BIOCHAR USE IN SOIL

GUIDELINES & INSTRUCTIONS

for Growers

David Yarrow, **May 2014**

this unfinished article is a work-in-process

Something old is new again.

6,000 years ago, ***terra preta*** was invented—famous charcoal-rich "dark earth" of Brazil's Amazon Basin—among the most fertile soils ever discovered on Earth—a stark contrast to sticky, acid, infertile clays left after the rainforest is removed.

Today, few possess the common sense of a woodland culture without stone or metal tools. Science is racing the Malthusian timeline to unravel how these remarkable soils were made. Charcoal plays unusual, previously unknown roles in these Amazon super-soils, but they had other essential ingredients, which must be combined in proper proportion and preparation.

Like baking cake, making fully fertile soil requires the right ingredients, the right recipe, the right process.

GUIDELINES

The fact biochar benefits soils and plants is verified by science and demonstrated in practice by trials in nation after nation. Yet, fresh, raw charcoal tilled into soil can retard plant growth the first year. Charcoal must undergo a few changes before it can serve as a soil and root media. By careful attention to a few details, new charcoal can quickly be ready for effective use in most soils.

For rapid results the first year, follow four simple guidelines:

The 4 M's

Moisten, Micronize, Mineralize, Microbe inoculation

full 5-page article: www.dyarrow.org/4Ms

INSTRUCTIONS

Biomass, biochar, compost, manure, minerals, microbes are normally added to soil in the fall, and have a few months to ripen and age. By spring, healthy soil will digest the new ingredients, and be ready to deliver energy and nutrients to new plant growth.

These instructions will speed up this timeline to prepare biochar that yields positive results quickly. The second year will show full benefits of biochar, trace elements & microbes. Our challenge is to show strong response the first year.

MOISTEN

Fresh-cooked, raw char is desert dry, and hydrophobic, too. It repels water. Fungi and earthworms avoid dry char. Life needs water. Water is the first ingredient of a living cell. How does moisture get deep inside char micropores?

Fresh char is also brittle, lightweight, dusty—and thus, easily airborne. A bit of water gives enough adhesion to stick together the finest particles and minimize loose clouds of black dust.

However, too much water makes char heavy, soggy, sticky. Char with excess water has clogged micropores that create unhealthy anaerobic environments. Heavy, sticky, wet char is harder to handle and screen.

Char's very fine micropore sponge gradually soaks up water. Char's water absorption rate and capacity varies, depending on type of biomass, micropore size, and production process. Char absorption capacity is easily measured by a simple test of overnight soaking, with free water measured before and after.

Char, especially newly made, doesn't easily or quickly absorb water. Its empty micropores are full of trapped air, to make it buoyant, so it floats. Capillary pressures of trapped air initially

resist absorbing water, slows moistening of micropore interiors. Extra effort and energy is needed to overcome this resistance. Extra time is needed to coax a first flood of water into micropores.

Second, tar and resin residues left from baking biomass form thin films that coat char surfaces, become beads in micropores—tiny tar balls in the char. Break open a fresh char, and this tar is visible as tiny, deep black specks that sparkle in sunshine. Rich in carbon rings—poly-aromatic hydrocarbons (PAH)—they're the final residue of high temperature cooking of sugar and cellulose.

Hydrocarbons are oily, thus water repellent. For char to admit water, these residues must be removed. Alkaline salts or organic acids can loosen and dissolve these oils. "Activated" charcoal for water filtration is steamed to flush resins from micropores—a process useful to biochar producers. Ultimately, microbes—especially bacteria—see these energy-rich rings as candy, and scavenge, scour and devour them for their hydrocarbon bonds.

I prefer to end a biochar-making burn by a burst of fine spray water, saturated with sea minerals (SEA-90) to create snap-crackling "live" steam—hot, pressurized, salty—to fracture char particles and force water with trace elements into micropores. Salt's corrosive alkaline action loosens and etches hydrocarbon resiidues, prepares them for digestion by microbes soon to follow, accelerates char preparation for soil.

