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How to Support Long-Term Fertility of Your Soil

Analysis by Dr. Joseph Mercola ✔ Fact Checked | June 13, 2023

STORY AT-A-GLANCE

- Austin Liu, principal biochar investigator at the Local Carbon Network, delved into how water-soluble nutrients are retained and exchanged in soil — and why this is so important for the health of your soil
- High cation exchange capacity, or CEC, and anion exchange capacity, or AEC, are metrics of fertile soil
- When co-composted biochar is added to soil, it significantly improves CEC and AEC; this, in turn, improves nutrient exchange, leading to improved fertilizer utilization efficiency and cleaner runoff
- Fertilizer utilization efficiency can serve as a proxy for nutrient utilization efficiency; the end goal isn't to improve the use of fertilizer but to improve the fertility of soil long-term, such that unnatural fertilizers aren't even necessary
- Biochar is created by slowly heating a biomass in a low-oxygen environment, such as a kiln, until everything but the carbon is burned off; the resulting biochar can then be added to compost before being placed into the ground

Fertile soil is a key to life on Earth. While industrial agriculture has decimated soil fertility via the use of destructive plowing, overgrazing and the use of carbon-depleting chemical fertilizers and pesticides, for decades researchers have been inspired by terra preta de Indio, or "dark earth of the Indians."[1]

This soil, found in the Amazon basin, is thought to be hundreds or thousands of years old — and it's among the most fertile soil in the world. This is despite the fact that it's in a tropical location, where large amounts of rainfall can cause nutrient runoff that leaves soil depleted.

There's much debate — and research — over what makes terra preta so fertile, but one theory has to do with biochar, a soil amendment similar to charcoal that can boost the carbon content of your soil while enhancing nutrient availability and retention.[2] Carbon sequestration can reduce the carbon dioxide load in the atmosphere, and once sequestered in the soil, the carbon actively nourishes soil health and improves water retention.

The Mechanisms Behind Long-Term Soil Fertility

Writing in Medium, Austin Liu, principal biochar investigator at the Local Carbon Network, delves into how water-soluble nutrients are retained and exchanged in soil — and why this is so important for the health of your soil. The reason why tropical soils tend to be poor for agriculture is because plants use water to absorb and transport nutrients — water-soluble nutrients.

These water-soluble nutrients are prone to leaching whenever soil is saturated with water, by rain or irrigation. Applying chemical fertilizers isn't any help, as they, too, are water-soluble. Liu explains:[3]

> *"What then is the difference between a soil that can retain water soluble plant nutrients and one which cannot? The difference is each soil's ion exchange capacity — cation exchange capacity for positive ions and anion exchange capacity for negative ions. Since the major water soluble plant nutrients are all ionic, the ability to capture and exchange ions results in the ability to capture and release water soluble nutrients."*

High cation exchange capacity, or CEC, and anion exchange capacity, or AEC, are metrics of fertile soil. Cations have a positive charge while anions have a negative

charge. Liu listed several examples of cation plant nutrients, which include potassium, magnesium, calcium, ammonium, iron, selenium and zinc.

Major anion nutrients include nitrate, phosphate, sulfate and chloride. Liu explains what this means in terms of keeping nutrients in your soil, rather than having them run off:[4]

> *"Cations dissolve into water because their positive charge attracts the negatively charged portions of water molecules; water molecules then surround the cation and pull it off of the salt crystal. Anions dissolve into water because their negative charge attracts the positively charged portions of water molecules, which surround them and pull them into solution.*
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> *In order for dissolved ions to not run off as water drains out of the soil, the soil must have plenty of ion exchange sites — sites which can attract these dissolved ions well enough to capture them out of the water, but hold them loosely enough that the plant can get these ions off when they need them. For cations, these sites are known as cation exchange sites and for anions, these are known as anion exchange sites."*

Composting Biochar Boosts Its CEC

Biochar promotes plant growth, particularly when it goes through the composting process. Biochar also stimulates soil fertility and plant growth via a slow release of nutrients from its nutrient-rich coating.[5]

This coating forms on co-composted biochar — biochar mixed with organic matter and composted — and "adds hydrophilicity, redox-active moieties, and additional mesoporosity, which strengthens biochar-water interactions and thus enhances nutrient retention."[6] Composting biochar also boosts the CEC. Liu says:[7]

> *"Aerated compost piles are hotbeds of aerobic bacterial fermentation by a diverse mixture of bacterial decomposers. Bacterial fermentation tends to produce weak organic acids, many of which react with and become*

incorporated into the coating that forms on biochar when it goes through composting.

Many familiar bacteria fermented foods serve as examples of this: lacto-fermented pickles and sauerkraut (which contain lactic acid), vinegar (which contains acetic acid), and kombucha (which contains lactic, acetic, gluconic, and glucuronic acids).

At the same time, decomposing organic matter often produces ammonia and amine-containing substances from all the nitrogen-bearing materials, while many alkaline mineral nutrients are released in the process of decomposition; since these substances are basic, the overall compost mixture does not necessarily become more and more acidic as composting progresses.

Much of the ammonia that would otherwise be emitted from compost reacts with biochar and becomes bonded to its surface, contributing to anion exchange capacity."

