Smithsonian Environmental Research Center
Newsletter

The Microbiology of Rusty Roots

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By J. Patrick Megonigal, Ph.D

On your next visit to a wetland, pull up a flooded plant and look at its roots. Chances are you will see a reddish-brown coating on the root surface called “iron plaque,” a solid made of iron (Fe) and oxygen (O). Iron plaque has long interested ecologists, in part because it is a dependable visual clue that a site is sufficiently wet to be a “wetland” by the legal definition. Scientists now recognize that iron plaque is relevant to another important environmental issue – global warming. The link between Fe and global warming is a classic story of resource competition that plays out in a narrow zone adjacent to wetland roots where the worlds of aerobic (with oxygen) and anaerobic (without oxygen) microbes meet. A wide variety of bacteria found in wetland soils are either competitors or participants in the action. I was recently funded by the National Science Foundation to investigate aspects of this microbially-driven Fe cycle. But first, some background on Fe and the microbes that use it.

Iron is the third most abundant element in the earth’s crust. In upland soils it exists in an oxidized form [Fe(III)] that imparts a variety of colors ranging from red to orange to yellow. Like animals, plants, and many microorganisms, tiny Fe-reducing bacteria “burn” organic carbon for energy in the process of respiration; a major difference is that they consume Fe(III) in place of O_2 in the process (Figure 1). By

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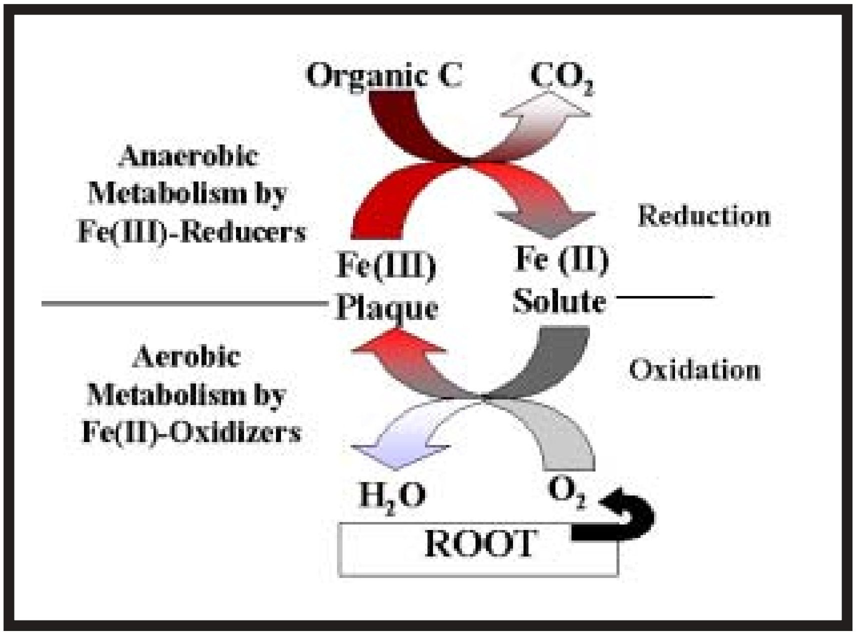

Figure 1. The root-associated iron cycle in wetlands.

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Figure 2. One of the bioreactors used to test the influence bacteria on Fe oxidation.

doing so, Fe-reducing bacteria change Fe(III) from a solid form to a soluble form [Fe(II)]. The soluble form moves with the anaerobic water until it makes contact with O_2 leaking from wetland plant roots. At this point, the Fe changes form once again, oxidizing from Fe(II) to Fe(III) plaque.

Although scientists have known for at least two decades that bacteria greatly enhance rates of Fe reduction, the process of *Fe oxidation* is still assumed to be a purely chemical process in which bacteria play no role. A major objective of our work is testing this assumption. I am collaborating with Dr. David Emerson of the American Type Culture Collection in Virginia, research associate Dr. Scott Neubauer of SERC, and Ms. Johanna Weiss, a Ph.D. Candidate at George Mason University, Virginia. We have successfully isolated the first pure cultures of Fe-oxidizing bacteria from Fe plaque. We have also determined these bacteria are living on the roots of plants in all sorts of wetlands including freshwater marshes, salt marshes, mountain fens, forested swamps, and submerged aquatic plants. Our objective now is to answer the question: Do bacteria accelerate the rate that Fe is oxidized and deposited on roots?

Dr. Neubauer approached this tricky question by measuring Fe oxidation rates in “bioreactors,” one of which was innoculated with a pure culture of Fe-oxidizing bacteria and the other with a sterile culture (Figure 2). Oxygen was leaked into the reactors at a slow rate to simulate the loss of O_2 from plant roots. Rates of Fe oxidation in the bioreactor with bacteria were higher by up to 50%! The next step is to repeat this study in a bioreactor that includes real wetland plants.

Johanna Weiss has looked closely at the chemical composition of Fe plaque (Figure 3). She found that Fe-reducing bacteria are able to use Fe(III) compounds on roots

Figure 3. Johanna Weiss and Dr. Pat Megonigal studying Fe reduction in a freshwater marsh in Virginia.

more easily than those in the soil. Thus, plant roots are a preferential site of Fe reduction because the plaque is composed of easily-reduced forms of Fe(III); roots are also a preferential site of Fe oxidation because they are a source of O_2 and harbor Fe-oxidizing bacteria. It seems the root surface is a hot-spot of biogeochemical activity!

But how does Fe link to global warming? As Figure 1 shows, Fe-reducing bacteria use organic carbon, but so do many other groups of bacteria including those that produce methane (CH_4) gas. Fe-reducing bacteria outcompete methane-producing bacteria for organic carbon because Fe-based respiration yields more energy. Thus, a rapid Fe cycle acts to suppress CH_4 emitted from wetlands. This is important because methane is a powerful greenhouse gas that has risen rapidly in the atmosphere along with CO_2. Methane accounts for 20% of current global warming and wetlands produce 40% of all CH_4. I expect our investigations on Fe cycling to shed light on the microbial processes that control the production of this powerful greenhouse gas.

Dr. Pat Megonigal is the newest member of SERC's scientific taff. He is the Principal Investigator of the Biogeochemistry Lab at SERC.

The Library Corner

1.) Did you ever need to know whether a certain book is still in print, or how many editions of it there have been? Did you ever wish this information was at your fingertips? It's true that these questions can often be answered when you access SIRIS, the online catalog. Now the SIL (Smithsonian Institution Libraries) offers you desktop access to another great tool - Bowker's Global Books in Print. On any SI computer, just go to:

http://www.globalbooksinprint.com

At this site, you may perform quick or complex searches for book, audio, and video titles. There is even information on forthcoming and out-of-print titles at this site. You can find contact information for American, Canadian and British publishers. Check it out – it may become one of your favorite sites! As always, be sure to "logout" at the end of your search session.

2.) Coming in August, a new SIL homepage for research purposes. It will be the new default page on computers in the branch libraries. Access to online databases, e-journals and SIL-generated digital content will continue on the new page. The new configuration is designed to get users to the tools and content they need in an even clearer and more expedient way.

Angela Haggins,
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