MICRONIZE

This is mostly surface area. A 2-inch cube has 24-square inch of surface area. Ground to dust, its surface area becomes a few acres. Thus, small particles have vastly increased capacity to adsorb and soak up soil ions. Microbes get easy, rapid access to water and nutrients in held by the char. Smaller particles with more surface area are more quickly colonized by microbes.

To blend biochar with other substances—rockdust, fertilizer, compost, inoculant—micronizing assures intimate mixing of materials at cellular and molecular scales. Biochar's vast inner micropores has huge adsorption capacity—an excellent media to absorb and apply other materials, such as micronized rockdust.

Char delivers multiple services to soil, and at a wide range of

particle sizes and structural scales. Experience and insight suggest assorted particle sizes are "best." Most soils do well with char ranging from fine dust to ¼-inch, rice-grain-size particles. Some soils, situations and applications require smaller sizes—1/8-inch, 1/16-inch, or less. Other applications (hydroponic, aquaculture) need ½-inch or larger chunks.

The finest dust distributes most widely, intimately in soil. Char fractures in small splinters so tiny, they insert between soil particles that separate, isolate and insulate electric charges, and begin to change soil stickiness, density and structure. Unreactive carbon dust quickly penetrates into soil, carried by water and electric charge. Carbon has uncanny capacity to disperse itself in soil.

The smallest char molecules—less than 100 carbons—are so light, with so many electric charge sites, they're "water-soluble." Such ultra-light, complex carbons dissolved in solution with electrolytes are very potent biological tools for a grower who wants to optimize foliar sprays and inoculants. A tiny bit of carbon "chelates" strong electric ion charges to dramatically improved adsorption, assimilation and nutrient flow.

Fresh, dry char is brittle, and crushes easier than the original biomass. Hardwood chars are dense, tough, and need extra energy and sweat to reduce to soil particle size. Softwood biochars crush far easier, while weedy biochars almost instantly turn to dust. For soil use, weedy may prove superior to woody.

Micropores act as shock absorbers, so char is hard to crunch in bulk. But a thin, single particle layer of char between hard, flat surfaces shatters in fragments. To crush hardwood char more easily, chip or chunk the wood before to charring. Dust is a nuisance and mild hazard in crushing operations.

Fresh, dry char easily crunches thru 1/4-inch screen to eliminate chunks and reduce particle size. Dry char screens better than wet, which cakes up on screen wires.

Quarter-inch screen is suited to most field applications. Eighth-inch screen char is better for fine textured potting soil and seeding mixes. Over 1/4-inch chunks are useful in water systems such as hydroponics, aquaculture, raingardens, and biofilters,

MINERALIZE: Charge Adsorption

Biochar isn't a fertilizer. Yet, a critical service of char is to capture ions, hold ions in soil, curtail ion loss by leaching and outgassing, deliver ions to microbes and roots. Carbon is like a battery to store electron and ion charges that power plant growth.

Fresh char is empty of ions. Raw char added to soil adsorbs the supply of ions, reduces nutrients available to plants, thus retards growth. To put raw char in soil is like buying batteries with no electrons. In soil, electric charge comes from minerals in solution, reacted into compounds, releasing free electrons.

We know char's huge capacity to soak up and hold ions—atoms with electric charge—makes it very effective to filter water. In soil, ions are nutrients, not pollutants. Char sucks nutrients out of soil solution to hold inside its vast micropores.

The wise way to prepare char for soil is to charge it with ions and essential nutrients. The more ions you charge into char in advance, the fewer nutrients char will soak out of your soil. This is simple, as blending with fertilizer, rockdust, compost, or a wet process—spray or soak. Moisture boosts ion mobility to improve nutrient adsorption into char.

Char's capacity to be charged with nutrients allows it to serve as a media to deliver fertilizer into soil with greater effectiveness, efficiency and stability. Growers can custom blend char with fertilizers needed by their soils. Soil tests (Appendix 1) are easy, accurate and cheap to assess soil mineral needs. Knowing the elements in deficit, or excess, and how much, is the best guide to choose materials to blend into char.

The best blend, most even spread, is material micronized to powder for maximize surface area and dispersal. Finer particles make minerals more accessible to water, ions and microbes. They are available far faster, quickly ready to power plant growth.

Take the time to give char a full charge. It's your soil battery.

