FIRST DRAFT

Using Biochar in Soil

Preparation & Application

Biochar's ultimate purpose and destination is soil, and improves almost any soil, especially with low rainfall or nutrient deficits. Adding char to soil makes this strategy carbon-negative, effective to reduce greenhouse gases and thus mitigate global warming.

Biochar improves soil by three critical services:

1) Sponge to soak up water, hold and slowly it release to soil
2) Storehouse to adsorp nutrient ions for exchange to biology
3) Substrate to provide habitat & refuge for soil microbes

However, fresh, raw char in soil can retard plant growth for one or two years. For optimal response with minimal application char requires processing to prepare it for use in soil.

In North America, biochar is a new soil additive, so procedures to add it are under-developed and experimental. This document details guidelines and instructions to prepare and use biochar in soil, with a database to evaluate results and improve practices.

Biochar Description

physical, chemical & biological properties

First: know your char. Char is made by different processes, at different temperatures, from widely varied plant or animal matter. Physical and chemical properties vary greatly, so it's crucial to know char's characteristics. Biochar science is infant, with few standard methods or criteria for analytical evaluation.

The current best technical paper on biochar characterization:

All Biochars are Not Created Equal,
and How to Tell Them Apart

Hugh McLaughlin, Paul S. Anderson, Frank E. Shields, Thomas B. Reed

www.carbon-negative.us/characterization

Source Material

First characteristic is the raw material. Sources vary greatly, from dense hardwood or softwood, to weedy matter like corn stalks or straw, to food wastes like rice hulls or fruit pits, to animal manures. Know the origin of biomass that became your biochar.

Production Process

Many technical methods produce biochar. Even equipment can vary in process parameters. Some are designed to produce biochar, but most are designed to yield energy or activated carbon, not biochar. Some yield alkaline char; others acid char. Learn temperatures, time and other production process factors.

Particle Size

For soil use, biochar particle size must be reduced. From the view of microbes, powdered biochar is most effective and efficient as a culture media. However, soil has need for larger particles, ranging from pea to sand grain sizes. Except hardwood, most char is easy to crush into suitable size and then screened.

Carbonization

Biomass must thoroughly charred, but can be less than 100%. Partial carbonization (torrefication) leaves residues digestible by microbial decay. Excess oxidation creates alkali, soluble ash.

Moisture

Water is crucial in biochar and soil. Char heated to 400+ degrees C is bone dry. Fresh from a burner, char repels water, due to tar and resin residues. Producers may quench fresh, hot char with water to stop oxidation and flare-ups; others blend char with compost, or spray compost tea or inoculants. Denser than char, water adds significant weight.

Minerals

In the focus on biochar as carbon for sequestration, minerals are overlooked. Yet, minerals are primary plant nutrients, and mineral balance (proportion) is fundamental to plant growth and health. Biochar minerals are embedded in the carbon matrix, not merely adsorped onto char surfaces by ionic attraction.

If char's primary minerals aren't within healthy proportions, it may disturb plant growth. This can be remedied by soil microbes, but initial effects may be negative. As microbial substrate, trace elements are crucial nutrients, but difficult to measure or evaluate.

pH (acid/alkaline)

Biochar is acid or alkaline, depending on production process—principally temperature, time and oxygen. pH affects both soil biology and plant vitality, so is valuable chemical information.

Ash

Ash (metal oxides) varies greatly with the production process. This alkali combustion by-product is a major factor affecting pH.

Micropores

A primary biochar benefit in soil is its vast internal surface area, due to its sponge-like micropores, enabling its extra-ordinary absorption and adsorption capacities. Assessing the micropore size, density and integrity is a critical concern, but no standards or analytical methods exist yet to assess this property.

Biology

Fresh from production, biochar is sterile. Yet, it's main service in soil is habitat for soil biology. Microbes don't consume char; they live in it, and rapidly improve soil fertility and plant vitality.

