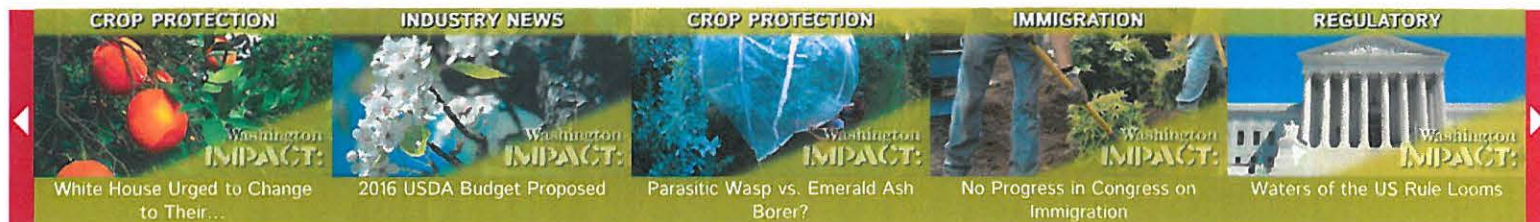


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### The Beef on Biochar: Understanding Its Potential Uses in the Horticulture Industry

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Dr. Matt Taylor and Dr. Brian Jackson

The biochar fire has begun and it is not being used to cook burgers, but as a potential growing media additive. Biochar is also referred to as "black carbon" and, in general, is a residue that remains from the incomplete combustion of organic material. This carbon is highly resistant to decay and can exist in soils for much longer periods than typical organic matter (hundreds or thousands of years). There are agricultural areas of the Amazon basin that contain large amounts of biochar that is 500 to 6,000 years old and is thought to be the result of human activity. These soils are considered some of the most fertile in the world due to the influence of biochar on soil structure, microbial activity, nutrient content, and physical and chemical properties.

Research and commercial use of biochar in agronomic crop production has been taking place since the early 2000s. More recently, interest from the horticulture world has been picking up steam with the commercial availability of biochar and horticultural mixes containing biochar increasing. Currently, there isn't much information available about biochars' use in container crop production but some research suggests increased cation-exchange-capacity (CEC) in mixes, moderate fluctuation of nitrate levels during crop production, and alleviation of certain disease progression caused by Phytophthora. Understanding the differences between sources and production techniques for biochar, as well as the physical, chemical, and biological properties is important when deciding to make changes to your current production techniques. This article will help you make the choice.

#### Production of Biochar

There are, in fact, many processes that can be used to make biochar including torrefaction, pyrolysis, and gasification. These processes differ in the temperature ranges and exposure time/speed of the organic feedstock

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to those temperatures. These factors result in biochars with varying physical and chemical properties. There is currently a lot of research being conducted around the country by private companies, universities, USDA researchers, and private individuals who are working to find and capitalize on potential benefits of using biochar in growing mixes. As a result of the process(es) of making biochar, it is conceivable that many unused or underused organic waste materials could be used as a value-added product. The main issue that should not be overlooked by companies or individuals who are working with biochar is that, like compost, biochar and is extremely variable from source to source, and one biochar is not like another (Figure 1). A brief look through the scientific literature in the past decade highlights dozens of ways in which biochar is made, most of which are small production methods/facilities that are incapable of producing large volumes. Other methods, such as gasification machinery at rice processing plants that burn rice hulls for the energy and have charred hulls as a by-product, can produce many tons per day.



Figure 1.

If biochar is to be used on a large scale across the country, methods of producing it will need to be large enough to supply large volumes, especially for agronomic use. It can also be a concern that the consistency and reproducibility of biochar (even from the same source) may not always be the same. Production of biochar, whatever the method, needs to be consistent (same feed stock, particle size, moisture content, time of charring, temperature of charring, etc) in order to assure the most reliable product possible. These variables are some of the reasons that our industry has had issues with using compost in production systems – the extreme variations that occur between and among sources, seasons, and years. Much like compost, biochar should be considered a verb and not a noun!

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#### Physical Properties

The physical properties of biochar, like any organic or inorganic material, are directly related to the particle size of the material. Depending on the feedstock source and method in which the char was made, particles can range from large and chunky (briquettes) to small (lots of fines; see Figure 2). There are a couple different ways that the particle size of biochar can be regulated/created. First, the feedstock can be processed prior to charring, usually in a hammer mill or some other machine to breakdown the material to a small size. This approach seems to facilitate a more uniform end product, likely because the consistency of particles allow for a more thorough and complete "burn" during the charring process. The second approach to particle size is to process the biochar after it's made. Pulverizing or grinding biochar into smaller particles has been done, however this can be extremely dusty and messy. Some researchers have reported the use of "pelletized" biochar (similar to the process of making wood fuel pellets; Figure 3). Practically speaking, it is more time and cost effective to adjust the particle size of the feedstock material prior to charring since the particle size doesn't change greatly (break down) during the biochar process. Regardless how the particle size is achieved, the incorporation of biochar in soils or growing mixes will change physical properties to some degree. The unique aspect of biochar, however, compared to other aggregates, is that it will not breakdown even after long periods of time. The changes in physical properties (porosity, air space, water holding capacity) of a soil or growing mix created with biochar are likely to remain constant over long periods of time which can greatly benefit the plant growing environment. In short, biochar can improve soil/substrate physical properties depending on the particle size and amendment percentage. Biochar has been made from dozens of feedstock materials over the years with some of the more common sources being wood chips (Figure 4), rice hulls (Figure 5), peanut hulls (Figure 6), and poultry manure (Figure 7).

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Figure 2.



Figure 3.



Figure 4.



Figure 5.



Figure 6.



Figure 7.

