A Primer on Biochar

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Biochar is charred woody materials used to improve soils, soil health, and soil production. It has many beneficial qualities, among them improving soil texture and facilitating an active soil food web. And, biochar resides in the soil for the long-term. Biochar is largely constituted by mineral forms of carbon – jumbled graphene sheets of fused aromatic carbon rings – that resist microbial decomposition, sometimes for millennia.

Numerous studies have indicated that raw and well-cured biochar improves crop production and soil health in a variety of soil types. While a few studies have reported declines in crop production using raw biochar, no studies using cured biochar – aged one season with compost or soil – have indicated crop decline. From our observations in the industry, Cannabis sure likes it.

Likewise, numerous studies indicate that biochar benefits soil organisms and helps remediate abused and toxin-laden soils.

This brief primer lists a few of the ways biochar biochar enhances and improves short- and long-term soil health and crop production and then summarizes why biochar does all these wonderful things.

How is Biochar Made?

Biochar results from pyrolyzing woody materials – usually at temperatures ranging between 700°F to 2200°F (370° to 1200°C) – with the optimal range between 1300° F and 2000° F (700°C to 1100°C) As the feedstock heats, volatile compounds gasify and exit to be burned, transformed to commodities, or lost to exhaust, leaving behind the mineral carbon and varying amounts of ash. Biochar makers use several different sources of feedstock, from wood chips or cord-wood to rice hulls, corn residues or bamboo. Any feedstock that contains ligno-cellulosic biomass can make char. People use various devices ranging from pit kilns to traditional charcoal kilns to retort kilns (that use volatile gases as fuel) to syn-gasifiers. Biochar quality depends primarily upon highest-heating temperature, heating time period, and feed-stock.

How does biochar enhance and improve short- and long-term soil health and crop production?

Nutrient-Buffering, Fertilization and pH-Buffering. Biochar delays the release of fertilizer minerals (like nitrogen and phosphorous) into the rhizosphere (root zone) and extends the duration of the release. Several mechanisms support this delay and extend pattern.
A primary mechanism supporting biochar's nutrient buffering is its tremendous capacity for **water absorption** and **water holding capacity**. Biochar has an enormous **surface-to-volume ratio** due to its complex surface, shaped from the burning and gassing-off of oils and solids. Because of variation in compounds in the original feedstock, variation of release heat in different compounds, variation of dissertation of these compounds, and several other factors, biochar is porous, and cavity-size varies greatly.

Its ability to hold water bestows biochar's ability to moderate the release of nitrogen in nitrate form and phosphorus in phosphate form, as biochar absorbs the nutrient-laden soil water solution. Biochar holds the water which in turn holds the nitrogen and phosphorous.

Likewise, biochar surfaces have extensive **cation-exchange capacity**. These complex surfaces with their tremendous surface-to-volume ratio, have abundant negatively-charged cation-exchange sites. So, as calcium and other cations contact biochar's positively-charged surfaces, they adsorb to the surfaces for later release into the solution by substitution or through biotic exchange.

In addition to nutrient buffering, biochar can bring fertilizing nutrients to the soil solution, as well. As carbon structures volatilize, they leave behind **minerals** inside the structure of the char. Further, as some burning does occur on the feedstock surface, it leaves behind mineral salts, especially calcium carbonate. Calcium carbonate, a salt (ash) from the burning process, tends to adsorb to the surface of biochar, thereby raising pH, and providing calcium for the soil food web. Some biochar (for instance, some pine-based chars) also contribute potassium to the soil solution.

Furthermore, due to its ability to adsorb cations, biochar (and especially well-cured biochar) can buffer soil pH by removing base cations from the soil solution. And, due to its ability to absorb water with anions, it has the ability to buffer acidity as well. (As a note of caution, raw biochar can increase pH due to calcium carbonate contribution.)

Beneficial Physical Properties and Soil Texture. Biochar can reduce soil bulk density, improve porosity soil water-holding capacity, and reduce the overall stickiness of some heavy clays.

Biochar relieves **soil bulk density** by creating air-spaces around it's variously shaped particles and by virtue of its own porosity – characterized by a wide-range of pore-sizes and shapes. And, by virtue of it's porosity, biochar exhibits great water holding capacity. Biochar sucks up water and holds on to it for gradual release into the soil solution.

Soil Food Web Support Services. Biochar provides many benefits to a thriving soil-food web and encourages bacteria as well as fungi. Biochar has diverse dimensional structures, due to slight variations in conditions within each particle, and thus, it provides habitat for diverse organisms. It's surface complexity and porosity provide a structural environment for bacteria and bacterial colonization and protection from larger bacteria-eating nematodes and protozoa. Recent research suggests that high-temperature biochar (700-1,000°C) displays electromagnetic conductivity independent of the surface salts. Since biofilms and micro-organisms transmit electrons as an energy form electron transport, a surface EC may facilitate biofilm formation. And, finally, biochar holds water, necessary for biological processes supporting bacteria growth.

Induced Resistance to Pathogens. Recent research indicates that biochar can induce a plant's pathogen-resistance system through *Systemic Acquired Resistance* (salicylic acid pathway) and through *Induced Systemic Resistance* (ethylene and jasmonic acid pathways).

Notes of Caution

Biochar also can cause problems in soil, primarily if the biochar is low-quality. Some characteristics to be aware of include:

Hydrophobic, Stinky, and Woody char. When biochar heating temperatures are not high enough or the process is too short, volatilized carbon compounds can re-condense into biochar surfaces, creating hydrophobic surfaces that repel water. This char smells like creosote (dirty stovepipes) because it contains creosote and many similar compounds.

Likewise, these condensed compounds can discourage microbial colonization. Fortunately, curing low-temperature biochar with compost can eliminate most of these problems.

Another problem with low-temperature chars is that often they have uncharred wood at the core, diminishing the overall effectiveness of the char. Woody char still maintains the benefits of high-quality char, though they are proportionately diminished.

Biochar can pull nutrients from the soil. Un-cured biochar can pull nitrogen-rich water from the available water reserve, thus making nitrogen unavailable. However, curing or “charging” biochar eliminates this potential problem

Biochar can raise soil pH. Uncured biochar surfaces often hold mineral ash, especially calcium carbonate, which can raise the soil pH. Again, curing the biochar by mixing with good-quality compost eliminates this tendency.

CONCLUSION

Aside from benefits to farmers and gardeners, biochar offers some wider social and environmental benefits. Primary among these benefits is that biochar sequesters carbon so well. Currently, atmospheric carbon is a serious problem. Biochar sequesters carbon that would otherwise be respired (by microbes) or burnt and released as CO_2. And, it offers an economic use for the millions of tons of biomass burned every year at great financial expense (especially in labor). This economic use conceivably can make other important forestry practices feasible, for example forest restoration and fuels management in the wildland-urban interface.

Since biochar as a phenomenon is relatively new to western science, we are only beginning to understand it. We are learning, for example, that most temperate soils have evolved with a large amount of char from natural burning – a notable characteristic of soil that has been neglected until now. This understanding is leading to new understandings on the mechanics of soil. Likewise, though the current and recent research is encouraging, the research is not extensive, especially concerning specific applications. Thus, we will be learning much about biochar's benefits and constraints in the future.