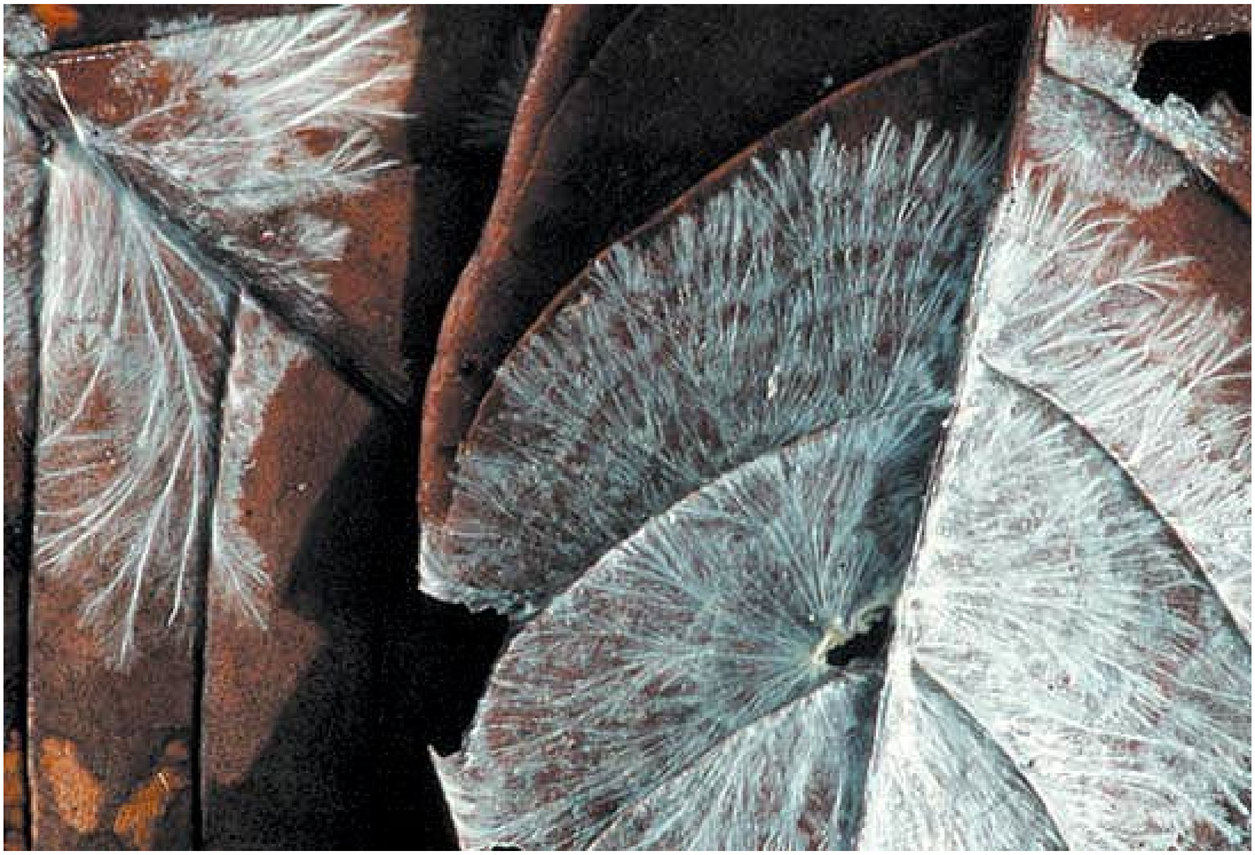
BIOCHAR and MYCORRHIZAE
Critical Symbiosis for Optimum Soil Structure & Fertility

Because this is such important information, I re-typed an attachment about "**Mycorrhizae and Biochar**." It is pasted below.

Let me make this issue more lucid: the biochar research of Dr. Makato Ogawa, a Japanese scientist with 30 years of biochar research, shows very clearly that biochar is the preferred habitat of mycorrhizal fungi. The fungi live in char, sporulate profusely in char, and rapidly colonize the char. In Ogawa's microphoto below, yellow spheres are spores, white whiskers are the fungal mycelium ("hyphae"), black are bits of biochar.

Fungi send their thin white treads of "hyphae" out of the char into and through surrounding soil. Each thread is a hollow tube with an acid-secreting "mouth" at its end, which seeks out and sucks up water and nutrients such as Calcium and Phosphorus, and pumps them back to the fungal body in the char. Thus, char is transformed into a living storage reservoir of water and nutrients. The next photo shows how the hyphae fan out over leaves, forming dense white mats that are mostly sugars plus proteins. These dense networks of fungal thread scavenge nutrients from the decaying biomass, dissolving minerals to pump them back to feed the main fungal bodies.

Mycorrhizae and plant roots form close symbiotic associations in which plants secrete sugars to feed the fungi, and fungi share water and nutrients they scavenge from surrounding soil. Dense networks of fungal hyphae become extensions of the plants' feeder roots. Thus, plants become far more efficient to obtain water and nutrients from soil, are far more drought resistant, and grow faster and larger, even in poorer soils.

