the redox potential, which is the relative availability of oxygen. The biological component covers the quantity and functioning of anything living within the soil, including arthropods and detritivores, microbes (fungi and bacteria), plant roots, and organic matter, which is the dead and decomposing remains and waste products of once living things. Lastly, the physical component relates to the texture and structure of the soil, which is the relative sand, silt, and clay content and how those particles are aggregated and layered. The combination of texture and structure determines properties such as soil strength, level of aeration, capacity to hold water, and the rate of water movement (infiltration and percolation).

Each of these three components interacts with and influences the others, and together they determine the suitability and quality of a given soil (Figure 1).

An ideal soil management program in arboriculture addresses all three of these components, providing balanced, holistic soil care for trees. The chemical/nutritional component can be efficiently influenced by direct applications of fertilizers, while materials such as compost and mulch affect the biological component most by feeding the soil food web. The physical component is improved by mechanical tillage using hand tools, excavation equipment, or augers, by hydraulic or pneumatic deep soil fracturing, or by air tillage with a jet of high-velocity air that will not damage roots and utilities already in the soil being treated (Figure 2).

Biochar is a form of charcoal added to soil to achieve a desired improvement in soil functions (Figure 3). Charcoal is made by partially combusting organic materials, a process termed pyrolysis, where combustion is interrupted

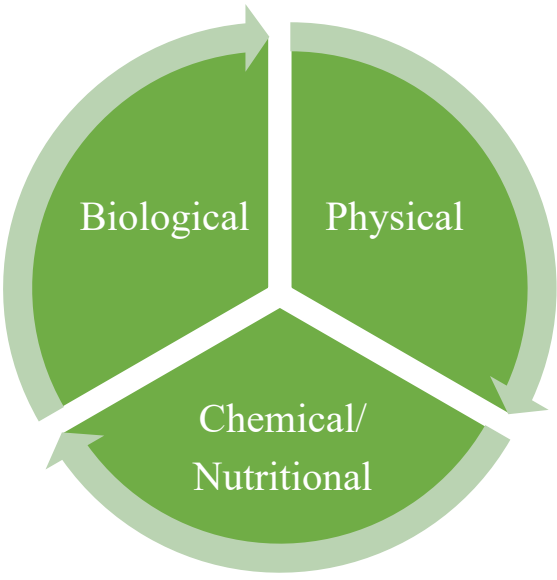


Figure 1. Good soil is rich in pores and organic matter and allows dense root development.

by limiting the oxygen supply so that a skeleton of stable carbon remains. Modern biochar manufacturing uses precise controls to maximize charcoal yield and quality while minimizing air pollution from combustion. Many biochar systems use green landscape waste, agricultural or forestry residues, or salvaged wood as a feedstock, effectively recycling wood and organic material that might otherwise go to waste. When dry, good charcoal for use as biochar should refract light when held up to the sun, should be resonant with sound when dropped or struck, and should burn without producing a flame. However, laboratory testing results within the specifications for your desired application provide the most precise indication of quality. There are three additional attributes to consider:

- Biochar products are OMRI (Organic Materials Review Institute) Certified
- Biochar products meet IBI (International Biochar Initiative) Standards
- Biochar products are derived from natural wood biomass of known origin

Getting third-party lab results showing a biochar you are interested in using to be within IBI standards is the best way to verify the quality of a biochar.

Figure 2. Air tools allow excavation and loosening of soil around roots without damaging them.

Application of biochar enhances the three components of the soil to different degrees. Biochar improves nutrient use efficiency and availability, helping somewhat with the chemical properties of the soil, but it does not provide much in the way of nutrients. Biochar enhances microbial habitat and increases microbial respiration, but it does not provide much in the way of a direct food source for microbes. Biochar most directly enhances physical soil properties by providing long-term porosity and stabilizing macropores and soil aggregates against future compaction.

Because of this, biochar has been gaining popularity in the green industry over the last decade, with many new products appearing on the market every year. Adding charcoal to soils in combination with other amendments is an ancient, historical practice around the world, from South America, to Central Europe, to East Asia, so it appears that we are now just rediscovering its applications.

