

Amending Substrates with Biochar

BIOCHAR — WHAT IS IT? AND CAN IT BE USED IN CONTAINER SUBSTRATES?

By James Atland

Biochar is charred organic matter that remains after a process called pyrolysis. Pyrolysis is a thermochemical decomposition of organic matter. In this process, organic matter is subjected to extremely high temperatures (200 to 800° C) in the absence of oxygen. Because there is no oxygen, there is no combustion or flames. The organic matter is charred instead of being burned in the traditional sense. Biochar is essentially the same as charcoal, with the primary distinction that biochar is intended for some form of soil or agricultural application.

Brief History of Biochar

How did the buzz around biochar begin? Well, it really started back in the 1870s when an American geologist, James Orton, described large patches of the Amazon Basin in Brazil as having “black and very fertile” soil. Soils of the Amazon Basin are typically highly-weathered, grey-colored, infertile, and generally poor for growing crops. However, as Orton described, some patches of soil found throughout the basin were so dark they approached blackness, and these sites were highly fertile. These patches of soil, usually 10 to hundreds of acres in size, were known as “terra preta,” or black earth, by locals of the Amazon Basin. It wasn’t until the 1990s that scientists realized these pockets of dark fertile soil were actually enriched by charred organic matter. Based on archeological evidence, it is likely that these regions of char-enriched soils are anthropogenic in origin, and likely the result of land clearing (with fire) by indigenous peoples over many thousands of years.

This lesson in archeology posed an interesting

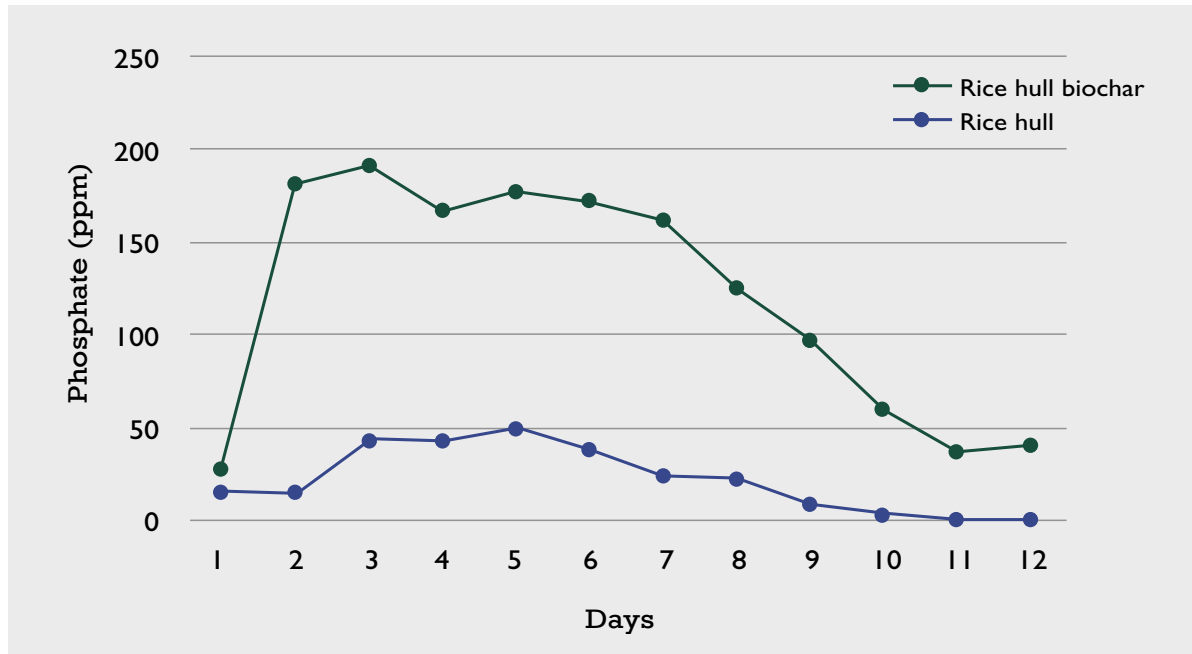


Under typical production regimes, floriculture and nursery crops respond very little to biochar amended in the substrate.