Minerals

Sea Minerals: Soils, even organic farms, are routinely deficit in trace elements and nano-nutrients—often acutely. Unrefined ocean minerals are a complete, almost-ideal blend of all water-soluble elements in optimum biological ratios. Sea minerals—Nature's perfect trace element fertilizer—should be blended into char for soil to install a full charge of nano-nutrients.

www.SeaAgri.com

Rockdust: Rockdust and powdered stone benefit Midwest soils, especially southern soils that missed mineral renewal in an Ice Age. Rock elements are weakly soluble, thus slow-release, slow-acting for longer-term fertility. Rockdusts depend on microbes to digest and release minerals from the geology. Blending rockdust with biochar plus microbe inoculant assures bacteria and fungi are present to digest rock-bound minerals.

www.rockdustlocal.com

Carbonatite: unique, very dense, deep magma bedrock in northern Canada. Very high paramagnetic index, with calcium. phosphorus and potassium. Special carbon-smart feature is it reacts with CO_2 to form carbonates, which act as soil pH buffer.

www.spanishriver.com

Trace Elements: Boron, copper, zinc, cobalt, manganese, molybdenum, selenium, other trace elements may be deficit & need extra additions. Good soil tests assay them; corrected by a few pounds per acre. Biochar is effective bulking agent to uniformly spread small amounts over large areas.

Calcium: #1 cation, often low in soils, principal ion to charge into char. Micronized limestone ($CaCO_3$) or gypsum ($CaSO_4$) mixed in char, moistened, delivers this critical cation to soil, microbes and roots. Soil pH guides choice of type of calcium.

Phosphorus: #2 anion, often low, weak availability. Rock phosphate micronized is best to blend in biochar, with microbes that mine and mobilize this anion. Synthetic phosphorus fertilizers also adsorb into biochar for efficient delivery to roots.

Nitrogen: Biochar adsorbs N in both forms: nitrate (NO_3-) & ammonia (NH_4+). The soil N-cycle is driven by bacteria, so inoculation with N-fixing bacteria is more crucial than loading char with chemical N. Start with compost made from ruminant herbivores boosted with SumaGrow, or similar inoculant.

MICROBE INOCULATION: substrate

Fresh char is dead and lifeless as moondust. Yet, char's most crucial service in soil is to be populated by microbes. The final "**M**" brings life to char as microbes—specific species, special families, entire cultures. The intent is to import a full array of "cheap labor" to do menial metabolic work in soil fertility cycles. The ultimate goal is to bring char to life—inert char colonized by fully functional, diverse microbe communities.

This **4th M** is a key paradigm leap from 20th century chemical to 21st century biological farming. This puts the biology back into soil as a "**Soil Food Web**" of interactive organisms. Transition to this advanced mindset imposes a burden to learn intelligent ways to handle living organisms, not mere dumping on inert chemicals.

First challenge is finding colonies of effective microbes to deploy in soil. Most agricultural soils are badly disturbed, often largely lifeless, so microbes must be "outsourced." But where to find healthy, diverse cultures?

Commercial compost is often poor quality, incompletely digested, with inferior, unbalanced, unstable microbial cultures. Animal manures are often badly handled, toxic and regulated. Commercial cultures are narrow selections of a few microbes bred in an artificial lab, not seasoned by life in soil and weather.

Second challenge is to get microbes to inhabit char. Microbes are seeded into char and encouraged to colonize micropores. They undergo a huge population explosion to multiply and occupy char. Such massive growth spurt demands significant extra energy, nutrients and other cell resources.

Third challenge occurs when char is put in soil. Microbes undergo a second, even greater, population expansion as they deploy and proliferate amid soil particles. This again puts heavy demand on energy and nutrients for rapid growth and copious reproduction. Char provides stable sites for microbes to establish strong colonies, and extend themselves throughout soil.

Inoculation success isn't blind luck or random chance. Success requires the right microbes, right substances, right recipe, right environment, and right timing to assure microbes don't just survive, but come alive and thrive.

Natural Colonies

Composted Manure: Aged animal manure is Nature's #1 inoculant, simple, universal, success-guaranteed. Plant biomass passed through animal digestive tract—especially ruminants—is inhabited by a full menu of digestive microbes.

