Biochar Use in Soils

Biochar used in potting mix. Photo courtesy of Robert Flanagan

Biochar enhances soils. By converting agricultural waste into a powerful soil enhancer that holds carbon and makes soils more fertile, we can boost food security, discourage deforestation and preserve cropland diversity. Research is now confirming benefits that include:

- Reduced leaching of nitrogen into ground water
- Possible reduced emissions of nitrous oxide
- Increased cation exchange capacity resulting in improved soil fertility
- Moderating of soil acidity
- Increased water retention
- Increased number of beneficial soil microbes

For farmers and gardeners, biochar provides a unique opportunity to improve soil fertility for the long term using locally available materials. Used alone, or in combinations, compost, manure, and/or agrochemicals are added at certain rates every year to soils, in order to realize benefits. Application rates of these inputs can be reduced when biochar is used as a soil amendment. Biochar remains in the soil, and single applications provide benefits over many years.

In many regions, soil loss and degradation is occurring at unprecedented rates. Loss in soil productivity occurs despite intensive use of agrochemicals, concurrent with adverse environmental impacts on soil and water resources. Biochar can play a major role in expanding options for sustainable soil management by improving upon existing best management practices, not only to improve soil productivity but also to decrease nutrient loss through leaching by percolating water. Areas with low rainfall or nutrient-poor soils will benefit the most.

Some common questions on biochar in soils are presented below. For a detailed guide on how to set up biochar field trials and measure results, please download a free copy of the Guide to Conducting Biochar Field Trials from the IBI website:
http://www.biochar-international.org/extension

How does biochar affect soil biology?
Decades of research in Japan and recent studies in the U.S. have shown that biochar stimulates the activity of a variety of agriculturally important soil microorganisms. The pores in biochar provide a suitable habitat for many microorganisms by protecting them from predation and drying while providing many of their mineral nutrient needs.

What is the evidence that biochar benefits soils in actual field conditions?
Field trials using biochar have been conducted in the tropics over the past several years. All showed neutral to positive results on yields when biochar was applied to field soils and pH and nutrients were managed appropriately. Large scale field trials have recently begun on highly fertile Iowa Mollisols by the US Department of Agriculture's Agricultural Research Service (USDA-

ARS). First year results are positive, yet it will take several years before definitive results are available (Laird, D., 2009 at: http://cees.colorado.edu/docs/soils/Laird_Soils_Presentation_NABC2009.ppt).

There is also evidence from thousands of years of traditional use of charcoal in soils. The most well-know example is the fertile Terra Preta soils in Brazil, but Japan also has a long tradition of using charcoal in soil, a tradition that is being revived and has been exported over the past 20 years to countries such as Costa Rica. The Brazilian and Japanese traditions together provide long-term evidence of positive biochar impact on soils.

How does biochar affect soil properties like pH and CEC?
Biochar reduces soil acidity which decreases liming needs, but in most cases does not actually add nutrients in any appreciable amount. Biochar made from manure and bones is the exception; it retains a significant amount of nutrients from its source. Because biochar attracts and holds soil nutrients, it potentially reduces fertilizer requirements. As a result, fertilization costs are minimized and fertilizer (organic or chemical) is retained in the soil for longer. In most agricultural situations worldwide, soil pH (a measure of acidity) is low (a pH below 7 means more acidic soil) and needs to be increased. Biochar retains nutrients in soil directly through the negative charge that develops on its surfaces, and this negative charge can buffer acidity in the soil, as does organic matter in general.

CEC stands for Cation Exchange Capacity, and is one of many factors involved in soil fertility. “Cations” are positively charged ions, in this case we refer specifically to plant nutrients such as calcium (Ca2+), potassium (K+), magnesium (Mg2+) and others. These simple forms are those in which plants take the nutrients up through their roots. Organic matter and some clays in soil hold on to these positively charged nutrients because they have negatively charged sites on their surfaces, and opposite charges attract. The soil can then “exchange” these nutrients with plant roots. If a soil has a low cation exchange capacity, it is not able to retain such nutrients well, and the nutrients are often washed out with water.

Can you add biochar to alkaline soils?
Most biochar trials have been done on acidic soils, where biochars with a high pH (e.g. 6 – 10) were used. One study that compared the effect of adding biochar to an acidic and an alkaline soil found greater benefits on crop growth in the acidic soil, while benefits on the alkaline soil were minor. In another study, adding biochar to soil caused increases in pH which had a detrimental effect on yields, because of micronutrient deficiencies which occur at high pH (>6). Care must be taken when adding any material with a liming capacity to alkaline soils; however, it is possible to produce biochar that has little or no liming capacity that is suitable for alkaline soils.