Benefits

The basic chemical structure of biochar—sheets of carbon stacked together—strongly resists both compaction and microbial degradation. It has nutrient exchange capacity comparable to other forms of soil organic matter, such as humus, and a very high surface-area-to-volume ratio. When woody materials go through pyrolysis, their internal vessel structure remains intact, creating a network of macropores and micropores through which air, water, and soil microbes can move.

Increasing soil air-filled porosity is a notable property of biochar. This counteracts the effects of soil compaction by restoring the downward infiltration of rainwater, the

Figure 3. Biochar provides long-term porosity and resilience against future compaction.

movement of air to deeper layers of the soil, and the ability of roots to penetrate the soil and grow outward and downward. Trees can then develop more robust root systems, which lead to more resilience against stress and better canopy growth. Micropores in biochar will hold water at field capacity, which will increase the water-holding capacity of coarse soils (sandy or gravelly). Biochar can buffer extremes of wet and dry soil conditions by providing both drainage and water-holding capacity.

Improving nutrient use efficiency is another notable feature. Nutrients bond to biochar until they can be used by plants or soil microbes. This means that the same results can be achieved with less fertilizer. It also means that major reductions can be made to the leaching and runoff of nutrient pollutants which harm waterways.

Achieving long-term carbon sequestration to address climate change is a long-term result of biochar. Biochar is largely stable in the soil for decades to hundreds of years, resulting in a net increase in soil carbon and a decrease in atmospheric carbon when used properly.

Figure 4. Soil renovation by incorporating compost and biochar with air tools rebuilds healthy topsoil while preserving roots.

There are certain soil conditions that can be better candidates for biochar than others. Those include:

- Soil with very low organic matter content
- Soil with high clay content but poor aggregation
- Soil with high sand or gravel content and poor retention of water and nutrients
- Compacted sites or sites which will receive heavy foot or equipment traffic
- Sites that have poor drainage or standing water, or which dry slowly
- Container and planter soils

Applications at these types of sites maximize the benefits of biochar, as they predominantly possess issues related to the physical soil component. However, it is important to understand the limitations of biochar. Since biochar predominantly influences the physical component directly, it can take several years to see the full benefit of an application as roots begin to take advantage of better soil physical conditions. Biochar is not necessarily an immediate fix, but rather is a long-term solution. Biochar properties tend to improve over time as it weathers and becomes fully integrated into the soil. However, biochar is more likely to provide immediate benefits when biologically activated by being applied with compost.

Biochar is not itself a fertilizer, as it is mostly chemically inert and does not contain much that can be absorbed by a plant unless charged with a separate fertilizer or compost product. Biochar may somewhat influence the pH of the soil due to its ash content. This is similar to the way mulch influences soil pH, in that it may weakly raise or lower the soil pH depending on starting conditions, but only gradually over long periods of time with repeated applications. Therefore, biochar is not a direct or

immediate solution to trees suffering from pH and micronutrient issues. The same can be said of its influence on the biological component. Biochar provides a structure in which microbes can live, which results in an indirect influence on that component of the soil. But by no means should biochar replace applications of mulch or compost, which have more influence on the biological complexity of the soil.

Applications in the Landscape

There are several ways to use biochar in the landscape. The following practices are how the authors are using biochar operationally based on published research, internal trials, and operational experience.

Biochar can be applied in combination with compost by tilling into the root zones of trees using air tools, a process termed "soil renovation" (Figure 4). When soil renovation is limited to specific sectors or trenches radiating out from a tree to create root break-out zones, it is termed "radial trenching." Typically, the goal is to loosen the soil to a depth of 12 inches (30 cm) and increase organic matter content to over five percent by mixing in an inch (2.5 cm) or more of compost and a quarter inch (0.6 cm) or more of biochar. The area can then be topped with mulch or planted with turf as desired. Irrigation is important if this procedure is performed during dry periods of the year. When this procedure is performed outside of root zones, tillage can be performed more efficiently with rotary tillers or conventional excavation equipment.

Biochar can also be blended and applied with compost as a topdressing over turf or mulch areas (Figure 5). When applying over turf, mixing biochar at a rate of five to ten percent with compost and spreading up to a quarter inch (0.6 cm) of the blend is the typical recommendation. Mulched beds can take more materials at any single application. When applying to turf, preceding topdressing with core aeration and overseeding is great for annual turf renovations.

