Biochar: A Home Gardener's Primer

WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS147E

Home gardeners may have heard about biochar, but may not understand exactly what it is and what it does. This fact sheet provides a quick overview of what biochar is, the science behind its manufacture and use, and how it affects soil, plants, and the environment.

What is biochar?

Biochar is a fine-grained charcoal left behind after **pyrolysis** of crop residues, livestock manures, and other organic material used in alternative fuel production (Figure 1). These alternative fuels, or biofuels, are produced by high temperature processing of organic materials in the absence of oxygen—a process known as pyrolysis. Biofuel researchers initially regarded biochar as nothing more than a waste product of pyrolysis. However, further investigation revealed some unique properties. For instance, biochar is so slow to decompose that scientists widely consider it to be a long-term repository for stored carbon.

From a global standpoint, biochar's ability to store rather than release carbon might be its single most important attribute. Properly "cooked" biochars do not release carbon dioxide into the atmosphere and their physical structure remains virtually intact. Their resistance to decomposition means that good biochars will not release carbon dioxide over the long term, either. Furthermore, biochars applied to wet soils like those found in rice paddies decrease methane and nitrous oxide production. Since, carbon dioxide, methane, and nitrous oxide are three of the most important greenhouse gases contributing to climate change, both biochar production and use may help slow this troubling phenomenon.

Researchers have identified some potential uses for biochar in addition to carbon storage. Biochar is similar to activated charcoal and has been used successfully to treat sewage and waste water. It is also exceptionally well suited for restoring degraded soils, such as those found near mining sites, because it tightly binds toxic heavy metals and neutralizes unnaturally acidic soils.

How is biochar made?

The best biochar consists of finely textured, porous particles made by using extremely high temperatures (at least

Figure 1. The material shown on the left is too coarse to be considered a high quality biochar, while the fine-textured material on the right is a high quality biochar.

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500°C) in the complete absence of oxygen (pyrolysis) as shown in Figure 2. During pyrolysis, organic matter breaks into fragments whose surfaces are covered with negatively charged chemical compounds. The hotter the temperature, the smaller and more porous the fragments become. These small, porous biochar particles have proportionally more surface area than large, solid particles. So slow-cooking at high temperatures (over 500°C) for several hours will produce a lightweight, fine-textured, negatively charged biochar.

Do not be tempted by the numerous websites that offer "home recipes" for making biochar from yard waste. Proper pyrolysis is impossible to achieve at home since oxygen is present and temperatures are too low. Improper cooking also generates carbon dioxide and other pollutants. You are better off using pruning debris and other home-garden wastes in your compost pile or on top of your soil as a natural and sustainable organic mulch layer. Ideally, biochar can be made commercially from excess crop residues, invasive plant species, such as kudzu and English ivy, and other organic materials that might otherwise end up in landfills.

Production techniques influence biochar's physical, chemical, and biological properties, which in turn affect how it works in the soil. The science behind biochar is complex: there are many variables associated with both making and using biochar. First, a finished biochar is specific to the material that was burned to produce it. A biochar made from straw is different than one made from coconut husks, yard waste, or wooden pallets. Second, the range of temperatures and times used for cooking biochar produces biochars that are chemically and physically different from one another. The highest quality biochars are cooked for several hours at temperatures from 350°C to 700°C. Finally, the effectiveness of biochar is highly dependent on soil characteristics, such as texture, organic content, and mineral nutrient levels.