Currently, no consensus exists for standards or analytical methods to assess and quantify this key biological property.

Field Trial Design

Biochar use in soil is a new strategy, with many unknowns and uncertainties. Adding biochar to soil should be an experiment, done carefully, thoughtfully, with orderly planning, application, observation, measurement of results, and documentation.

Designing a science-based experiment requires significant planning and discipline, but small test plots are always advised before large scale applications. A simple manual to design and conduct biochar soil trials was published in April 2009:

IBI Field Trial Guide

Dr. Julie Major, IBI Extension Director

www.carbon-negative.us/FieldTrialGuide

Toxicity

Before adding biochar to soil, test for toxicity to plants or soil life. Two tests below are detailed in the ***IBI Field Trial Guide*** pg 8. For reliable results, several replications of each are advised.

Seed Germination

An easy test for toxicity to plants is to germinate 20 seeds on soil only, and 20 seeds on soil + biochar mix. If seeds germinate less on the biochar mix than soil only, your char may be toxic. If more seeds germinate on char, you may have black gold.

Earthworm Avoidance

This easy test indicates potential toxicity to soil organisms. A test pot is evenly divided between soil only, and soil plus biochar mix. Ten earthworms are released into the pot. After 48 hours, examine the pot to see which half the earthworms prefer.

Transport & Handling

Biochar is very light, extremely dry, brittle, and thus always includes significant powder. It easily becomes airborne in light wind, in transport or tillage. For soil structure and microbial action, powder is the most valuable, but careful effort is needed to prevent loss of this fraction by wind or water.

The best way is to moisten char with water, or blend with compost or other moist matter. Pelletizing, granulation or similar strategies also conserve char to assure its delivery to soil. Cover char in transport, and immediately till into soil to reduce losses.

Biochar Preparation

Applying raw biochar to soil can inhibit plant growth one or two years while microbes inhabit the char, form diversified, stable, functional communities, and gather balanced mineral supplies. Microbes also consume tar residues that inhibit water absorbtion.

Several weeks to a few months are needed to age char for soil. Proper preparation can reduce this time to two weeks, and reduce char volume needed for vigorous plant response. Four simple steps assure rapid response, high yield and healthy plants.

Moisture

Biochar's first service to soil is water digestion, retention and slow release from its sponge-like micropore matrix. Char must soak up water to be an effective substrate for microbial cultures and mobilize minerals for ion exchange with plant roots.

To moisten char, hydrophobic residues must be broken down and removed. This task is done mostly by microbes.

Size Reduction (Micronize)

Reducing char particle size also dramatically improves response. This increases external surface area that is accessible to water, ions and microbes, and increases the rate is saturated.

Char larger than dime-size must be broken down further for efficient action is the soil matrix. Weedy biomass such as crop wastes and food residues are easily crushed. Woody biomass, dense hardwood or nut shells need effort and energy to crush.

Screening separates larger particles from powder. Pea-size is useful in potting soils to substitute for peat moss, vermiculite, zeolite, and perlite. Sand-size grains are best for seed mixes.

Powdered char quickly changes soil structure and nutrient holding capacity by interaction with humic acids and mycorrhizal glomalin to build supra-molecules that initiate aggregation to form mega-structures within soil.

Mineralization

Biochar is an ideal media to deliver minerals. It adsorps both cations and anions to prevent loss by leaching. Clay only adsorps cations, with no internal pore capacity. Minerals enhance char's ability to support microbial communities, and thus improve plant response and reduce response time.

Assess the primary minerals your soil needs, and add them to char. Nitrogen is a primary mineral to add to char. Most Northeast soils are deficient in calcium and phosphorus. Ions adsorped into char's micropore matrix are readily available to microbes and plants by simple ion exchange (CEC & AEC).

Soluble versus powdered rock minerals… microbial digestion and liberation…. Micronized minerals….