Another possible method of incorporating biochar into the soil is to suspend dust-sized biochar in water and inject it into root zones hydraulically, with or without other liquid fertilizer products (Figure 6). Pneumatic or hydraulic fracturing of soil with pressures of 100 to 200 PSI can be performed in conjunction with liquid biochar injection to help stabilize the new fractures in the soil. Strong agitation allows 2.5 to 10 percent biochar by volume to be suspended in water. Make sure that filter and pump systems on equipment are compatible with biochar use.

Biochar also makes an ideal pure backfill medium for vertical mulching where the goal is to increase downward movement of air and water through the soil. A method to perform vertical mulching could be making vertical holes with an air tool so that soil is fractured as the tool moves up and down through the soil, rather than being glazed smooth as it would when using an auger to drill holes (Figure 7). Air tools will also cause less root damage and are safer to use around underground utilities than augers.

Figure 5. Topdressing around trees with compost, biochar, and mulch helps to restore natural nutrient and carbon cycles.

Figure 6. Pneumatic and hydraulic fracturing combined with biochar injection open and stabilize soil pores.

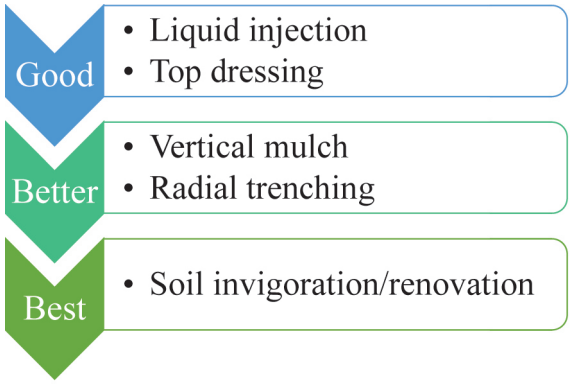
Augers can be employed where air tools are not powerful enough to penetrate the soil to a deep enough level. Chip or rice-sized biochar provides nearly two-thirds pore space as a backfill, maximizing downward air and water movement while promoting root growth.

Finally, biochar can be used to amend soils during tree plantings by mixing it and compost with backfill soil dug from tree planting holes. Applications may range from 5 to 25 percent by volume for both compost and biochar, depending on the starting qualities of the soil. However, at least 50 percent soil from the site should be used so that trees can adapt to the mineralogy of the surrounding soil. The objective for site preparation for planting is to provide an ideal initial growing environment to improve the trees' chances for survival and successful establishment by allowing it to rapidly build a robust root system (Beeson and Keller 2001; Gilman 2004).

These techniques can be used in combination. Conduct intensive work in the immediate area around a tree to maximize the potential for successful establishment and early survival. Conduct less intensive work further out in root zones to encourage the outward expansion of root systems for long-term growth and health.

There are, of course, pros and cons of each technique. In general, the more soil is disturbed, the more immediate and larger impact the biochar application will have on the landscape. Therefore, the techniques that involve deep tillage are considered the best methods by the authors for applying biochar. However, these techniques are more disruptive and more expensive relative to the other available techniques. Thus, depending on the client and property for which biochar is being applied, the other less disruptive techniques may be a better fit.

Figure 7. Vertical mulching by backfilling vertical holes made with an air tool with biochar reestablishes downward movement of air and water into the soil.



Most biochar applications will benefit from being made in tandem with compost or some other nutrient source. Recall, as discussed above, that biochar will not directly provide large amounts of nutrients or feed soil microbes. Microbial inoculation is not necessary when using biochar in a typical landscape setting because beneficial microbes will already be present, simply waiting for more favorable conditions in which to proliferate.

Two notes of caution: be sure to wet biochar to the point where it is no longer dusty before using it in the field to avoid making a mess and breathing in the dust. Also, remember that biochar will combust when it is dry if there is an ignition source and if it can get air, so treat it as you would treat other wood products, such as logs and wood chips, with fire-safe practices.

Further Reading

International Biochar Initiative – **https://www.biochar-international.org**

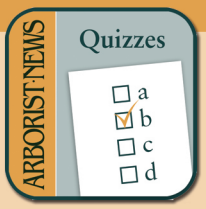
Literature Cited

Beeson Jr RC, Keller KG. 2001. Yard waste compost as a landscape soil amendment for azaleas. *Journal of Environmental Horticulture.* 19(4):222-225.