question for modern-day farmers. If charred organic matter, added over many thousands of years, could improve soil fertility in the Amazon Basin, could fertility of poor soils today be improved by adding charcoal? Through research and experimentation, the answer was, “Yes!” Previously infertile soils in

the Amazon Basin, if amended with high rates of charcoal, were shown to be more fertile and conducive to crop growth. This caused a buzz in agricultural circles. Simple and inexpensive charcoal could be used to improve the fertility of soils! But the buzz didn’t last long. While adding charcoal

Figure 1. Phosphate release in a greenhouse substrate over 12 days from rice hulls versus rice hull biochar.



to infertile soils did improve fertility by increasing soil pH and cation exchange capacity (among other factors), adding charcoal to already fertile soils like those found in the U.S. heartland was ineffective at best. The benefits of adding charcoal to already fertile soils just were not great enough to justify the expense and effort of applying the charcoal.

In the mid-2000s there was renewed interest in biochar for two overlapping reasons. First, bio-fuels were the hottest trend in science. There are many ways to generate biofuels, or synthetic fuel from biological systems. But one very promising approach was to take organic matter or manure, subject it to pyrolysis, and collect the liquids and gases released from the biomass as it was heated. These carbon-rich gases and liquids are precursors to diesel fuel. After removing these volatile organic compounds for synthetic biofuel production, what is left is a black, charred mass that we call biochar.

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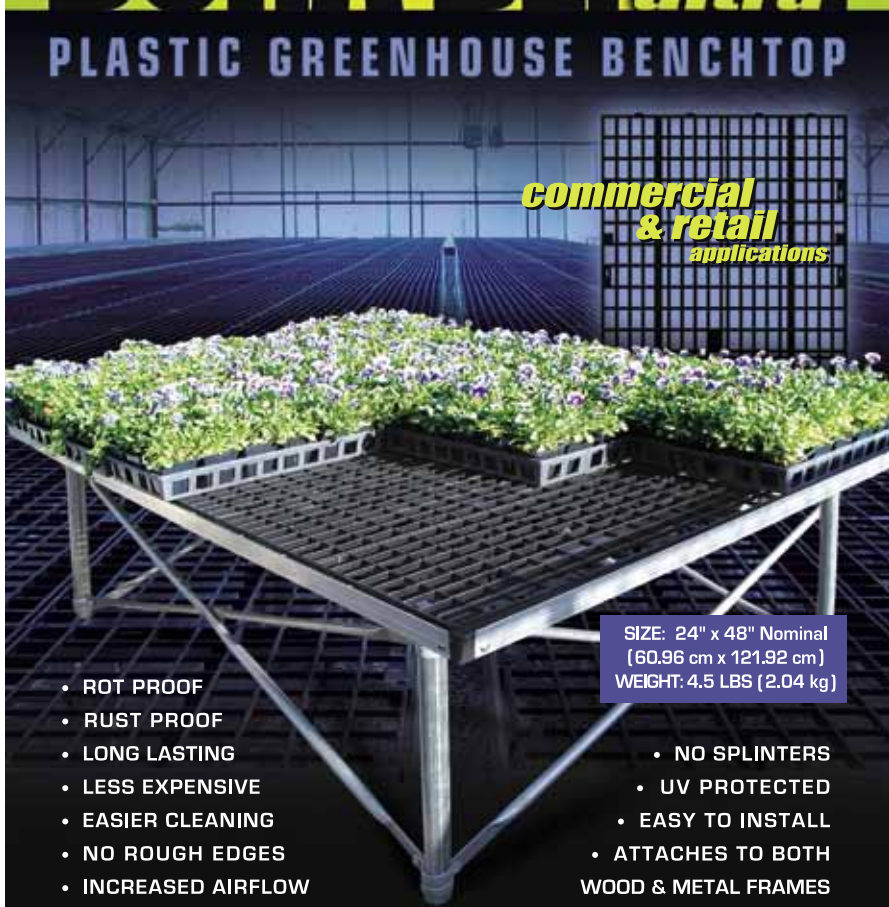
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The second factor in the renewed interest in biochar was the speculation that carbon added to the soil, in the form of biochar, would remain stable for centuries or eons. This was a powerful argument. You could take an agricultural biomass, subject it to pyrolysis to extract fuel, then add the remaining

biochar to soil for long-term carbon sequestration. It was thought, if done in large enough quantities, that this might not only slow greenhouse gas emissions of carbon dioxide into the atmosphere, but it might reverse the trend! The jury is still out on this. First, it's not clear if this form of energy

production is sustainable long-term, and it's also argued that biochar added to the soil may not be stable for thousands of years as originally thought. Despite the veracity of the claims, biofuel generation through pyrolysis re-ignited (no pun intended) the idea of adding charred organic matter to soils.