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#### Chemical Properties

Similar to physical properties, chemical properties of biochar can be quite variable based on the feedstock and production techniques. Table 1 shows the ranges of pH and some major elements that can be found in biochar. The carbon in biochar is contained within a diverse range of carbon molecules with differing structures and functional groups. Some of these molecules have hydrophilic and/or hydrophobic regions, which can improve the soil retention of organic molecules such as PGRs and pesticides. The molecules and structures also give biochar a significant amount of negatively charged sites for cation exchange capacity (CEC) and positively charged sites for anion exchange capacity (AEC). The added CEC and AEC that comes from amending horticultural substrates with biochar could potentially reduce leaching of fertilizer and improve nutrient use efficiency. A study by Altland and Locke (2012) at USDA, showed that amending a peat based substrate with 10% biochar reduced leaching of both nitrate and phosphate.

Table 1. Range of chemical properties that have been shown to exist in biochar

| Chemical Property | Potential Range |
|-------------------|-----------------|
| pH                | 6.0 - 10.0      |
| Carbon            | 20 - 88%        |
| Nitrogen          | 0.1 - 6%        |
| Phosphorus        | 0 - 7%          |
| Potassium         | 0.1 - 6%        |

The range of pH for biochar in table one is very broad. However, in most cases biochar has an alkaline pH and adding it to substrate will cause the pH to rise. This could present an issue if biochar is added to pre-made

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horticultural mixes. If you are mixing your own substrates on site, lime rates should be adjusted accordingly to account for the biochar. To date, there has been no research conducted to determine the change in pH buffering capacity that may occur when biochar is added to a substrate.

The nitrogen content of biochar can be misleading. Occasionally, biochar can have a significant percentage of nitrogen (N), but this N can be tightly bonded to carbon molecules and unavailable to plant roots. In some cases, the addition of biochar has been shown to reduce the availability of N. A similar effect can be observed with phosphorus (P) where biochar can act as a source. However, some studies have shown that the addition of biochar to soils can bond with and tie up available P. The pyrolysis temperature during production of biochar controls the amount of P since P volatilization occurs at temperature above 1300°F. Potassium (K) in biochar is better understood, and in cases where biochar has high amounts of K, it can be used as the sole source of K as long as the production times are short. In most cases it will only supply supplemental K. In addition to N, P, and K, biochar can also have a significant amount of calcium and magnesium. When using a horticultural mix that contains biochar, fertilization practices will most likely not be adjusted unless the chemical properties of the biochar are fully understood and the proportion in the mix is of a high percentage.

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#### Microbial Properties

Some researchers have indicated that biochar can serve as a haven for beneficial microorganisms and help prevent disease. In a greenhouse study with peppers, researchers indicated yeasts, fungi, *Pseudomonas*, and *Trichoderma* were greater and plant growth was improved in pots with biochar compared to those without (Graber, 2010). Agricultural research indicates a positive effect of biochar on disease incidence, the presence of mycorrhizal fungi, and the richness of bacterial species. However, the effect of biochar in horticultural systems on the presence and pathogenesis of disease causing organisms as well as the presence of beneficial organisms is poorly understood. More research is needed to understand these effects.

#### Use in Container Substrates

While biochar has been proven to yield great results in field soils, the amount of information and scientific data available on its benefit in horticultural substrates is limited. The physical, chemical, and biological benefits of biochar in a soil are often seen over many years. The challenge with seeing such results in container plant production (substrates) is that these crops spend so little time in the containers that little advantage has been proven at this point. When you consider the ideal growing environment that greenhouse and nursery growers provide their plants (good substrate with adequate physical properties, proper pH adjustment, sufficient water, luxury consumption of nutrients, etc), it can be difficult to observe growth differences (improved performance). However, with more research and understanding of the potential benefits of biochar (chemically and physically) it is conceivable that cultural practices could be modified (lower fertility, lime, aggregate use, etc) to better allow the natural properties of biochar to enhance substrate properties while cutting costs of inputs (fertilizer, lime, etc). Areas of great interest concerning biochar and substrates include increased or improved pH buffering, source of potassium and phosphorus, or improved porosity by using biochar as an

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aggregate in place of perlite.

### Current Research

Research across the country continues to evaluate biochar for both field (soil) and container (substrate) plant production. Much work is being done on the effect of biochar on nutrient charge and retention in production systems as well as a more in-depth look into its chemistry to assess pH modification potential. Container production of horticulture crops is based on such precision and accuracy (at least that's the goal) so any new material or component introduced into our growing systems needs to also be precise and reliable. From a substrate perspective, more calculated research needs to be conducted especially on the processing and production side of biochar before it can be fully understood and its potential benefits utilized.

### Conclusion and Future Outlook

When purchasing and using biochar it is critical that the specific chemical and physical properties are understood in order to use the product effectively. If you are considering using a mix with biochar or adding biochar to your current mix, it is advisable to try this on small portion of your crop in order to effectively gauge the value of this amendment to determine if this product is right for your operation. It is also advisable to not assume every source and batch of biochar is the same (will yield the same properties or benefits).

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Figure 1. Biochars made from various feedstocks by different methods (torrefaction, pyrolysis, gasification) and at different particle sizes can yield very different products.

Figure 2: Biochar produced with yellow pine. Note the small particle size (0.02 to 0.08 inches).

Figure 3. Pelletized biochar can be made from any biochar feedstock/material.

Figure 4. Biochar produced from pine wood chips.

Figure 5. Biochar produced from rice hulls. Even during the intense high temperatures of the charring process, the particles remain mostly intact and retain their shape.

Figure 6. Biochar produced from peanut hulls.

Figure 7. Biochar produced from poultry manure yields very fine particles compared to other feedstock materials.

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