Castings: Earthworms are animals, thus, their castings are a manure that is an effective inoculant.

Indigenous Forest Fungi: Nature's #2 inoculant is leaf mold grown in "duff" and surface soil of undisturbed forest. Forest soil ecology is usually mature, diverse, complex, stable, fungal-dominant, exportable. As inoculant, a gallon of rich forest humus is all you need, not bushels of leaves, duff & forest fluff.

On-farm Microbe Incubator: On-farm biomass bin dedicated to incubate and culture microbes adapted to local soil, climate and crops. A farm can seed and feed its own biomass in a bin by careful protocol to sustain a thriving, diverse microbe culture. At intervals, decayed biomass, humus and teeming microbes are extracted to inoculate farm soils.

CULTURES & COLONIES

Biochar inoculation is only in infancy, yet already a wide variety of choices are available. With the diversity of soils, climates, crops, and farming methods, likely no microbe culture is "best," except those locally adapted.

Effective inoculants seed a complex diversity of microbes—an instant community development. Bacteria are tiny, tough and easy to import, but fungi are fussy, larger and need extra environmental support. Many microbes have particular requirements before they take up residence, including moisture, temperature, pore size, pH, carbon/nitrogen, etc. For mutual benefit, many microbes engage in "symbiotic" relations with other strains and families, and function best in partnership.

As pointed example, *Rhizobia*—well-known N-fixing, "symbiotic" bacteria—live as colonies in pink nodules on roots of peas, beans, vetch, clover, other legumes. They wrap a special protein around a Molybdenum atom—a trace element—to make *nitrogenase* enzyme, which split N_2 gas to bond with O_2 to form nitrate (NO_3). N+O bonds are high energy, electron-rich, delicate, unstable. Thus, N-fixing bacteria need other microbes, such as bacteria to restrict O_2 from the local enzyme environment.

US National Academy of Science inventoried over 250 Nitrogen-fixing microbes. Most are bacteria; a few are fungi. Many are symbiotic with specific host plants, but many are free-living, adapted to a range of environments. Free-living N-fixing bacteria and their partners should be in every char inoculant.

To find a "starter culture" to jumpstart your soil's microbial food web, there are two different kinds of sources:

Natural Colonies: extracted from natural environments with native materials (*above*).

Man-made Cultures: developed in artificial environments by man-devised processes, like laboratories and incubators (*left)*.

INOCULATE: quest for culture

Growers must learn to handle these living organisms carefully, intelligently, so they don't merely survive, but have enough energy to thrive, proliferate and colonize char micropores, and

Man-made Cultures

BioDynamic 508 (Cow Horn Prep): Biodynamic farming can claim the oldest soil inoculant in use. Cowhorn packed with blended herbs and manure, buried tip down in soil in winter. Black sponge forms in cowhorn: a rich microbe culture.

www.biodyn.com

SumaGrow: 9 fungi+16 bacteria + humates & trace elements; liquid, proven on many crops, 50-100% fertilizer reduction.

www.sumagrow.com

EM (Effective Micro-organisms): Dr. Higa of Okinawa in 30 years of research, wide use in Asia for multitudes of chores, from soil and foliar sprays to compost additive to sanitation. Three primary bacteria strains create microbe foundation.

www.EMAmerica.com

BioAg (SCD Probiotics): EM-type bacteria inoculant, use in farming, food processing, waste management, sanitation, made in Kansas City, varied blends of three foundation microbes: lactobacillus, phototrophic bacteria, yeast.

www.scdprobiotics.com

Trichoderma (BioGreen Planet): common soil fungi with many species. Inoculation is dry powder packed in wheat bran. 25 years successful use worldwide.

www.bgp.com

then proliferate again in soil. These population expansions need extra support and nutrients to occur successfully.