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Does Biochar Improve Field Soil?

There have been hundreds of papers published on the effects of biochar on soil properties. As you can imagine, there is not 100 percent agreement among all these papers as to how beneficial biochar is or can be. Generally speaking, biochar has been shown to be very beneficial in highly weathered tropical soils, soils with low pH, or soils with low cation exchange capacity. Biochar has been less beneficial when applied to fertile soils typical of agriculturally productive regions in the United States.

What are the Properties of Biochar?

The properties of biochar vary greatly. A colleague of mine, Dr. Jim Locke, made an apt analogy in comparing biochar to compost. Many of us are familiar with compost, and understand the vast number of compost types. The properties of biochar depend on the agricultural feedstock that is being pyrolyzed, just as compost properties depend heavily on the original material being composted. The properties of biochar also depend on the pyrolysis regime. Pyrolysis generally occurs at temperatures ranging from 200 to 800° C, and can last minutes to hours. Different heating regimes result in biochar with varying degrees of charring and different properties, just as the composting process (length of time, size of pile, etc.) affects the properties of compost.

All that to say, the properties of biochar vary considerably from one source to the next, just like compost. But there are some generalizations we can make about biochar. First of all, the pH of biochar is almost always very high, usually 8 to 10. We have found that amending typical greenhouse and nursery container substrates with 5 to 10 percent biochar (by volume) only increases pH up to 0.5 point. Even though the pH of most biochar materials is high, it has

minimal effect on overall substrate pH. The rice hull biochar we evaluated also had minimal effect on substrate CEC. Biochar has many of the same properties as activated charcoal, so it can chemically adsorb many pesticides. Biochar amended into substrates might reduce the effectiveness of soil applied fungicides, insecticides and maybe even preemergence herbicides.

Specific and Unique Properties

As mentioned previously, each biochar type will depend on the properties of the original feedstock. Agricultural biomass materials used for pyrolysis are, like all biomasses, comprised primarily of carbon, hydrogen and oxygen, with relatively minor concentrations of other elements such as iron, phosphorus, calcium, magnesium, etc.



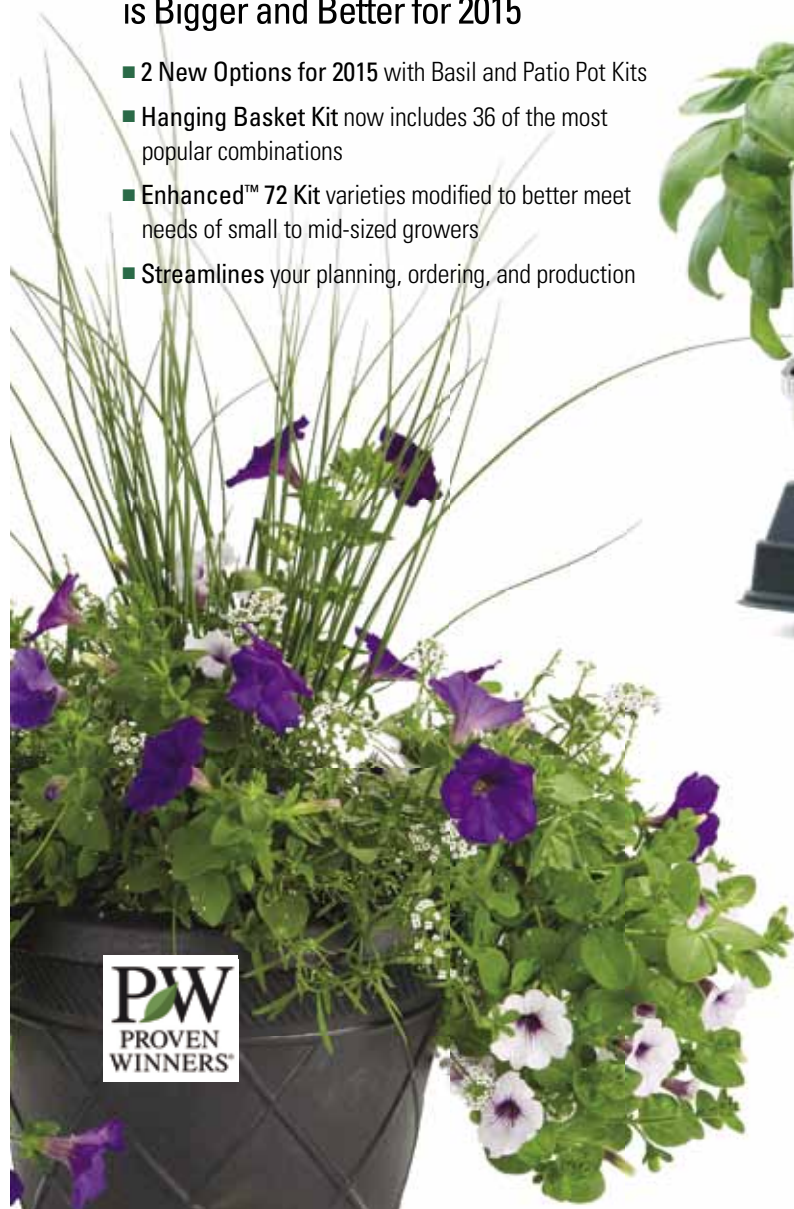
A USDA-ARS biological science technician measures nutrient release in greenhouse substrates amended with various forms and rates of biochar.

