WHICH ORGANISMS BENEFIT FROM BIOCHAR: **MICROBES, WEEDS, OR CONIFER SEEDLINGS?**

By Jessica Miesel, Gregory Bonito, and Monique Sakalidis

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Biochars are charcoal-like materials produced by heating biomass with limited oxygen availability (Figure 1), and are typically produced as a byproduct of pyrolysis or gasification bioenergy systems. Biochars show promise as soil amendments because they can help improve crop yields by increasing soil moisture content and nutrient retention, but some studies have shown that decreases in plant growth can also occur. Biochar technology and application as an agricultural amendment can contribute to environmental benefits such as increasing soil carbon content and protecting surface water quality by decreasing non-point-source pollution. Pyrolysis and gasification bioenergy systems can use waste biomass for feedstocks, thereby also supporting air quality by displacing fossil fuels.

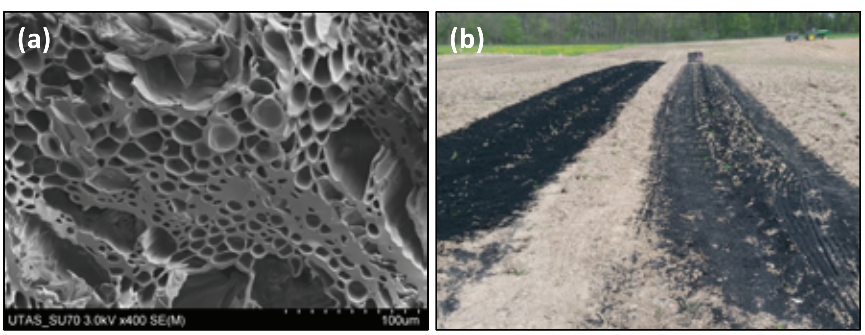

Figure 1. Panel **(a)** shows a scanning electron microscope image of an example biochar (*Photo credit: Dr. Jocelyn, biocharproject.org*). Plant cell walls often persist through the charring process, providing a physical structure that contributes to biochar's ability to help increase moisture content and nutrient availability in sandy soils, and provides habitat for microbes. Panel **(b)** shows two biochar treatments applied at MSU's Tree Research Center in May 2016, before discing into the soil (*Photo credit: D. Warnock).*

Whether biochar increases or decreases crop yield depends on the specific combination of biochar type, soil type, and crop. To help ensure that growers can make informed decisions about biochar amendments, we (Michigan State University researchers Miesel, Bonito, Sakalidis, and Lisa Tiemann) are investigating Balsam fir and Colorado blue spruce response to contrasting biochar amendments at MSU's Tree Research Center. We are conducting this study in partnership with the Michigan Christmas Tree Association (MCTA), with funding from the Michigan Department of Agriculture and Rural Development (MDARD). The purpose of the study is to determine which organisms benefit from biochar, and why: microbes, weeds, or conifer seedlings? We identified this question after examining results from previous projects supported by MSU's Project GREEEN and the MCTA, which showed that biochar applications in sandy soils can lead to statistically significant increases in moisture content and nutrient retention (i.e., less nitrogen lost through leaching), as well as increases in the rates at which microbes cycle nutrients into plant-available forms. However, we also observed more weed biomass and more conifer seedling mortality in areas treated with biochar, at least in the initial years of a field trial. These results illustrate the importance of understanding the short—and long-term benefits and risks of biochar amendments. Our current project will combine greenhouse experiments, field measurements, and laboratory analyses to provide information about how soil microbes, weeds, and Christmas tree species respond to contrasting types of biochar treatments.

In addition to measuring soil moisture content, soil nutrient dynamics, seedling growth, and plant tissue nutrient content in seedlings and weeds, two key components of our study focus on the relationships between ectomycorrhizal fungi and conifer seedlings (Figure 2). Because soil microbial communities, and especially ectomycorrhizal fungi, play a critical role in seedling vitality, identifying and quantifying fungal species growing in and around seedling root systems will allow us to determine how biochar applications influence fungal guilds that promote overall seedling health, and their survival during drought. By identifying biochar treatments that selectively benefit a seedling's most compatible microbial associates, our results will help determine how to modify soil environmental conditions to favor uptake of water and nutrients by tree seedlings. This can increase a seedling's potential for continued growth during drought, and its competitiveness against herbaceous weeds—which could also help decrease the need for fertilizer and herbicide applications.