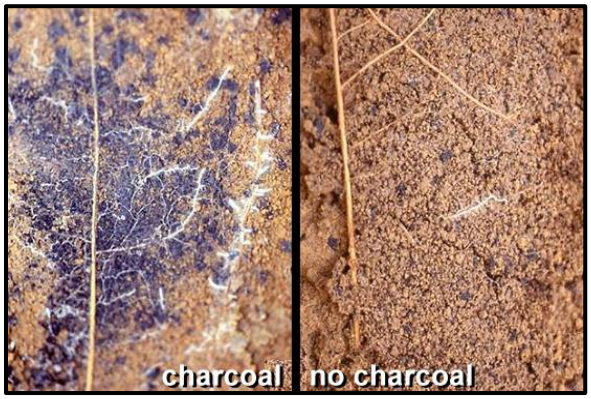
The universal, easy, natural way to bring life to biochar is to blend with compost, preferably mature, manure compost, fully loaded with a diversity of vigorous digestive organisms. The other alternative is to buy commercial inoculants to spray onto or blend into raw char. There are many products already on the market with proven but variable effectiveness.

Finding suitable quality compost with a healthy population of active digestive microbes isn't easy. Compost markets are flooded with low grade, poorly digested, unbalanced products. Yet, the key to inoculation success is begin with a strong, stable, diverse microbe culture, so every effort should be made to locate and culture a viable, reliable starter colony.

There's lots of inferior, weak, sour compost. Shop around, learn to identify quality compost. Smell is a universal standard to detect quality. Use only quality compost for biochar, soil inoculant and compost tea. Or make your own.

Most researchers use 50:50 compost:biochar blend. Some had success with 3:1 (25%), even 4:1 (20%). My experience is 9:1 (10%) is optimum for potting soil mix, 19:1 (5%) is adequate to jumpstart seedbed soil, but I used the finest grade particle size.

An alternative is to spray or saturate biochar with compost tea, or another concentrated microbe solution. However, microbial cultures deployed by compost tea are thinner, weaker, less dense than those inoculated directly with compost cultures.



COLONIZE: residence for microbes

For quick colonization, particle size is a key factor. Microbes can't move around far or fast, so inoculant and substrate must be in blended thoroughly and in close contact with each other. Both compost and biochar should be small particles—rice grain down to powder—for maximum intimate contact so microbes migrate quickly into biochar.

Two key ingredients are air and water. A migrating, growing colony must breathe in adequate oxygen, or digestion becomes anaerobic, sour and stinky.

Water, a universal activator of biology, allows life to move around. Lightly moisten a new blend by sprinkle or mist, then mix water and air carefully throughout the blend. Use unchlorinated water from a spring, well, pond, or stream. If you must use chlorinated water, add 1% sea minerals, filter with char, let sit overnight, and oxygenate by vortex stirring.

The next factor limiting growth is mineral elements—cations, anions and trace elements. The more nutrients present in the substrate, the more quickly and happily microbes can multiply and become established in char. Even good compost benefits from a boost of extra nutrients, inoculants and stimulants to enhance success. Remember, microbes must multiply and proliferate in two extra-ordinary, rapid population explosions. You can support and favor this growth spurt with extra calcium, trace elements and digestible carbon.

Trace elements are special concern since they're needed for critical cell high-level structures such as DNA, RNA, membranes, and reproduction enzymes. The least of all elements are often the most crucial for rapid, accelerated growth. The simple solution is to charge char in advance with full spectrum, unrefined sea minerals, which delivers 84 elements in balanced ratios.

APPLICATION RATE	gallons / square foot				tillage:	6 inches deep	
gal/100 sq.ft.	1	5	10	15	20	25	30
lbs/100 sq.ft.	4	20	40	60	80	100	120
cups/sq.ft.	0.2	0.8	1.6	2.4	3.2	4.0	4.8
% carbon	0.3	1.3	2.7	4.0	5.3	6.7	8.0
soil mix ratio	1:373	1:74	1:36	1:24	1:18	1:14	1:12
tons/acre	0.9	4.4	8.7	13.1	17.4	21.8	26.1

Allow aerated, blended biochar and compost, plus extras, to sit at least two days—or up to two weeks—in a warm, moist place. Don't stir, or in any way disturb the blend while microbes multiply and migrate, and fungi grow white whiskers of hyphae. Significant time is needed for a full diversity of microbes to inhabit char and establish multi-function communities and supporting infrastructure. The longer they're left undisturbed, warm, moist, with air, the better colonized char micropores will be.