Gilman EF. 2004. Effects of amendments, soil additives and irrigation on tree survival and growth. *Journal of Arboriculture*. 30(5):301-310.

The authors are technical advisors with the Davey Institute. They can be reached at Christopher.Fields-Johnson@davey.com and Chelsi.Abbott@davey.com, respectively. All photos and images courtesy of the authors.

Arborist News CEU Quiz Questions



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A passing score for this quiz, **Applications of Biochar for Arboriculture**, requires sixteen correct answers. Quiz results will display immediately upon quiz completion. CEU(s) are processed immediately. You may take the quiz as often as is necessary to pass.

CEU(s) for this article apply to: A, U, M, T, Bs, Bm

1. What are the three properties which indicate a charcoal is of high quality for use as biochar?
   a. Refractory
   b. Resonant
   c. Burns without flame
   d. All of the above
2. How is charcoal made?
   a. Open burning of green waste
   b. Incomplete burning of biomass under low oxygen
   c. Incomplete burning of biomass under high oxygen
   d. Complete burning of biomass in a specialty kiln
3. What is the best material to use to make charcoal for use as biochar?
   a. Woody biomass
   b. Household demolition waste
   c. Animal manures
   d. Municipal food waste
4. Which is not a good method of applying biochar?
   a. Topdressing
   b. Incorporation with air tools following tillage
   c. Vertical mulch backfill
   d. Foliar application
5. Which organization provides standards or certifications for biochar products?
   a. International Biochar Initiative
   b. Organic Materials Review Institute
   c. American National Standards Institute
   d. a and b
6. Which component of the soil will biochar directly influence?
   a. Chemical
   b. Physical
   c. Biological
   d. Nuclear
7. How does biochar help enhance soil physical properties?
   a. Provides porosity
   b. Stabilizes soil aggregates and macropores
   c. Reduces soil strength and resistance to root penetration
   d. All of the above
8. How does biochar help enhance soil chemical properties?
   a. Supplies nutrients like nitrogen in large amounts
   b. Dramatically lowers pH to an acceptable range
   c. Enhances nutrient use efficiency
   d. Immobilizes essential nutrients
9. How does biochar help enhance soil biological properties?
   a. Provides microbial habitat
   b. Provides an energy source for microbes
   c. Provides a carbon source for microbes
   d. Inoculates soil with beneficial microbial organisms
10. What should be applied in tandem with biochar in almost all cases?
    a. Lime
    b. Sulfur
    c. Compost and/or fertilizer
    d. Mycorrhizae
11. What is a major safety consideration for biochar?
    a. Protect it from being ignited
    b. Avoid breathing biochar dust
    c. Never mix it with other organic products
    d. a and b
12. What are the three main components of soil properties?
    a. Physical, hydrological, and biological
    b. Biological, physical, and chemical
    c. Chemical, hydrological, and pH
    d. pH, redox potential, and organic matter
13. What are the environmental benefits of biochar?
    a. Recycling green waste
    b. Carbon sequestration
    c. Reducing nutrient pollution in water
    d. All of the above
14. What are the benefits of modern biochar manufacturing compared to primitive methods?
    a. Increased air pollution emissions
    b. Improved charcoal quality and yield
    c. Low cost of equipment and facilities
    d. All of the above
15. To what depth should you loosen up the soil when performing air tool work?
    a. 4 inches (10 cm)
    b. 6 inches (15 cm)
    c. 10 inches (25 cm)
    d. 12 inches (30 cm)
16. What is the most impactful yet disruptive method of applying biochar?
    a. Soil renovation
    b. Vertical mulching
    c. Topdressing
    d. Soil injection
17. Biochar application offers immediate results.
    a. True
    b. False
18. Which site cannot be improved by using biochar?
    a. Compacted sites
    b. Sites with high organic matter and good drainage
    c. Sites with high clay content and poor drainage
    d. Sites with low organic content and high sand content
19. What percentage of aboveground problems are theorized to be influenced by belowground issues?
    a. 0%
    b. 40%
    c. 80%
    d. 100%
20. The three components of soil interact and influence each other.
    a. True
    b. False