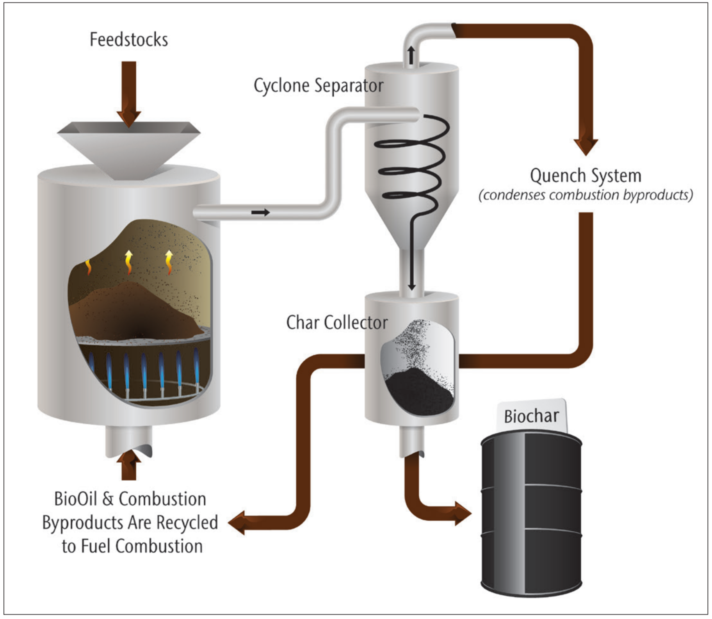

Figure 2. Production of biofuel and biochar by pyrolysis. Illustration by Andrew Mack, PREC.

How does biochar work?

Because biochar remains virtually intact for centuries, it can permanently change a soil's character. For example, this porous material improves aeration of poorly drained or compacted soils, while increasing the water-holding capacity of fast-draining, sandy soils. The porous nature of biochar also provides a physical home for bacteria and fungi, including beneficial mycorrhizal species.

Biochar's negatively charged surface binds to positively charged chemicals, including hydrogen ions and many plant nutrients in the soil (Figure 3). This phenomenon has two effects on soil characteristics. First, binding the hydrogen ions raises the pH of the soil, making it increasingly alkaline. Second, soil nutrition is enhanced because biochar binds and retains nutrients that otherwise might leach out of the soil. Biochar can improve urban soils by tightly binding lead, cadmium, and other heavy metals found in urban soils, preventing their uptake by plants and soil life. As biochar attaches to heavy metals, it sheds other bound ions, many of them plant nutrients. This process of ion exchange contributes to increased levels of available nutrients for plant uptake.

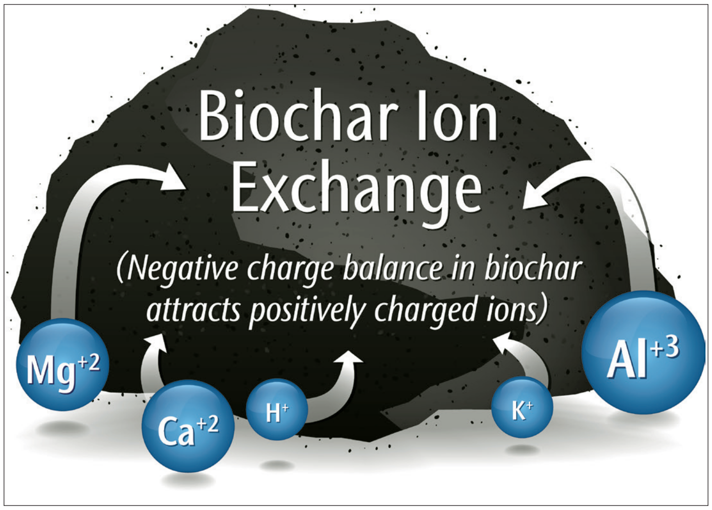

Figure 3. Biochar's negatively charged surface will bind positively charged elements. Illustration by Andrew Mack, PREC.

How are soil organisms affected by biochar?

Overall, biochar has a positive effect on beneficial soil microbes. The habitat it provides for fungi and bacteria also hides them from grazing protozoa, such as amoebas. Together with the biochar, these microscopic communities continue to change soil characteristics in positive ways. For instance, pathogenic bacterial populations decrease when biochar is added. This could be due to improved soil structure, or to competition from beneficial microbes housed in the biochar. Earthworm populations, however, often decline in biochar-amended soils, possibly due to pH changes or dehydration.