Now comes confusion. Science likes weight, business likes volume, farmers like acres, gardeners like square feet. Then, convert hectares to acres, meters to feet, gallons to cubic feet. And temperature: F or C?

Add to this technical complexity that "carbon-smart" strategy is new, untested, unknown, unsanctioned by authority, with no standards, no best practices to advocate and advance. We all await more field data and observation before taking positions on application techniques or rates. We still have much to learn. Yet, a few things are clear:

Char must be prepared for success and rapid response in soil.

Biochar (or most any carbon) blended with fertilizer boosts fertilizer efficiency to reduce the need for fertilizer.

Char—properly moist, micronized, nutrient charged, microbe alive, root zone dispersed—gets strong, rapid response at a few hundred pounds per acre—not tons. Then, by small annual additions, growers get good results while gradually raising carbon, CEC, AEC, microbe density, diversity, productivity and other keys to soil fertility and crop health.

QUANTITIES

Research with infertile Amazon clays suggest 10 to 20 tons an acre of char is needed to create arable, productive soil—amounts no frugal farmer can afford. But most growers begin with soil much better than poor rainforest clay. Recent research at several universities shows strong results at only a few hundred pounds an acre. However, char must be prepared—charged and inoculated—before it's spread on soil.

APPLICATION RATE	% char / square foot				tillage:	6 inches deep	
% char	1	2	3	4	5	8	10
gal/100 sq.ft.	3.75	7.48	11.23	14.95	18.69	29.92	37.39
lbs/100 sq.ft.	15.0	29.9	44.9	59.8	74.8	119.7	149.6
cups/sq.ft.	0.6	1.2	1.8	2.4	3.0	4.8	6.0
soil mix ratio	1:99	1:49	1:32	1:24	1:19	1:12	1:9
tons/acre	3.3	6.5	9.8	13.0	16.3	26.1	32.6

My 2010 seedling trials with 8 kinds of char showed soil mixes with 5 to 10% biochar blended with composted manure and sea minerals gave 25–50% greater growth. Consistently, plants potted with a bit of biochar grew faster, larger, stronger. My results suggest almost any plant biomass—from hardwood to bark to straw—works well as biochar, with significant variation in yield, qualities and effects.

Generally, 5% is a minimum optimum level for biochar in soil. This is just under 20 gallons/100 sq. feet, or just over 16 tons per acre. *Terra preta* in the Amazon was regularly measured with 9 to 10% carbon, sometimes higher, even double. Research, and my seedling trials, reveals that benefits fall off beyond 10% char.

In healthy soil ecology, not all carbon should be char. Some carbon must be in digestible, mobile forms—compostable, capable of decay by microbes. For the moment, my ballpark is 50:50 char:compost, or 5% char and 5% humic substances.

Growers ready to jump in with both feet the first year can install 20 gallons per 100 sq. feet right away. This immediately establishes a 5% biochar level. In the garden, this is 3 cups per square foot. For potting mix, one part biochar to 19 parts soil.

APPLICATION RATES

To calculate the numbers in the two **Application Rate** tables, I assumed a fine-screened (1/4–inch) biochar, tilled six inches deep into a 100-square-foot bed. Conveniently, for Terra-Char:

1 quart = 1 pound, thus 1 gallon = 4 pounds

However, these numbers will vary extensively, depending on type of feedstock, production process and moisture content.

Most growers will achieve this 5% level as small annual increments—5 gallons per 100 sq. feet in each of 4 years. It's smart to start with one big step the first year, followed by small ones. This can be an initial 10 gallons/100 sq. feet (2.7%), followed by 5 gallons (1.3%) for two years.

Biochar is excellent media to blend with fertilizers to improve their delivery and efficiency, both as lightweight bulking agent and high capacity ion adsorption. Small doses (1 gallon/100 sq. feet) are useful as an annual fertilizer extender and carbon booster.

Growers measure materials by volume, thus one **Application Rate** table lists **5-gallon Increments**, the other as **% Biochar**.

APPLICATION METHODS

Application Rates above are to broadcast biochar all over a bed. However, growers can optimize a small amount of material by ways that target and concentrate char near crop roots. This can be seed dressing, banding, side dressing, root drenches, or other operations to deposit the char on or near crop roots.

