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Understanding Biochar Series

What The Various Constituents Of Biochar Do Upon Being Put In The Soil

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As produced, a given biochar possesses some properties derived from the starting biomass and other characteristics determined by the process used to convert the biomass to biochar. While it is useful to understand how the final qualities of the biochar are created, such insights are less relevant to the subsequent utilization of the biochar in growing applications. The most important considerations for the future of a biochar, once created, are what are the levels of the various constituents, and how do they behave in the soil. Fortunately, biochar is composed of a few simple types of materials, and they all behave in predictable, if different, manners in the soil.

Conceptually, it is useful to divide the compounds present in the biochar into two groups: those that dissolve in water (water-soluble) and those that don't dissolve or do so only over a very long time, like more than a century. The difference is the water-solubles are going to leave the biochar and enter the soil water, where they will either be washed away, if there is excess water, or they will be able to interact with the soil microbiology, and usually get eaten. The insolubles, on the other hand, will likely remain with the soil. Having said that, if the bulk soil erodes away, the insoluble biochar will likely be taken with it, but that is more a soil management issue than a biochar property.

The most important difference between water-soluble compounds and water-insoluble is the duration of their impact; water-soluble effects occur within the first growing season or two, whereas the insoluble impacts are essentially permanent, persisting from one growing season to the next. Furthermore, water-soluble impacts can be either positive or negative, depending on specific nature of what is being dissolved into the soil water. As such, it is useful to understand the water-soluble impacts associated with adding biochar to the soil, since they are likely the first effect that will be observed in the crop.

The most obvious water-soluble phenomenon is the presence of soluble organic compounds, which results from biomass that has not been sufficiently carbonized to render it resistant to biological decay. This represents a range of compounds from leachable sugars all the way to heavy tars and are referred to as “mobile matter” or “labile carbon”. Overall, they are a symptom of lower quality biochar and are fairly easy to detect by either a sweet and/or burnt odor or requiring soap to get the black off one’s hands after handling (called the Soap Test). Some researchers claim tarry low temperature biochars stimulate the development of microbial populations in soils, but this effect appears to happen only in soils with exceptionally low initial biological activity, such as sandy, desiccated or chemically-fertilized soils.

The other class of water-soluble compounds relates to ash constituents. The types and levels of ash were discussed in *UB#2: Measuring Biochar Properties – focus on Ash Levels and Value*, which can be reviewed for additional insights. The issue we will be focusing on here is the impact of increased salts in the soil water, which can manifest itself as elevated **tds** (total dissolved solids) and conductivity, in addition to influencing pH.

Both tds/conductivity and pH are “Goldilocks” phenomena – not too much and not too little is what the soil microbiology and plants prefer. In general, elevated tds will correct itself with natural precipitation events over time – unless it is a very dry growing climate and there is essentially no liquid moisture leaving the soil. In growing systems that are irrigated, excess salts rapidly flush out, unless the incoming irrigation water contains elevated levels, commonly referred to as “brackish” water.

Soil pH is a big issue, and sometimes gets more attention than it deserves. The pivotal concept is whether the soil has any soil microbiology present, which allows the plant to basically control the pH of the surrounding soil. This is done by the plant providing root extrudates to the soil microbiology, which then excrete organic acids if the soil pH is higher than the plant desires, and consume excess organic acids if it is too low.

The problem is when there is too little soil microbiology, and the plant has nothing to feed to correct the soil pH. This is a common problem when using chemical fertilizers, the nefarious “better living through N-P-K”, when the soil microbiology is suppressed and the soil pH is dictated by the excess inorganics present in the soil. In those cases, it is probably better to fix the problem with the lack of soil microbiology than to attempt to micro-manage the soil pH by adding more inorganic salts, such as lime or ammonium sulfate.

Unfortunately, if the soil pH is out of kilter and there is too little life in the soil, the pH inhibits both the development of soil microbiology and plant growth, including germination. It becomes a vicious circle, especially when using chemical soil amendments. For those situations, about all one can do is avoid anything to make the soil pH more out of balance, such as would happen if biochars that contain supplemental lime were added, and/or add some organic-rich soil amendments to stimulate biological levels in the soil.

Over time, the soil properties will correct and control the effects of water-soluble amendments, which is why the emphasis should be on the long term effects of the majority water-insoluble portion, the carbon-rich micro-porous essence of biochar. The unique biochar properties, created during the transformation of biomass by pyrolysis, are explored in *UB#1: Understanding Biochar – what happens when Biomass is heated (pyrolyzed)*. The challenge is translating the graphitic micro-porous uniqueness of biochar into the impacts observed in the soil, and understanding how to take advantage of those impacts in growing systems.

Here’s one way of looking at this: let’s take the adjectives “graphitic micro-porous” apart in pieces, starting with “porous”. Biochar is mostly open space – voids – over the range of the sizes from the gaps between the particles in the soil all the way down to cracks and crevices literally the size of single sugar molecules and smaller. As discussed in UB#1, over 85% of the volume of biochar is open space that is either occupied by air or water, and is capable of alternating between the two. This does two important things in the soil; it provides space for water to accumulate during precipitation events and it creates aeration pathways that prevent soil compaction and anaerobic conditions often encountered in clay soils.

The “micro-“ modifier of porous means the pores are tiny – really tiny – the size of individual molecules tiny. Unfortunately, both adsorbents, like biochar and activated carbon, and soils have pores divided into classes of micro-, meso- and macro-pores, and the pores are two completely different ranges of sizes. For example, if the size of the biggest carbon micro-pore was scaled up to the size of a single drop of water, the equivalent scale largest soil micro-pore would hold 20 million gallons. On this scale, bacteria are about the size of minnows, and the rest of the soil microbiology is like traditional bigger fish.

This range of pore sizes in biochar allows for many unique interactions with the soil microbiology by providing “right-size” habitat for microbes – the proverbial “condominium for the soil bugs”. While the biochar meso- and micro-pores are too small for even bacteria, the macro-pores cover a range of sizes that includes virtually all soil biota and their spores (which greatly improves the survival of soil biology between periods of active growth).

The last unique feature of the biochar is the walls of all those pores are made of graphite - essentially pure carbon. Graphite as a material has the unique property of attracting organic molecules to “adsorb” to its surface. The net effect of having biochar in the soil is to provide enormous amounts of surface area to allow organics to collect on them, thereby leaving the soil water that much cleaner. For example, adding a layer of biochar ¼ inch thick (= about ¼ pound) to a square foot of soil adds 150,000 layers of graphite, and both sides of every layer can help purify the soil water.

The biochar adsorption effects are multiple and manifest themselves in improved soil moisture retention, decreased plant nutrient leaching and increased soil biota survival between crops. In addition, the biochar adsorbs humic and fulvic acids from the soil water when detritus is decaying, and store these materials as increased soil organic matter, providing additional CEC and water retention capacity. Then, between growing seasons, when there are no plant extrudates to feed the microbes, the biochar desorbs the humic and fulvic acids back into the organic-deficient soil water and provides critical carbon sources for the soil microbiology to survive until the next crop.

In summary, the water-soluble organics and ash in biochar influence the initial period when the biochar is initially introduced into the soil. The long term impact is dominated by the water-insoluble and essentially permanent graphitic micro-porous structure, created out of the original plant biomass and transformed by pyrolysis into the biochar. The result is a a material that transforms the soil into a cleaner and more productive environment for both the soil biota and the plants being grown.

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