How long does biochar last in the soil?
The stability of biochar is of fundamental importance in determining the environmental benefits of biochar. There are two reasons why stability is important: first, stability determines how long carbon (C) applied to soil as biochar will remain sequestered in soil and contribute to the mitigation of climate change; and secondly, stability will determine how long biochar can provide benefits to soil and water quality. Biochar is not a single material, and its characteristics vary depending upon what it is made from and how it is made. Most biochars have a small labile (easily decomposed) fraction in addition to a much larger stable fraction. Scientists have shown that the mean residence time of this stable fraction is estimated to range from several hundred to a few thousand years.

Does biochar help soils retain moisture?
More studies, especially field studies, are needed on the question of water retention with biochar, but the results so far consistently show benefits in sandy soils where this function is most needed. The Australian national science agency, CSIRO, released a comprehensive review of biochar in February 2009 which looked at work done on biochar impact on soil moisture retention. While it found few studies that directly addressed soil moisture retention with biochar, it found that “Many studies where the effect of biochar on crop yield has been assessed have cited moisture retention as a key factor in the results.”

What kind of biochar should you add to your soil and where can you buy biochar?
It is important to note that not all biochar is the same. Biochar is made by pyrolysing biomass—pyrolysis bakes the biomass in the absence of oxygen, driving off volatile gases and leaving behind charcoal. The key chemical and physical properties of biochar are greatly affected by the type of feedstock being heated and the conditions of the pyrolysis process. For example, biochar made from manure will have a higher nutrient content than biochar made from wood cuttings. However, the biochar from the wood cuttings may have a greater degree of persistence over time. The two different biochars will look similar but will behave quite differently—to test to see how they might perform in your soil, it is important to carry out a simple germination test or a worm avoidance test (see field trials guide http://www.biochar-international.org/extension).

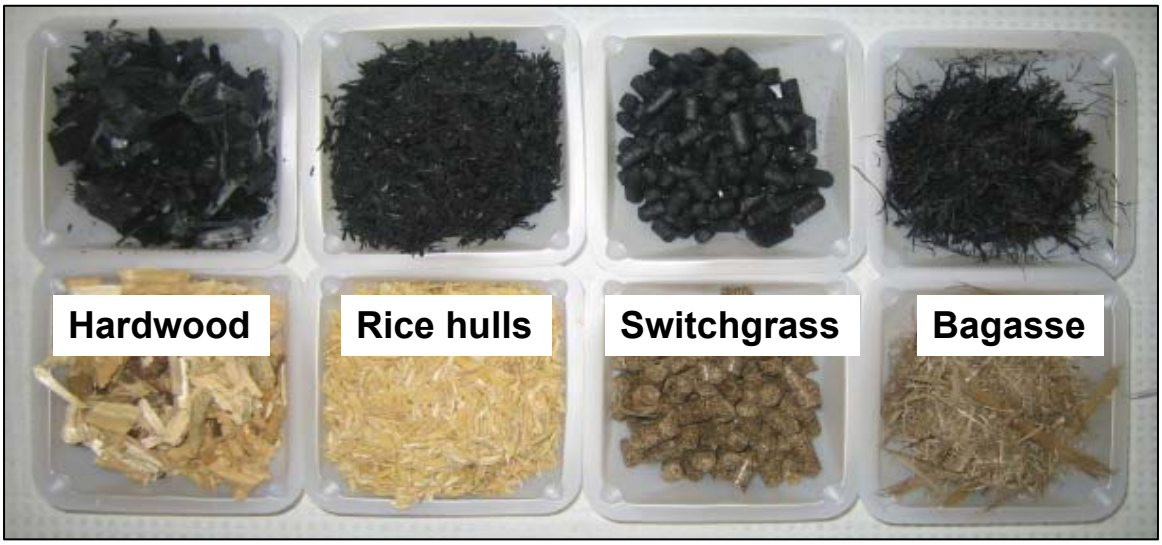
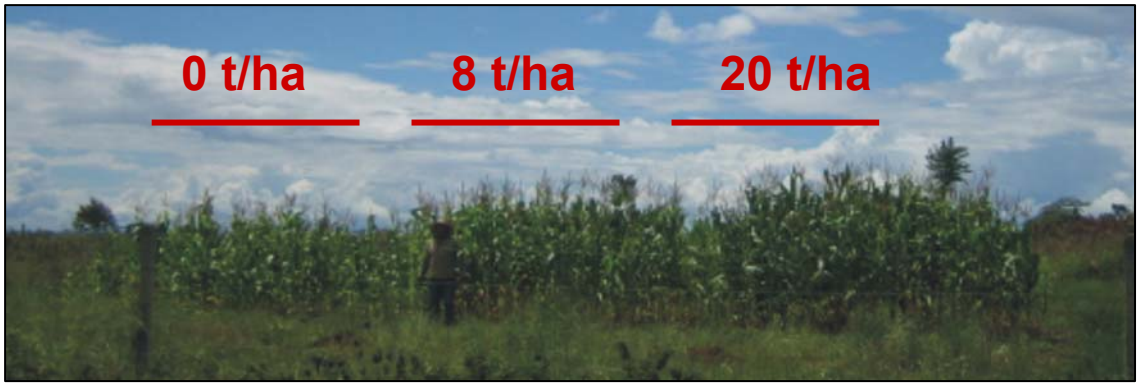