By intelligent preparation and deliberate placement, maximum effects can be had with a minimum of biochar. Details vary greatly by crop, farm and equipment, and by circumstance.

In the photo at left, the test crop is a double row of transplant broccoli. Biochar and inoculant applied in two narrow bands, with sea minerals and inoculants added, then rototilled in to concentrate material in the broccoli root zone.

NO-TILL

If tilling to mix biochar into the root zone isn't an option (no-till, pasture, orchard, lawn, golf course…), special effort is needed to get char down to roots and microbes. Experience reveals soil has remarkable, unexpected ability to move carbon, and char rapidly migrates down into soil. Earthworms, other soil organisms, decaying roots, and fungi play roles to move biochar. Ultimately, it's fungi that penetrate the tiniest pores to spead carbon in soil.

First principle is to screen char and apply the finest particles. Char's electric properties affect soil particle charge immediately on contact, and steadily inserts itself into inert dirt, shifting it toward living, loose, open soil.

Dumping dusty char on bare soil isn't recommended, since wind easily blows this fine char away. One solution is to roughen soil surface without ripping deep roots. Moistening or pelletizing can assure proper placement.

POTTING SOIL

Vegetable growers get top value blending biochar in potting mixes for seedlings. Biochar-rich potting mix nurses seeds into vigorous growth and sustains seedlings transplanted in less fertile field soil. The soil plug with each transplant adds char to soil, while seeding soil with microbes and micro-nutrients. Over several seasons, field soil will be fully enriched with char, nutrients and microbes.

Trials indicate biochar works well to replace peat, vermiculite and perlite. Properly charged, inoculated and aged, biochar does as well, if not better. Biochar, however, is the one based on a renewable, sustainable resource. Biochar provides many similar services, including lightweight structural matter, aeration, water absorption, moisture conservation, ion adsorption, nutrient supply. The great advantage over peat is biochar is only apply once, then stays for decades, while peat decomposes in one to three years.

In side-by-side tests of compost+char, compost+peat+char and compost+peat+vermiculite, peat mixes got faster starts, but compost+char yielded larger, greener plants, bigger total harvest. Peat mixes had an easy time with seeds, since char wasn't charged properly before planting, and was water repellant.

White clover was seeded as a winter cover. Compost+char grew slowest at first, but when turned under, compost+char was thicker growth. In the 2nd year, seeds do fine in char+compost.

Feedstock is a major variable. Many types of char are created with special characteristics. We don't know enough yet to select specific feedstocks, but we know some work better than others.

Particle size makes a big difference in response. Small, finer particles blend more thoroughly, intimately, rapidly. For potting mixes, I crush homemade char through a 1/8-inch screen

COMPOST

Biochar needs compost to occupy its micropores. Compost benefits from biochar's nutrient capture and microbe support. Trials on five continents show biochar added to compost boosts both process and final product:

1) char adsorbs gases (ammonia and volatile nutrients)
2) char absorbs water, ups retention capacity, cuts leaching
3) char adsorbs nutrient ions, curbs leaching and outgas
4) char provides stable refuge for microbes to inhabit and a media to export cultures to new compost.

There are few systematic trials yet. The best I've seen are in Australia, New Zealand, Japan, Germany, and Switzerland.

Most use 5% to 20% biochar by volume blended in new

compost. Research reports shorter digestion time, greater nutrient content of finished compost, to indicate stronger, more efficient microbial digestion. One farmer covered composting poultry manure with a layer of biochar, and observed it eliminated any odors. Another farmer blends biochar with poultry litter simply because it ends odor, so his product can be used on golf courses, lawns, corporate plazas, public parks, athletic fields, schoolyards.

COMPOST TEA

Compost tea is a strategy to brew up a concentrated solution of microbes and nutrients to apply to soil and plants. A small amount of compost is added to a large volume of water, plus nutrients, then this is aerated for 24 hours to cause a microbe population explosion. The liquid is used as a soil drench around roots, or filtered to use for foliar feeding.

A special form of char to add to these solutions is very low molecular weight, water-soluble carbon molecules. These very small complex molecules enhance the absorption of nutrients by soil, microbes and plants. Char "chelates" mineral ions to surround them with a halo of carbon atoms, and thus allow biology to handle and digest mineral charges more efficiently.