Mycorrhizal fungi are known to protect conifers from soil-borne pathogens, but very little information exists about the effects of biochar on pathogenic microbes or on the interaction between pathogens, biochar, and mycorrhizas. In addition to studying how biochar influences mycorrhizal colonization, our study will also determine how biochar treatments affect seedling tolerance to pathogens.

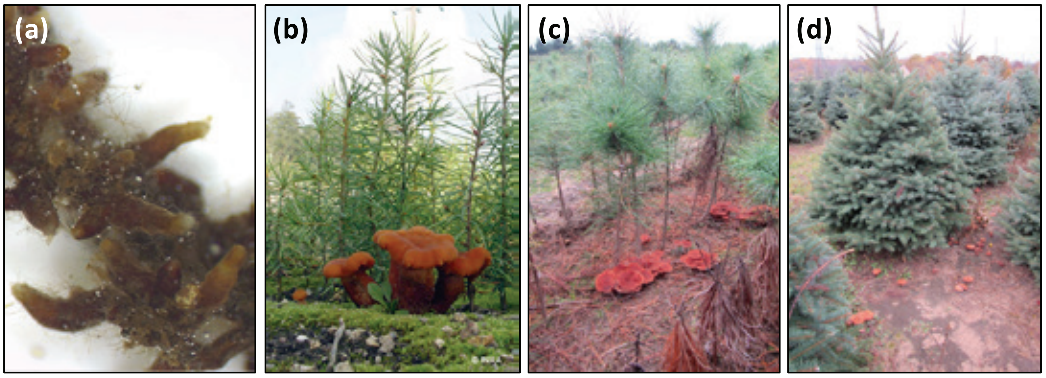

Figure 2. Early ectomycorrhizal (ECM) colonization leads to persistence, and can contribute to a tree's resilience to pathogens. Panel **(a)** shows a high-resolution microscope image of an ECM root cluster on Douglas-fir, with extraradical mycelium emerging *(Photo credit: B. Rennick)*. Panels **(b)**, **(c)** and **(d)** show fruiting bodies of *Laccaria,* a model ectomycorrhizal fungus. Our study will provide information about how biochar influences fungal guilds that promote overall seedling health (*Photo credits: G. Bonito).*

Although biochar amendments can increase soil moisture content in sandy-textured soils, they can have the opposite effect in clayey soils by helping to increase porosity. Understanding how biochar affects soil moisture differently depending on soil characteristics can be important for pathogen management. For example, Phytophthora root rot is a disease that can cause widespread mortality in conifer species. Typically, Phytophthora root rot is recognized by a reddish "flame" beneath the bark at the base of the tree, necrotic, blackened sloughing roots, and red needles (Figure 3). Phytophthoras thrive in wet and low-oxygenated soils, so amending areas that tend to hold excess water with biochar may help alleviate pathogen pressure by making sodden soils more porous. In the Spring of 2019, we have planned a series of experiments where we will inoculate Colorado blue spruce and Fraser fir in soil amended with biochar and Phytophthora spp. Once several weeks have passed, we will rate the seedlings for disease severity, and above—and below ground plant biomass. We will also evaluate the conifer seedling mycorrhizal community before and after the experiment to determine how the microbial community composition changes in response to biochar and pathogens, alone and in combination with each other. This experiment will provide critical information on the impact that biochar may have on the mycorrhizal community, pathogen virulence, and seedling growth and health.

The results from this current study will contribute to our broader research goals: to promote sustainable land use choices that provide environmental and economic benefit to agricultural producers. We will present additional preliminary results from this project at the Michigan Christmas Tree Association's Winter Meeting—we hope to see you there!

Figure 3. *Phytophthoras* thrive in wet and poorly-oxygenated soils, causing root damage that interferes with a seedling's ability to absorb water and nutrients. Root rot leads to major economic losses for growers. Although biochar can help increase soil moisture content in sandy soils, it can also improve drainage in fine-textured soils, such as where *Phytophthora* is a concern. Our study investigates the effects of biochar on pathogen virulence and seedling growth and health. *Photo credit: Monique Sakalidis.*