Photo courtesy of Julie Major

Some biochar materials, for example those made from manures and bones, are mainly composed of ashes (so-called “high mineral ash biochars”), and thus can supply considerable amounts of nutrients to crops. Keep in mind that this fertilizer effect will likely be immediate and short-lived, just as is the case with synthetic fertilizers. Conversely, the carbon content of high mineral ash biochars is low (e.g. < 10%), and thus longer-term nutrient retention functions will be less for a given amount of material.

The biochar market is still in its infancy, but there are sellers of the product. You may be able to find a biochar seller in your area by searching the Member Directory on the IBI website. With no current standards, it is important to gather as much information as possible on the biochar you will use—be aware of the feedstock, how it was made, if the product has been tested in soil, and if any results are available. Some suppliers inoculate their product with microorganisms or add nutrients to it as well. A soil testing lab in your region can conduct analyses on the biochar so you can see what you are putting in your soil. To find a testing lab in your region, you can contact cooperative extension services, universities with agronomy departments, gardening stores, etc. Labs often have online order forms and offer analysis packages.

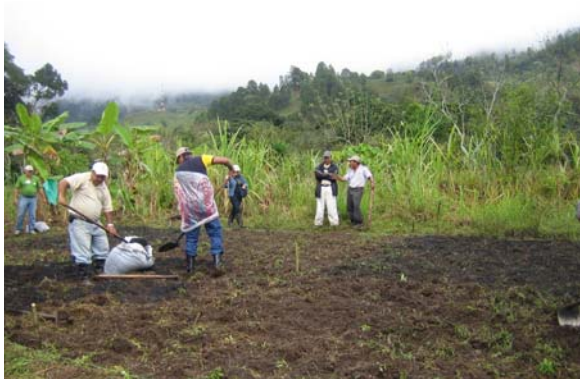
How much biochar should you add to soil?
Given the variability in biochar materials and soils, users of biochar should consider testing several rates of biochar application on a small scale before setting out to apply it on large areas. Experiments have found that rates between 5 – 50 t/ha (0.5 – 5 kg/m^2) have often been used successfully.



Biochar application rates in a field trial in Colombia. Photo courtesy of Julie Major

How Do you Apply Biochar to Soil?
Biochar can be applied along with other amendments like compost, manures or crop residues, and it does not need to be applied when each new crop is established to provide benefits over time. Several techniques can be considered for biochar application to soil. At all times, controlling erosion by wind and surface runoff with water must be kept in mind. It is important not to apply biochar when it is windy to avoid losing material.

Uniform topsoil mixing
Biochar is broadcast over the entire application area, usually after primary soil preparation (e.g. by hand hoeing or disk tilling). This method can be used before crop establishment. Application can be done using lime or manure spreaders. Biochar can also be applied as a liquid slurry, possibly mixed with liquid manure which decreases the chance of loss from wind. After application, incorporation is achieved by hand or with disking or chisel tillage. The most appropriate methods will depend on soil conditions and individual farm capacities. Uniform application could also be considered during the establishment of turf, golf greens, athletic fields, and general landscaping after construction. Uniform biochar topsoil mixing is the incorporation technique most widely used to date.


Digging biochar into the soil in Honduras, photo courtesy of Julie Major

Application to planting holes
When establishing orchards, tree or palm plantations, application of biochar to individual planting holes is a technique that minimizes erosion losses.

Banding
Biochar can be banded at different depths, again by hand or using machinery. Deep banding may facilitate thoroughly covering the biochar with soil, thereby minimizing potential losses after application. This is also an option where crops or trees are already established. Around trees, a circular band of biochar can be applied, or several holes can be made around the base of the tree and biochar applied to the bottom of these holes.

FOR MORE INFORMATION

See the IBI website www.biochar-international.org
Ask the Extension Director/Field Trials Guide: http://www.biochar-international.org/extension
IBI Publications and Research Summaries: http://www.biochar-international.org/publications/IBI
Practitioner Profiles: http://www.biochar-international.org/projects/practitioner/profiles