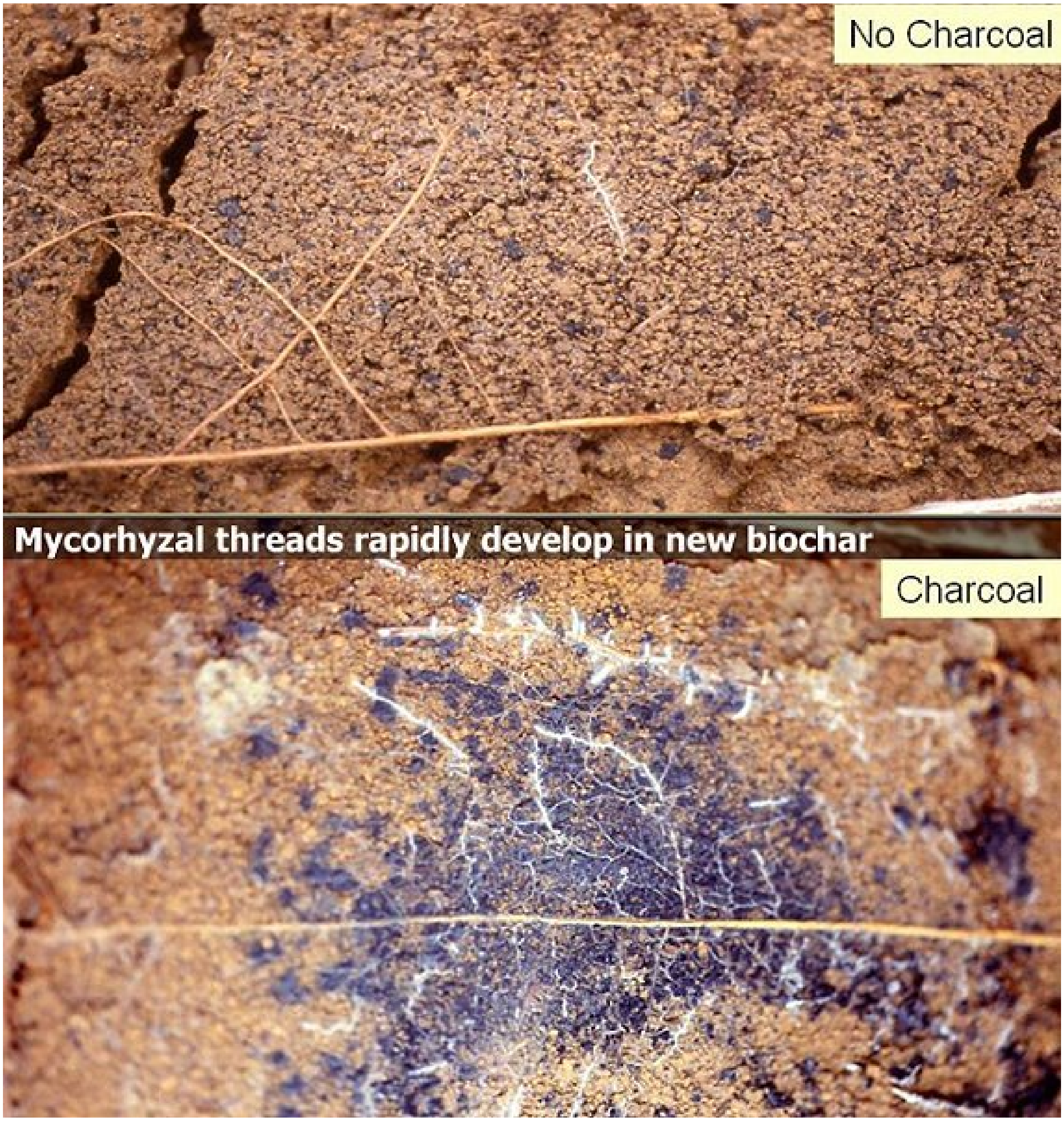


I saw this symbiosis of mycorrhizae and biochar vividly in March 2009 when i visited Alex English at Burt's Greenhouses in Kingston, Ontario, Canada. Burt hired Alex to replace a fuel oil burning furnace with a wood-chip fired Blue Flame furnace to heat 15 commercial greenhouses supplying five retail stores. Alex had then converted the wood furnace by restricting the under-air and adding over-air to the combustion chamber. Thus, he could optionally starve the fire for oxygen and yield biochar rather than ash. 2009 was his first winter to operate this modified monster burner (www.carbon-negative.us/AEnglish).

I noticed in a corner of the burner room a 10-foot diameter steel tank filled with water that was early on used to quench hot biochar exiting the furnace. Floating on the water were several 1/4 to 1/2-inch chunks of char. Each bit of blackness was surrounded by a halo of white fuzz. Fungi had colonized the bits of char, and were sending their pale whiskers of hyphae out around the char in search of water and nutrients.