Trace elements are critical to biology at parts per million or less. These least of all elements have big effects because they are co-factors to build complex biomolecules such as enzymes, vitamins, hormones, and regulatory chemicals. The best trace element source is sea minerals and other sea products, since sea water contains every water soluble element (nearly 90) in ideal ratios for biology, from primary elements at parts per thousand to pico-elements at parts per trillion.

Inoculation

Charged with water and minerals, char is ready to inoculate with microbes. This biology is what makes biochar effective to sustain fertility and structure. Research shows char is an ideal microbial media, preferred by microbial cultures.

Microbes first task is to devour and scour pyrolysis residues—tars, resins—potentially toxic poly-aromatic hydrocarbons (PAH). Fresh char's black, shiny surfaces is from hydrocarbon residues. Inoculated and aged, char becomes dull gray and lusterless.

Mycorrhizae prefer char, live in its micropores, send white fungal tubes (hyphae) into soil to suck up water and nutrients, and pump them to the char. Char becomes a microbial supermarket stocked with water and nutrients, waiting to feed plant root hairs.

Depending on particle size and microbial vigor, inoculation can take two weeks to six months.

A simple way to inoculate char is to blend with compost. In fact, char and compost need each other, since char is sterile, and compost is unstable and digested by decay. Compost's decaying biomass releases nutrients to feed microbes, who feed plants. A 50/50 blend is suitable, but other ratios are effective.

Another way is spray char with compost tea, made by adding compost to water, then bubble air through to oxygenate the solution. Aeration and stirring boost microbe propagation rates.

Nitrogen-fixing bacteria are a special concern. This fourth most abundant biochemical must be in ratio to carbon (C/N ratio). Biochar fosters special strains of N-fixing bacteria different from *Rhizobia* on legume root nodules. Tropical N-fixing bacteria are different than temperate climate bacteria, so inoculants should be local and regional cultures.

Application

Putting biochar in soil is a new practice, with minimal science and experience to guide decisions on how and how much. This information deficit for clear, reliable recommendations will change rapidly in the next few years as experiences accumulate, and standard processes and materials are proven and perfected.

Rates

In Amazon *terra preta*, char is as much as 9% (occasionally 20%), from two to six feet deep. In soils trials, 10% seems to be an upper saturation limit, beyond which further benefits are minimal. Per acre, this amounts to 10 to 20 tons. In farming, this large volume is unreasonable—physically and financially.

However, in farm and nursery practice, 12 to 18 inch depth is adequate to affect the active root zone of plants. This can reduce the volume required to 1 to 5 tons per acre.

Inoculation further reduces application rates to as little as a few hundred pounds per acre.

Successive applications over a few years are advised instead of adding a large amount all in one year.

Methods

When applying uninoculated, unmineralized char, fertilizers must be added with char the first year or two. Microbes of the soil food web need this time to get established and fully functional. The wiser approach is to apply char that is inoculated with appropriate minerals and microbes.

Soils with abundant organic carbon and microbial life are self-inoculating, and may not need mineralization and inoculation.

Broadcast
Banding
Side dressing
Planting hole
Tillage

Equipment

Currently, equipment suitable to spread biochar is not available. As a result, growers must improvise with ingenuity to deposit char on soil and till it into the root zone…….

Field Trial Registration

Using char in soil isn't new, but a documented effective agricultural practice 6000 years old. But to modern growers, the practice is unknown and strange. Because biochar is new today, it's crucial to monitor and study its effects and effectiveness. Every grower should approach biochar as an experiment, keep careful records, and register their trials in a shared database.

Fill out the attached **Field Trial Data Sheet** and return to the Carbon-Negative Network, which will compile an online directory of experiments. The Network will gather and post results of trials. The Data Sheet is available online at:

www.carbon-negative.us/DataSheet

The International Biochar Initiative has a Field Trial Registry, directed by Dr. Julie Major. The final four pages of the ***IBI Guide to Biochar Field Trials*** is Dr. Major's **Field Trial Data Sheet**.