How is plant growth affected by biochar?

As you might expect, the beneficial effects biochar has on the soil environment also translate into plant benefits. Crops grown in biochar-amended soil consistently show increased growth. This may be due to improved nutrient and water availability and an increased number of beneficial microbes. Other biochar benefits include improved drought tolerance and greater resistance to root and leaf diseases. Gardeners should be cautious when using biochar, however. Application of too much biochar can injure plants, possibly by increasing soil alkalinity past the plant's tolerance level. Also, applying biochar to soils rich in organic matter can temporarily reduce nitrogen levels because increased microbial activity will compete with plants for this nutrient.

There are good reasons to be excited about the possible benefits of biochar in home gardens. A solid body of research is available that describes the benefits of adding biochar to crops, soils, and soil microorganisms.

Can we use biochars in our gardens?

Currently there are only a handful of studies on biochar with direct relevance to home gardens and landscapes. So far, biochar appears to benefit soils where turf grasses and trees are planted. Turf grasses perform better in more alkaline soil conditions like those that biochar can create. Lawns with compacted, poorly drained soil benefit from the increased aeration and drainage that biochar can provide. Both coniferous and broad-leaved trees have shown improved growth and disease resistance in soils amended with biochar. Biochar can also reduce the weight of planting mixes used for container plants and green roof gardens.

If you want to try biochar in your garden, be sure to use only a commercially produced biochar with well-defined characteristics. Be careful when applying biochar because improper application can create problems in your garden. For instance, adding too much biochar can injure beneficial soil organisms like earthworms, or reduce the effectiveness of soil-applied pesticides. You will also want to

Table 1. How biochar application affects soils and plants.

Benefits	Drawbacks	Best Use
Decreases soil bulk density	None	Compacted soils
Improves aeration	None	Heavy or compacted soils
Increases soil aggregation	None	Fine-textured soils
Improves water-holding capacity	Can cause waterlogging in heavy clay soils	Excessively drained, sandy soils
Increases soil sequestration of carbon	Can be washed out of saturated soils	All soils
Increases soil alkalinity	May injure acid-loving plants and earthworms	Soils used for alkaline-tolerant species, such as turf grasses
Increases cation exchange capacity (CEC)	None	Low nutrient and sandy soils
Binds salt	None	Soils contaminated with de-icing salts or exposed to tidal floods, or naturally salty soils
Binds nutrients, such as nitrogen and phosphorus, reducing their leaching	Not as effective on silty soils	Sandy and acidic soils
Binds organic material (OM)	None	Soils subjected to erosion or runoff
Binds and/or detoxifies heavy metals, such as lead, mercury, and chromium	None	Acidic soils
Binds and sequesters organic contaminants, such as polycyclic aromatic hydrocarbons	None	Application rates greater than 2% of soil volume
Binds and degrades pesticides	Soil-applied pesticides will be less effective	All soils
Reduces greenhouse gas emissions (CO_2, CH_4, and N_2O) from wet soils	None	Waterlogged soils, especially sandy types
Enhances fungal biodiversity, including mycorrhizal species	None	All soils
Increases availability of plant nutrients (N, P, K)	Levels of sodium can increase depending on biochar source	All soils
Decreases need for nitrogen fertilizers	None	All soils
Increases plant nutrient uptake and enhances plant growth	Less effective in OM-rich soils; use of excessive biochar in OM-rich soils can reduce growth	OM-poor soils and dry soils
Increases plant drought resistance	None when used appropriately	
Increases plant disease resistance	None when used appropriately	

monitor your plants in the first few months after applying biochar for signs of nitrogen deficiency. Overall leaf yellowing is an indicator of low nitrogen. Adding a nitrogen fertilizer can treat this temporary deficiency. Table 1 summarizes the benefits and drawbacks of biochar, along with optimal conditions for use. This information may help you decide whether your garden and landscape soils might benefit from biochar additions.

Further Reading

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