In soil, hyphae travel several feet through soil in their quest for water and nutrients. An Ogawa photo below shows the difference in the extent of hyphae growth when biochar powder is added to soil. The bits of biochar provide fungi-friendly habitat, and allow the hyphae to grow faster and further.

The SCD Probiotic (BioAg) we currently use in the SARE-funded "Growing with Biochar" project (www.dyarrow.org/SAREbiochar) as a biochar inoculant is a culture of lactobacillus, phototrophic bacteria and yeast. This three microbes provides a biological foundation of the fundamental organisms required to jumpstart a fully diverse community of microbes. But it does not contain mycorrhizae. We are smart to add a mycorrhizal inoculant to our biochar before distributing it in soils. Thus, I recommended to Steve Moring that he investigate Mycorrhizal Applications, inc. (www.mycorrhizae.com) as a source for inoculants. Dr. Michael Amaranthus, founder and CEO, has been a leading scientist researching mycorrhizae for 20 years. I have confidence in his company's products.



I saw the effects of fungi, including mycorrhizae, in my own garden soils, which I carefully cultured for over a decade. Originally, my soils were nutrient-poor, sandy glacial till that could hardly support a ratty, spotty lawn. I added lots of organic matter, compost, rock powders, sea solids, and microbial products to the soil. I never tilled and hardly ever dug this soil, but just left it in place, cutting little furrows to plant seeds, or small holes to transplant seedlings. Earthworms, fungi, insects, bumblebees, and all other lifeforms were left undisturbed to create their complex infrastructures. The soil grew large, healthy, abundant vegetables and herbs. Many vegetables and herbs self-seeded year to year, and I planted less and harvested more with less and less effort. I even had morel mushrooms sprouting from soil each spring.

In 2011, I was forced to move, so I dug up some of my soils to donate to a new community garden in North Troy (www.carbon-negative.us/CCG). By then, the gritty, granular sand was transformed into something more like sponge cake—thick, light, fluffy, large chunks soil that sat on my shovel in a single, solid, soft lump—the ideal image of perfect "crumb" structure. This remarkable texture and cohesive body was mostly due to the huge biomass of fungal mycelium that had grown in the soil, forming a soft, slightly sticky matrix that bound the particles of soil and organic matter into a soft, cohesive mass. It was truly lovely soil, and I was heart-broke to have to give it up.

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Biochar and Mycorrhizae: Super Soil-Fixers of the Future??

Biochar and mycorrhizae—two "hot" research areas—are converging to help address challenges posed by global warming, alternative energy production and modern non-sustainable agricultural practices.

Biochar (charcoal produced by pyrolysis of biomass feedstocks) incorporated into soil can act as an extremely stable conditioner and fertility enhancer while storing Carbon for up to thousands of years. Furthermore, the pyrolysis manufacturing process produces bio-oil and syngas—alternatives to fossil fuels.

Although modern research on biochar is in its infancy, the technology is nothing new. Ancient civilizations in the Amazon Basin utilized biochar (also known as *terra pert*) to sustain soil fertility in tropical croplands. Still productive today, some samples from this region date back over 6,000 years.

Mycorrhizal fungi's significant role in long-term atmospheric CO2 storage is another topical field of study. The many soil health and plant growth benefits from these ubiquitous plant symbionts are already well-documented, but it is the burgeoning knowledge related to the glycoprotein *glomalin* that is creating a whole new realm of soil knowledge. Glomalin, produced exclusively by arbuscular mycorrhizal fungi, is an organic adhesive permeating most soils, and is a primary factory in creating friable soil texture.

The really big discovery is that glomalin is 30 to 40 percent Carbon, which is stored in soil for up to 42 years. A major component of soil organic matter, glomalin accounts for up to 27 percent of Carbon in soil. The U.S. Department of Energy is currently funding studies to determine glomalin's promising potential to offset atmospheric CO2.

So, where is the convergence? Biochar and mycorrhizae both augment soil sustainability *and* they both implement substantial long-term Carbon sequestration. The bonus is that combining these two remediations apparently compounds their cumulative beneficial properties into a powerful "2 + 2 = 5" soil scenario.

Researchers believe that biochar contributes to pro-mycorrhizal soil environments via multiple mechanisms:

- Biochar appears to modify soil pH, Cation Exchange Capacity and water holding capacity toward a more favorable environment for mycorrhizal colonization and activity.
- Biochar seems to promote microbial populations, further stimulating mycorrhizal performance
- Biochar may favorably influence the complex chemical communications between plants and mycorrhizae, and may vitiate certain inhibitory compounds.
- Boichar's myriad, tiny pores may serve as physical "shelters" for mycorrhizal hyphae and various symbiotic bacteria, protecting them from microbial predators.

Most studies indicate that mycorrhizae and their associated plants grown in biochar-treated soils significantly out-perform non-biochar controls.

Much more research is needed, but perhaps the soil amendments of the future will be mycorrhizal inoculants embedded in biochar carriers—simultaneously addressing *three* vital global issues: soil and crop sustainability, atmospheric CO2 mitigation, and alternative energy needs!