BIOLOGY

Can Soil Microbes Slow Climate Change?

One scientist has tantalizing results, but others are not convinced

By John J. Berger on March 26, 2019

Credit: Getty Images

With global carbon emissions hitting an all-time high in 2018, the world is on a trajectory that climate experts believe will lead to catastrophic warming by 2100 or before. Some of those experts say that to combat the threat, it is now imperative for society to use carbon farming techniques that extract carbon dioxide from the air and store it in soils. Because so much exposed soil across the planet is used for farming, the critical question is whether scientists can find ways to store more carbon while also increasing agricultural yields.

David Johnson of New Mexico State University thinks they can. The recipe, he says, is to tip the soil's fungal-to-bacterial ratio strongly toward the fungi. He has shown how that can be done. Yet it is not clear if techniques can be scaled up economically on large commercial farms everywhere.

Johnson, a trim 67-year-old microbiologist who is as comfortable using the latest metagenomics technology as he is shoveling cow manure into a composter, thinks society can only maximize carbon storage, increase soil's water-holding capacity and grow plentiful crops if it restores the soil microbiome. "We currently have very degraded soils physically, chemically, but mostly biologically," he says. "Microbes restore this balance."

Johnson conducts precise soil-biology experiments into how to increase the capacity of agricultural systems to absorb carbon from the atmosphere. In a recently completed four-and-a-half-year field trial, Johnson planted fast-growing cover crops and applied a microbe-rich solution derived from a vermiculture (worm) compost produced in a low-tech composter of his own design. The bacteria, fungi and protozoa fed a soil food web of nematodes, microarthropods and other beneficial organisms.

Through photosynthesis, the cover crops pulled CO_2 from the air, sank roots deep into the earth, and towered over the land. The results were unusual—and highly controversial. Johnson reported a net annual increase of almost 11 metric tons of soil carbon per hectare on his cropland. That's equivalent to removing about 16 metric tons of carbon dioxide per acre from the atmosphere annually—roughly 10 times the increase that other scientists have reported in many different soils and climates.

Johnson ascribes these improvements, along with large increases in crop yields, to improved soil health stemming from the application of the microbes from his vermiculture, leading to an increase in the soil's fungal-to-bacterial ratio.

Professor Rattan Lal of Ohio State University, widely regarded as a leading authority on soil carbon sequestration, says he was “intrigued” by Johnson’s outcome. “I want to understand why he’s getting such exceptional results.” Lal thinks that further, larger-scale trials are needed to validate Johnson’s work, of course.

Johnson is also conducting meticulous laboratory studies. They focus on the correlations among fungal-to-bacterial ratios and soil health, fertility and crop productivity. He reports finding increases in fungal-to-bacterial ratio, plus large increases in soil carbon and other nutrients as a result of his management practices.

In all this work, Johnson maintains that as the ratio of fungi to bacteria increases, the soil biome becomes more efficient in utilizing carbon and other nutrients and that the soil therefore releases less CO2 to the atmosphere. The jury is still out, however. Although peer-reviewed soil science literature contains some confirmation, other findings in submerged, forested and subarctic soils—admittedly different circumstances—failed to confirm the relation.

Keith Paustian, a professor of soil and crop sciences at Colorado State University, says he has seen some “quite high rates of carbon accrual” in degraded croplands that were converted to productive perennial grass systems. But he has not seen strong evidence that the same outcome can be produced by adding microbes.

EXTRAORDINARY CLAIMS

Johnson asserts that if his approach were used across agriculture internationally, the entire world’s carbon output from 2016 could be stored on just 22 percent of the globe’s arable land. He says that would provide net benefits of $500 to $600 per acre rather than net costs, if credits are provided for carbon capture and related benefits are counted, such as reduced irrigation and increased soil fertility.

To arrive at his global carbon-capture numbers, Johnson projected results from cropland plots of three to 75 acres of various soil types in five states. That is still a fairly limited sample. Henry Janzen, a research scientist at Lethbridge Research and Development Center in Alberta and a professor at the University of Manitoba, cautions that such a projection is risky. “Every ecosystem is unique,” he says. “A practice that elicits soil carbon gain at one site may not be effective at another. And always, the rate of carbon gain will depend on a host of interactive factors, including soil properties, previous management practices, climatic conditions and the vagaries of human whims.”

Janzen also points out that soils do not absorb carbon indefinitely. After some years or decades, they inevitably approach a new steady state. For that reason, he says, soil carbon sequestration is rarely seen as a long-term solution to increased atmospheric carbon dioxide concentrations.

Johnson acknowledges those factors but says managing soil to improve the health of its microbial life can provide strong carbon gains before the soil’s capacity levels off. He is in the process of scaling up his experiments to try to replicate his results on even larger plots in different geographies with a variety of cover and commodity crops, “to assess the impact for the rest of the world.”

A NEW PARADIGM?

Johnson's work is based on a somewhat different paradigm from that of most conventional soil scientists. They often seek to boost agricultural productivity in traditional ways by adding fertilizer and using pesticides and herbicides as needed. This approach is anathema to Johnson. He decries almost every conventional farming practice—plowing, bare fallowing, and the application of herbicides, insecticides and fungicides. All these, he says, "assault soil microbiota." He claims that glyphosate (sold in commercial products such as Roundup) will kill *Aspergillus* fungal species in soil. *Aspergillus* is often regarded as a marker of fungal presence and is important in carbon and nitrogen cycling.

As for fertilizer, Johnson believes he has demonstrated that microbially inoculated soil enriched with tilled cover crops naturally accumulates more than enough nitrogen for vigorous plant growth. (Nitrogen is the limiting nutrient in most agricultural situations.) In one of his plots where he reports having increased net primary productivity five times, the soil accumulated 770 pounds of nitrogen per acre per year.

Much of this fixation is done by free-living nitrogen-fixing bacteria. Because a normal crop only requires about 180 pounds of nitrogen per acre, Johnson says it would be unnecessary to add artificial fertilizer to a system like this.

As with all of Johnson's work to date, this result has appeared only in the form of reports and other "grey literature." Harold van Es, professor of soil and water management at Cornell University's School of Integrative Plant Science, is one of Johnson's severest critics.

"In science, we strongly believe that research should be subjected to peer evaluation," van Es says. "His ideas should not be at all presented as scientific facts."

The fungal-to-bacterial ratio is indeed important, van Es says. "But there are many ways to increase that ratio," not just Johnson's approach. "Reducing tillage has similar effects and this has been much more widely documented."

Although Johnson has irked some soil scientists and even aroused some ire, as climate change intensifies in speed and fury, many scientists believe it is important to leave no stone unturned in the search for ways to limit carbon emissions quickly. Perhaps the soil's microbiome can be a powerful tool.

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