Soil Health

Getting a Reaction from the Land

Can the Johnson-Su System Turn Back the Clock on Soil Health?

Before he started dairy farming in 1979, Dale Pangrac was a science teacher. So perhaps it's no surprise that on an overcast day in early July, he's intrigued by the living experiment taking place on his operation near Utica in southeastern Minnesota.

"It is fascinating — the more I learn the more I want to learn," says Pangrac after spending the morning working with Land Stewardship Project staffers to fill two mini-silos with a mixture of barley straw, hay, manure, and bedding pack from his cow herd. Those stacks will sit and percolate for about 12 months, hopefully creating an inoculant that will take Dale and his wife Carmene's soil to a whole new level biologically. And what they and four other farm operations learn from this composting project could take soil science to a whole new level as well.

Since the summer of 2021, the Land Stewardship Project has been working with the Pangracs and the other farmers to research if a particularly innovative, low-labor approach to breaking down waste material can be a critical linchpin in efforts to bring the soil back to life. Through this initiative, LSP staff members have erected Johnson-Su Bioreactors on four farms in southeastern Minnesota and one farm in western Wisconsin. Invented by molecular biologist David Johnson and his wife, Hui-Chun Su, the bioreactor system represents a radical departure from the traditional way of taking organic material and breaking it down into a source of fertility via composting. Rather, the inoculant created by the bioreactor system activates the soil's innate ability to cook up its own fertility, akin to a baker introducing yeast to bread dough, giving rise to a chain reaction of ecological activity.

"We're not really going for a lot of nutrients or high fertility," says Maks Kopish, a southwestern Wisconsin vegetable producer who is serving as a consultant on LSP's research project. "We're really looking for a diversity of microorganisms, specifically fungi."

Kopish explains that traditional composting relies on frequent turning of the waste material to keep oxygen flowing and thus prevent the material from becoming anaerobic. This greatly reduces the timetable for producing a finished product, which can be an excellent source of fertility for soil. The disadvantage to such a system is that it demands lots of labor during the breakdown process, and, if done on farm scale, can be infrastructure intensive, requiring turning equipment and lots of room for windrows.

One big advantage to the Johnson-Su system is that it's scalable. A stack can be set up for less than $50 using locally available materials like wire mesh and landscape fabric. Larger operations can simply build more stacks, while smaller farms can rely on one or two. They can even be scaled to work for backyard gardens.

Mixing the "recipe" for a bioreactor on the Cotter farm in June 2021 — the composters utilize material readily available on-farm. (*LSP Photo*)

The Johnson-Su process requires a few hours of work on the front end — filling the five-foot-tall by 12-foot diameter stacks — but then that's about it. Other than some management required to add and manage moisture, the stacks are left alone for 12 to 18 months. PVC pipes are used during the construction process to create air shafts; this allows the stacks to breath during the composting process. During the first few days, the temperature is monitored to make sure the stacks heat up to a thermophilic phase of at least 131 degrees Fahrenheit in order to destroy pathogens and weed seeds. After the material cools down, red worms are added to assist further breakdown and the stacks are left to do their thing for several months.

That "quiet time" is key. It turns out all that tossing and turning in a traditional composting system is hard on the long, delegate filaments that make up fungi. And fungi are key elements in creating a self-sufficient soil biome.

"The fungi will actually be breaking down the mineral structure of your soil to make those nutrients available to plants," says Kopish. "We're trying to get back to where plants and fungi are working together. It's a cyclical balance where they're returning just as much as they're taking."

The original recipe developed by Johnson and Su consists of one-third leaf litter, one-third dried cow manure, and one-third wood chips, which are piled into the miniature silo-like structures. Through this LSP project, which is being funded by a grant from the Minnesota Department of Agriculture's Agricultural Growth, Research, and Innovation Program, farmers are experimenting with variations on the original recipe, utilizing chicken and hog manure, for example. Most of the research on the Johnson-Su Bioreactor has focused in areas like New Mexico, and studies in that region show material produced by this composting system greatly increases a soil's fungal biomass, which results in, among other things, greater crop yields and more sequestration of carbon.

Kopish has been using the system since 2020 and after one growing season is already seeing better aerated, livelier, soil.

"It's just amazing how quickly the soil structure begins to get built once you introduce this inoculant," said the vegetable farmer. "And I think the plants just respond in kind, because they're feeding microbes and the microbes are feeding them. Just in one growing season, I've seen that in our gardens. It's just mind-blowing."

One of the goals of the LSP initiative is to see how this system performs under replicated trials in the harsh climate of the Upper Midwest. There are questions around what happens when a Johnson-Su stack freezes in the winter — will it stop biological activity permanently, or can it be part of the process of creating an active biome by aiding in the break-down process?

According to the University of Illinois, the per-ton price of anhydrous ammonia fertilizer has more than tripled since 2020. And with war waging in Europe, there are indications this upward trajectory will continue in the immediate future. Pile on top of that the fact that we may be reaching what's called "peak phosphorus" in coming decades, and it's become more evident than ever that we need to build the kind of healthy soil

Bioreactor, *see page 27…*

…Bioreactor, *from page 26*

that generates its own fertility. Continued reliance on outside inputs to replace the nutrients being mined from our fields is simply not viable in the long term.