ORCHARD & VINYARD

Perennial crops require a different strategy to apply char that adjusts to the structure and growth of roots, and the need to not disturb perennial roots by tillage. Perennial crops are commonly symbiotic with many microbes, so the carbon, micro-nutrients and microbes are a special benefit to these crops.

When planting trees, grapes, vines, canes, and such, char plus enhancements should be applied in the zone of optimum root growth. Initially, char is blended into soil for the planting hole. Each year after, char is banded in a larger ring around the planting hole, to encourage roots to grow outward from the stem. Active feeder roots are usually located at the "drip line" below the outer edge of the leafy canopy.

In an existing orchard, tillage isn't possible to mix char and enrichments into the root zone. The principles detailed above for no-till apply here.

NURSERY

First is to screen char and only apply the smallest particles.

ANIMAL FEED

Research in several countries in Asia, Australia, Europe, South America yields consistent evidence that feeding char to livestock improves digestive efficiency, health and productivity. Animals put on more weight per pond of feed. Some studies report less methane gas from (in)digestion.

Biochar is added to feed at 1 to 5% of total ration.

When manure is added to soil, char is added, too, fully charged and inoculated, ready to improve soil structure and nutrients. In the European Union, biochar is recognized and approved for agriculture, but most biochar is fed to animals, then spread on land.

ROOF-TOP GROWING

Because it is so lightweight and water absorbent, with a very high nutrient adsorption capacity, biochar is an ideal material to include in roof-top and other container gardens. Biochar can create low density, high capacity soils suited to architectural and engineering constraints of rooftops.

HYDROPONICS & AQUAPONICS

Biochar is an excellent addition to rooting media in hydroponic beds. It is lightweight, adsorbs nutrients, attracts roots, provides microbe residences, improves water filtration. Unlike other organic media, biochar does not decay or degrade in constant contact with water. Micropores make it an ideal media to filter pollutants, and provide abundant habitat for microbes to nurse plant roots.

biofilter

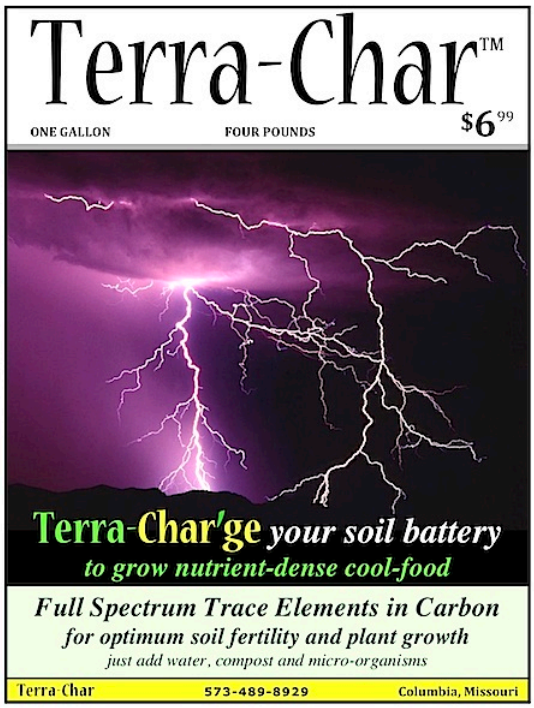
FURTHER INFORMATION

Carbon-Smart Farming: www.dyarrow.org/CarbonSmart
Make Smoke, Burn Smoke, Doug Brethower, MO
The Biochar Solution, Albert Bates,
US Biochar Initiative, Gloria Flora, MT
International Biochar Initiative, Kelpie Wilson

Terra-Char™

www.terra-char.com

Reliable, professional quality biochar made from oak lumber scraps by Phil Blom in Columbia MO, who chose to invest in new, emerging technology to assure American independence in fertility, food and energy.



This spring Terra-Char™ begins to operate a new facility with larger capacity biochar production, able to capture gas & liquid biofuels, and produce hot water & process heat.

1-page Terra-Char™ Info Sheet:
www.dyarrow.org/terracharge