Biochar is a solid material derived from the carbonization of organic matter — charcoal. It has been used as a soil amendment in agricultural production for centuries to improve soil structure and cation exchange capacity. Perhaps the best-known example of biochar use in agriculture is the “terra preta” (dark earth) soils of the Amazon. Scientists have found that these rich loam soils were created by pre-Columbian civilizations by incorporating charcoal and fish bones into the soil. The result is soil nine times more fertile than the surrounding unamended soil; the amended soil was capable of supporting agriculture to feed populations in the millions. Today biochar is receiving renewed interest in agriculture, both for its soil-building properties and for its use in carbon sequestration to combat climate change.

**BIOCHAR PRODUCTION**

As mentioned above, biochar is produced from organic matter — wood, leaves, manure, etc. — that is heated with little to no available oxygen and at relatively low temperature (<1,000 °F). This process, called pyrolysis, results in the thermochemical decomposition of the organic matter. Unlike normal microbial decomposition of organic matter that produces water and carbon dioxide, pyrolysis of organic matter produces biochar and biogas; both processes also release mineral nutrients. The biogas is generally a mix of hydrogen, carbon monoxide and light hydrocarbons (methane, acetylene, ethylene, etc.), depending on the feedstock. These can be captured and used as fuel for heating or power generation. The biochar, which is virtually pure carbon, can then be used as an agricultural soil amendment.

**BIOCHAR AS A SOIL AMENDMENT**

The carbon in biochar is highly resistant to decomposition and therefore can hold carbon in soils from hundreds to thousands of years. Thus, biochar can be viewed as a permanent addition to soils, making it particularly advantageous in perennial crop systems like citrus.

Biochar is naturally found in soils around the world as a result of vegetation fires as well as historical soil management practices (e.g., terra preta soils). Biochar can be an important tool in areas with highly depleted soils, scarce organic resource availability, or inadequate water and/or chemical fertilizer supplies. In highly depleted or leaching-prone soils, biochar can be an important tool for preventing groundwater contamination by increasing soil retention of fertilizer nutrients and agrochemicals. Biochar itself is not a fertilizer; it is a stable form of carbon and a permanent soil amendment.

One of biochar’s important effects on soil comes through improving the number and diversity of beneficial soil
microbes (Fig. 1, page 6). The fine porous structure of biochar serves as a habitat for microbes, protecting them from drought and predation as well as providing for some of their carbon, energy and mineral needs. Understanding specifically how biochar affects the soil ecology is a very active area of research.

Biochar has a negative charge, which allows it to buffer soil pH. In addition, the negative charge gives biochar a high cation exchange capacity (CEC), allowing it to hold plant nutrients in the soil. Cations are positively charged ions, with calcium (Ca²⁺), potassium (K⁺) and magnesium (Mg²⁺), among others, being particularly important to agriculture.

These basic forms of mineral nutrients are those that plants take up through their roots. Soils high in organic matter or clay content have naturally high CECs and retain mineral nutrients well, making them available to plants as they are needed. However, highly leached sandy soils like those throughout much of Florida have very low CEC, and mineral nutrients can be easily leached with rain or irrigation water.

Although biochar itself does not contain any appreciable amounts of nutrients, its addition to poor soils can greatly enhance their nutrient-holding capacity and potentially reduce fertilizer inputs. Cited benefits of biochar on soil properties include a 50 percent increase in CEC, a 10 percent to 30 percent increase in fertilizer efficiency, 18 percent higher soil moisture retention, 20 percent to 120 percent increased crop productivity, 40 percent increase in beneficial mycorrhizal fungi, and a 50 percent to 72 percent increase in biological nitrogen fixation.

Biochar has also been tested for remediating toxic chemicals in contaminated soils, and one study reported a tenfold reduction of cadmium in soil after application of biochar, with subsequent reduction of phytotoxicity.

SOIL AMENDMENT IN FLORIDA CITRUS

Florida citrus soils can be highly variable. In an article published in the April 2010 issue of Citrus Industry (“Citrus Tree Health and HLB Incidence,” page 14), we presented data on how very small changes in soil composition, particularly organic matter, can have huge impacts on tree growth, productivity and health. A more in-depth presentation of these data was recently published and is available on the EDIS website (http://edis.ifas.ufl.edu/pdffiles/SS/SS55700.pdf). In addition to demonstrating the potentially huge benefits from amending our poor soils, these data show that such amendments are not required over an entire grove, but only on the weakest soils. Targeting amendment efforts at the weakest areas makes soil amendment an affordable management tool.

BURN PILES: POTENTIAL BENEFITS FROM BIOCHAR AMENDMENTS TO CITRUS SOILS

Many growers have observed the effects of burn piles on subsequent citrus growth. Initially the transplanted trees may perform poorly on burn-pile locations, and then after some months or years, the trend may reverse and they grow exceptionally well thereafter. Burn piles actually produce mostly ash from aerobic combustion, and very...
little biochar. The ash tends to over-supply nutrients and especially alka-linity, thus stunting initial growth until the excess soluble components are weathered and leached from the soil, leaving mostly the insoluble biochar.

We have been collecting data to understand the growth differences of 4-year-old citrus trees growing on burn pile-affected soil and surrounding un-affected soil (Fig. 2, page 8). The trees that grew on the dark carbon-enriched soil had 67 percent more canopy volume than trees in adjacent unamended soil (Fig. 3, page 8). The soil carbon, measured by loss-on-ignition (LOI), and the CEC were 4.5 times higher in the burn-pile area, compared to the native soil levels. Also, extractable soil copper concentration in the grove soil was high (139 lb./acre), but was re-duced to negligible levels (0.4 lb./acre) in the burn pile, biochar-amended soil.

More research is needed to fully understand the burn-pile phenomenon, but, more importantly, studies testing the effects of biochar sources, rates and application methods on citrus are required to develop reliable recom-mendations for Florida. Ideally, biochar should be produced on location with citrus trees removed from groves, thus reducing the high cost of transporting a bulky material. Biochar yield from citrus trees would depend on the stand-ing biomass in the grove, probably in the range of a few tons per acre.

Currently, the Florida citrus industry can be considered carbon posi-tive because the trees are ultimately burned. That is, the carbon dioxide released to the atmosphere during the growing and then burning of the trees exceeds the carbon dioxide that is sequestered by the trees through pho-to-synthesis and biomass storage. The conversion of dead trees to biochar can permanently improve our citrus soils for better production and store carbon long-term. In so doing, the Florida citrus industry could become carbon neutral or even carbon negative (a pro cess that removes carbon dioxide from Earth’s atmosphere).

Biochar is a soil amendment with proven benefits to many crops, includ-ing citrus, based on observations of tree growth in burn pile-affected soil. Biochar improves nutrient retention and soil structure, leading to improved crop productivity and health. And all of these benefits can be obtained from locally produced biochar made from normal agricultural waste material.

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The mission of the Florida Department of Citrus is to grow the market for the Florida citrus industry to enhance the economic well-being of the Florida citrus grower, citrus industry and the state of Florida. Douglas Ackerman, executive director, can be reached at (863) 537-3999. For more information, visit www.FDOCgrower.com