Inspired by the work of microbiologist Elaine Ingham, in recent years farmers and others have been investigating how they can use intense composting to build the kind of soil that is self-sustaining, and not reliant on a constant supply of chemical inputs.

"I've always tried to sustain myself without having to use too much outside inputs," says Tom Cotter, one of the bioreactor research project's participants. He farms 850 acres of organic and conventional crops and raises beef cattle in southern Minnesota's Mower County.

Pangrac says a desire to reduce spending on outside sources of fertility is also a big motivator for him. The Pangracs' 150-cow dairy herd is certified organic, and they have spent the past several years utilizing cover cropping, rotational grazing, and manure applications to build soil organic matter levels on their 900 acres. It's mostly worked, but Dale says he wants to take soil health to the next level. He became fascinated with utilizing his soil's natural ability to generate fertility after seeing Ingham speak about creating a self-perpetuating environment where microorganisms do the heavy lifting.

"The microorganisms and the plants communicate with each other," says the dairy farmer. "The plant feeds the microorganisms and in turn the microorganisms bring nutrients to the plant. It's quite a system."

As part of the research project, LSP is taking samples from the stacks and having Kopish examine them under a microscope. Samples have also been sent to the University of Minnesota for genomic sequencing, as well as to the Soil Foodweb laboratory in New York. Those samples will eventually be compared to material taken from conventional commercial composting operations.

Fungal vs. Bacterial

Kopish explains that the sampling is attempting to determine what's present in terms of active fungi, bacteria, protozoa, and nematodes. The goal is to create a product high in fungi and low in bacteria (bacterially dominant soils tend to sprout lots of weeds). High levels of predatory nematodes that will feed on pests such as aphid eggs are also preferred. It's early in the research, but at the six-month mark, sampling and microscope work showed compost that was relatively high in fungal material.

"But we're seeing some samples that are bacterially dominant at this point, or have indications that they are becoming bacterial," says Kopish. "So we have a couple of alarm bells like, 'Oh no, what's going on there?' "

Are the stacks too dry? Too wet? Too cold? Do the recipes need adjusted? Those are some of the questions Kopish, members of LSP's Soil Health Team, and the farmers themselves will grapple with in the next year or so. The current stacks will be torn down for the 2022 growing season so the farmers can apply the end product to their soil. After that, a new set of bioreactors will be set up (*see sidebar*) so that they can produce compost for the 2023 growing season, when the research projects wraps up.

Dale Pangrac plans on putting his Johnson-Su material in a compost brewer and then spraying it on his fields. He estimates that he can treat 400 acres with what his two stacks produce. Because the Johnson-Su compost is so concentrated, it can be applied at levels as low as half-a-pound per acre, according to David Johnson.

Setting up Johnson-Su composters on the Pangrac farm in July 2021 — the bioreactors utilize PVC pipes to create air shafts and keep oxygen flowing through the material. (*LSP Photo*)

Liana Nichols, who works for Wozupi Tribal Gardens near Shakopee, Minn., is also participating in the research project. She's hoping to use the compost created by the bioreactor as potting soil and as a soil amendment directly in the vegetable plots. Extract from the bioreactor can also be used to coat seeds.

Time Machine

After spending a morning erecting two bioreactors on his farm, Tom Cotter reflects on how much his soil has been damaged over the years as a result of tillage and intense chemical use. In a sense, we've gotten away with a one-way extraction — now it's time to put something back, he says. The farmer knows the Johnson-Su system is not a silver bullet, and, in fact, Johnson and Su say that the bioreactor works best when integrated with other soil health techniques like no-till, cover cropping, and managed rotational grazing. But Cotter hopes that mix of manure, forage, and other material percolating in those stacks standing in his machine shed represents a cutting edge spark plug that can actually wind the clock backwards.

"I hope it sets me back about 200 years, when biology was really healthy." ❒

Give it a Listen

On **episode 266** of the Land Stewardship Project's *Ear to the Ground* podcast, farmers involved in the Johnson-Su research talk about the importance of activating life in their soils: landstewardshipproject.org/podcast/ear-to-the-ground-266-activating-soil-life.

On **episode 271**, Maks Kopish describes what makes the Johnson-Su system so different from traditional composting and what role it could play in the future of regenerative agriculture: landstewardshipproject.org/podcast/ear-to-the-ground-271-focusing-on-fungi.

Bioreactor Field Day Aug. 26

On Aug. 26, LSP will be hosting researchers Hui-Chun Su and David Johnson for a Johnson-Su Bioreactor field day. The event will be held at the Dale and Carmene Pangrac farm in Utica, Minn. For details, see LSP's web calendar at landstewardshipproject.org/upcoming-events, or contact LSP's Shona Snater at ssnater@landstewardshipproject.org.

Want to Build a Bioreactor?

In June, Land Stewardship Project staff will be setting up Johnson-Su Bioreactors on five farms participating in the composting research project. If you'd like to volunteer to help, see landstewardshipproject.org/johnson-su-bioreactor-construction-events, or e-mail Shona Snater at ssnater@landstewardshipproject.org.