# Soils Under The Microscope

**By Dr. Doug Soldat,** Department of Soil Science, University of Wisconsin - Madison

Did you know there are between ten and one hundred times more bacterial cells in your body than your own cells? The composition of these organisms play a huge role in everything from how nutrients are absorbed in your body, to whether or not you get ulcers, or how susceptible you are to ear infections. Microbiology is one of the most active and exciting research areas in science today and scientists are making new discoveries everyday that are shedding light on how much influence those little critters have on our lives. The award for the most interesting and disgusting advance goes to the practice of "fecal transplanting" where the doctor, well… you can imagine. Fecal transplanting has been used with great success to cure or treat some intestinal disorders because the composition of the bacterial community in your gut has a large effect on how your plumbing works (or doesn't).

The point here is that microbiology is a poorly understood, but hugely important aspect of our lives. It is not a stretch to imagine the same applies to your soil and the turf that you grow on it. You are likely to encounter an increasing number of products that claim to alter or improve the microbiology of the soil to the benefit of "plant health", whatever that means. I hope to share some information with you that will help you make good decisions and keep your expectations realistic.

**Your Soil is Not Sterile**

Biological additives (i.e. compost tea) are often marketed to turf areas using the idea that the fertilizers and pesticides applied to the soil sterilize it, and disrupt important functions of the soil. Below is a figure I grabbed off the internet that shows one incarnation of this idea. But in fact, even in sandy soils that have been fertilized and treated with pesticides, researchers have consistently found high populations of microbial activity (Zuberer, 2012; Elliot et al., 2007; Bigelow, 2000). The scientific consensus is that fertilizer (synthetic or organic) actually increases microbial activity because the fertilizers stimulate plant growth, which in turn stimulates soil microorganisms (Bunemann et al., 2006). In terms of the impact of pesticides on microbial activity, Dr. Eric Nelson and colleagues at Cornell University studied the effects of repeated fungicide applications to soil organisms on a golf green. They hypothesized that the fungicide applications would dramatically change the soil microbial community, but that turned out not to be the case at all (Harman et al, 2006). Bacteria and fungi in the soil were similar regardless if fungicides were applied or not.

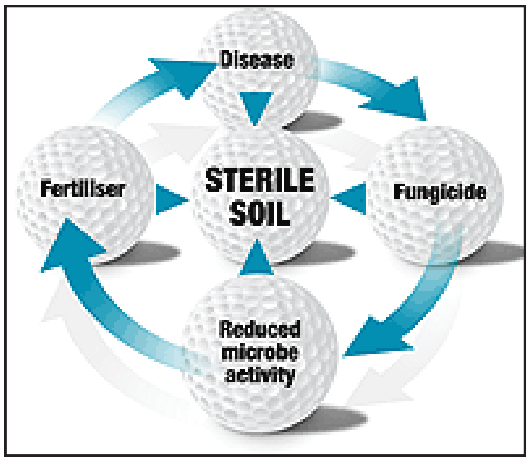


**Figure 1. A marketing figure from a soil biological testing laboratory showing the mistaken idea that fertilizers and fungicides lead to a sterile soil.**

Not only is your soil not sterile, but is the most diverse microbiological habitat on earth. There are approximately 4,500 mammal species, 20,000 birds species, maybe 250,000 plant species, and somewhere around 1,000,000 insect species. In a spoonful of soil there are estimated to be 8,000,000 species of bacteria (Gans et al., 2005), and maybe as many as one billion species in the soils around the world. That is an incredible amount of diversity. As you might guess, we have very little understanding of the function of the majority of these species let alone names for them. But in general, we know bacteria are responsible for the cycling of nutrients by converting one form of nitrogen, or sulfur, or carbon, etc. to another; but we would be stretching the facts to say that we know exactly what each of those millions of species are doing and which ones we should be promoting and which ones we should be discouraging.

**Testing for Microbes**

Unfortunately, you will likely come across a person who will try to tell you just that. There are a growing number of laboratories that test for the amount of bacteria, fungi, protozoa, and nematodes in your soil and give interpretations telling you if levels are "high" or "low". I like to use this quote from O.J. Noer's ABC of Turf Culture (1928) on the utility of testing for nutrients in the soil:

*"There is a tendency to place undue emphasis upon the value of chemical soil tests. This is true of some technical workers as well as salesmen. These methods have a promising future but their present usefulness is limited by imperfect [methods] and for a lack of definite correlation with field experience."*

Just replace the word "chemical" with "biological", and you'll be up-to-date. Soil testing for anything requires a great deal of time and effort. We are still working to refine nutrient soil tests 85 years after O.J.'s statement. So until we can look to research that can validate the interpretations of "low" bacteria or protozoa, I consider these new biological soil tests simply a gimmick or a novelty designed to sell you something you probably don't need.

**The Dilution Problem**

Microbial products are designed to change the community of organisms in the soil by adding "beneficial" organisms. This sounds great. However, let's take a minute to address the amount of product added in comparison to the native communities. We'll start with a compost tea that might have 40,000,000,000 colony forming bacterial units per gallon. That sounds like a lot!

You might apply this compost tea solution at a rate of 1 gallon per thousand square feet. Even though you are adding 40 billion or so bacteria, you're adding them to a soil that likely has about one quadrillion (1015) bacteria per thousand square feet. That is one bacterial cell from compost tea for every 250 million native cells. Not very good odds for changing the microbial make-up. Here is another example of a bacterial additive that we've tested at the O.J. Noer (which had no visual effects). The label says to apply 0.8 oz/1000 sq. ft. The product contains about 80,000,000 bacteria per oz. This means we are adding 64 million bacteria per thousand sq. ft. which is about one applied bacterial cell per 156 million native cells. These products might have pronounced effects if we apply them at levels where the added amounts can begin to compete with the native levels. But this is not going to happen at labeled rates.