Biochar even reacts to and bonds with ammonia in compost, reducing these emissions and increasing AEC. "The remarkable levels of nitrate and phosphate anions retained on co-composted biochar which are protected against leaching support this inference," Liu writes.[8]

Co-Composted Biochar Improves Nutrient Exchange in Soil

When co-composted biochar is added to soil, it significantly improves CEC and AEC. This, in turn, improves nutrient exchange, which leads to two primary benefits, Liu says.[9]

1. **Greater fertilizer utilization —** Fertilizer utilization efficiency on conventional farms is very low. Estimates vary, but it's suggested that up to 80% of fertilizer applied to farmland is lost by runoff or off-gassing. Not only does this lead to significant, unnecessary pollution in surrounding waterways, but the excess production of fertilizer is also damaging.

"The production of fertilizer is itself extremely damaging to the environment, incurring massive methane emissions far worse than what the industry self-reports," Liu explains. Runoff from chemical fertilizers spread on agricultural fields contributes to nitrogen and phosphorus in surface waterways and groundwater, leading to dead zones.[10]

In dead zones, animals in the area can suffocate and die, with those unable to easily swim away, such as burrowing crabs and worms in the sediment, being most affected. Other species, like shrimp and eels, may be forced to swim to shallower waters to find oxygen.[11]

In hypoxic marine areas, or waters with low or depleted oxygen levels (defined in the U.S. as dissolved oxygen equal or less than 2 mg/L, or parts per million (ppm)[12]), widespread die-offs of fish and shellfish, along with slowed and stunted growth, are common.[13] Using regenerative farming methods and adding biochar to soil significantly improves fertilizer utilization efficiency, however.

"More of the dissolved fertilizer ions would be caught by ion exchange sites to be made available to your plants, and less of it would be wasted," according to Liu. "Since the utilization efficiency is so critically dependent on retaining nutrients and effective exchange of nutrients with plants, boosting the CEC and AEC of your soil will give you much more effective use of any fertilizers you do apply."[14]

This isn't only about fertilizer, however. Liu points out that fertilizer utilization efficiency can serve as a proxy for nutrient utilization efficiency. And it's because of poor soil fertility that fertilizers are needed in industrial agricultural models. The end goal isn't to improve the use of fertilizer but to improve the fertility of soil long-term, such that unnatural fertilizers aren't even necessary.

2. **Cleaner runoff —** Another benefit of adding co-composted biochar to soil to improve CEC and AEC is cleaner runoff. While this won't stop runoff physically, it ensures the water that does run off is less damaging to the surrounding environment. According to Liu:[15]

> *"The dissolved nutrient ions that come off of poor soil would be much reduced in water draining off of soil with strong nutrient capture and retention. In addition, the chemical mechanisms involved in CEC and AEC in soil organic carbon are also associated with improved water retention.*
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> *From the perspective of pollution abatement — namely, the reduction of fertilizer pollution, algae blooms, nitrate pollution in drinking water, and the stinking dead zones that follow — improving the CEC and AEC of agricultural land is one of the most impactful measures that can be taken to counter fertilizer pollution."*

How to Make Biochar

Biochar is created by slowly heating a biomass in a low-oxygen environment, such as a kiln, until everything but the carbon is burned off. The resulting biochar can then be added to compost before being placed into the ground.

Historically, fire has been the driving force of the Earth's carbon cycle. Natural fires started by lightning burned large swaths of plants and trees, returning the carbon back to the soil in the form of charcoal. Today, most societies take steps to prevent wildfires and greatly restrict burning practices.

The documentary "Dirt Rich" starts out on the big island of Hawaii, where a local farmer shows how he makes his own biochar in a simple burning pit. If you want to create biochar at home, you'll find it's relatively easy. Charred wood left behind after a campfire is a form of biochar, for instance.[16]

To create your own, you'll need to dig an outdoor trench and fill it with biomass, such as brush, weeds, sticks and dried leaves. Light the biomass on fire, then monitor it carefully. You want a low-oxygen environment to prevent full combustion turning the materials into ash.[17]

To achieve this, add more layers of biomass onto the top of the pile to cover any air holes. You can layer until you reach the top of the hole. Once the flames have traveled

through the layers, put the fire out so you're left with material that looks like charcoal — not ash.[18]

Another simple option to radically improve soil quality and the nutrient content of your food is to mulch with wood chips. Simply lay down uncomposted wood chips on top of your garden, using whatever is available locally, typically a combination of leaves, twigs and branches.

The chips gradually break down and are digested and redigested by a wide variety of bacteria, fungi and nematodes in the soil, which is exactly what happens in nature. After a year or so, you'll develop lush soil underneath the chips that will happily support trees, vegetables or whatever else you're trying to grow.

Regenerative Farming Is Urgently Needed

Biochar is just one component of regenerative agriculture, which works with nature to grow healthy food in harmony with the environment. In regenerative agriculture, livestock and crops are integrated into a symbiotic, complementary system that mimics the way nature works.

At the other end of the spectrum, agrochemical companies are using gene editing, genetic engineering, chemicals and other "technologies" to create hybrid seed lines, crops resistant to winds, flooding and droughts and other lab-created agricultural elements.

Like biochar, holistic planned grazing methods naturally sequester carbon, control erosion and increase organic matter in soil.[19] Along with using biochar, composting, wood chips and other regenerative farming methods in your home garden, you can make a difference by supporting regenerative farmers in your area.

Whether at farmers markets, food co-ops or direct from the farm, the more we choose foods grown using regenerative methods, the faster we can improve soil fertility long-term and prompt meaningful, lasting change.

Sources and References

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