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During pyrolysis, much of the carbon, hydrogen, and oxygen in the original feedstock is volatilized and collected for the generation of synthetic bio-fuels. The remaining elements and nutrients in the original feedstock are left behind in the biochar, but at much higher concentration. For example, it has been documented that rice hulls have a relatively high concentration of phosphorus (P) and potassium (K). When rice hulls (often called par-boiled rice hulls or PBH) are amended into greenhouse or nursery substrates, a small but measurable amount of these elements become available for plant uptake. Some rice processors use rice hulls as fuel in gassifiers to produce synthetic gas to heat the boilers. What is left from this process is a form of rice hull biochar, sometimes called rice hull ash. We have found that rice hull biochar has much higher concentrations of P and K than rice hulls (see Fig. 1). Rice hull biochar also contains very high concentrations of silicon (Si), which some scientists believe is useful in rendering plants more resistant to biological and abiotic stresses. This form of biochar is not commercially available for horticulture, but it illustrates the concept of how moderate concentrations of nutrients in the biomass feedstock are concentrated in the biochar form.

Should Substrates be Amended with Biochar?

There is no good answer for this question. These are the facts that you should take into consideration.


Biochar could affect physical properties of your substrate. In our experiments, this impact was minimal when amended at rates of 5 to 30 percent

(by volume) of the substrate. Biochar is available in many different particle sizes. Some have suggested using biochar as a replacement for perlite. This is a reasonable suggestion if you can get biochar with coarse enough particles.

Biochar could affect substrate chemical properties. It will likely cause the pH of your substrate to

increase slightly. Biochar is not as effective as dolomitic lime for increasing and buffering pH, but you can expect from ½ to 1 pH unit increase with higher rates. In addition to pH effects, biochar generated from feedstock with high nutrient concentrations will have even more magnified nutrient concentrations (as previously discussed).

Some research has shown that biochar can induce systemic resistance in plants, which in turn reduces the severity of pathogens and some arthropod pests. For example, research has shown that biochar amended in container substrates can reduce disease progression and physiological stress caused by Phytophthora canker on oak and maple trees. An often cited benefit of biochar in soils and soilless substrates are the positive alterations in the soil biological community.

Biochar probably has limited utility in soilless substrates. Recall my comments about how biochar tends to show more positive benefits when applied to poor soil types. Now consider that container crops grown in soilless substrates are engineered to have optimum physical properties for proper aeration and drainage. They are fertilized with relatively high nutrient rates, irrigated on-demand, often grown in protective greenhouse structures, and managed with pesticides and cultural practices to reduce insect, disease and weed outbreaks. Nursery and floriculture crops may be the most pampered plants of all production systems. While the forms and types of biochar vary greatly, there is nothing inherently magical about them that will drastically, or even noticeably, alter or improve container substrates. They may have niche uses, especially for those biochar types with high nutrient concentrations (for example, rice hull biochar), but overall they are not likely to improve soilless substrates in a meaningful or impactful way. Like many biomass-derived materials, they can be amended in substrates at low concentrations (5 to 20 percent, by volume) without causing any harm. But in most cases, do not expect drastic benefits either. 

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