**A Promising Future?**

This is where Dr. Jenny Kao-Kniffin comes in. Jenny is an assistant professor in Horticulture at Cornell University with a doctorate in Soil Science from UW-Madison. At Cornell, she is working on using artificial selection to breed microbial communities (called microbiomes) that can improve turf growth. She does this by growing dozens of genetically identical turf plants in pots, then selecting the few pots that have the best and those with the worst growth. Since the grass is identical, and the physical and chemical properties of the soil are identical, the growth difference is related to the biological properties of the soil. She then extracts the microbes from the best and worst soils and adds them separately to a sterilized soil with turf seeds. She waits until those plants grow and again selects the best and worst looking pots and extracts the microbes and inoculates a new set of soils. Over time the poor performing selections get worse, and the good performing selection get better. This is similar to how grass breeder would develop new grass varieties, but in this case, Dr. Kao-Kniffin is breeding the soil. After several "generations" she can get differences in growth shown in **Figure 2.**

The plants in Figure 2 are genetically identical, but are showing different growth characteristics because they have different soil microbiomes. She's also using the same technique develop microbiomes that discourage weeds. She tells me this same concept can be applied to insect and disease control too. We have a long way to go before this information can be used to make a difference on your golf course, but work like Jenny's will lead to an increase in our understanding of the soil microbial community that will eventually result in something useful. The primary challenge, of course, will be translating this information from a greenhouse trial with initially sterile soils to a field setting that is already teeming with life. If it was easy, it would already have been done, but I remain optimistic.

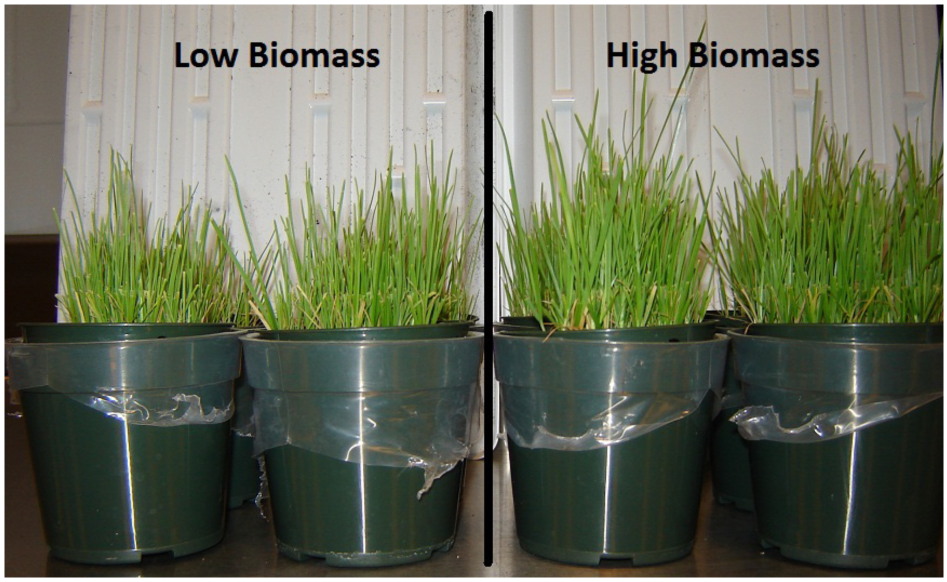


**Figure 2. Two genetically identical grasses grown in pots where the only difference is the make-up of the soil microbial communities. The soil microbes on the right have been selected to positively influence grass growth, while the communities on the left interact with the grass to produce less growth. Photo courtesy of Dr. Kao-Kniffin.**

In summary, our general increased understanding of the importance of the microbial communities in our bodies and elsewhere will likely stimulate an increase in products and services revolving around soil microbes. However, the vast diversity of microbes in the soil make or primitive tests almost useless, and products on the market seem to be too dilute to make a difference. However, advances in our understanding may one day results in new and useful approaches to managing your microbes.

**References:**

Bigelow, C. A., A. G. II Wollum, and D. C. Bowman. 2000. Soil microbial populations in sand-based root zones: Newly constructed greens may not be as sterile as once believed. *Golf Course Manage.* 68(10):65-69.

Bunemann, E.K., G.D. Schwenke, and L. Van Zwieten. 2006. Impact of agricultural inputs on soil organisms – a review. *Australian Journal of Soil Research.* 44:379-406.

Elliott, M. L., J. A. McInroy, K. Xiong, J. H. Kim, H. D. Skipper, and E. A. Guertal. 2007. Diversity of rhizosphere bacteria in USGA putting greens. [Online]USGA *Turfgrass Environ.* Res. 6(20):1-8.

Gans, J., M. Wolinsky, J. Dunbar. 2005. Computational improvements reveal great bacterial diversity and high metal toxicity in soil. *Science.* 309:1387-1390.

Harman, G. E., E. B. Nelson, and K. L. Ondik. 2006. Non-target effects of fungicide applications on microbial populations of putting greens. *USGA Green Sec. Rec.* 44(4):9-12.

Zuberer, D. 2012. Soil microbes: Some practical perspectives for turfgrass systems. *USGA Green Sec. Rec.* 50(15):1-5.