SOIL MICROBES

Some practical perspectives for turfgrass systems.

BY DAVID ZUBERER

The subject of soil microbiology is often perplexing to many because microbes are invisible to the unaided eye and dwell in an environment where they are rarely observed in their native habitat. That environment, the soil, is perhaps the most complex on earth. Soil microbes live in a world dominated by interfaces. These interfaces are controlled by the interactions of air and water with soil particle surfaces. Most microbes spend their entire existence in thin water films, or biofilms, surrounding soil particles. Yet despite the complexities of this habitat, most soils contain an active, thriving microbial population. In fact, one would have to look long and hard to find an environment completely devoid of microbes. That is not to say that the populations are not affected by their environmental conditions, because they certainly are. In most normal soils, for example turfgrass locations (Figure 1) and agricultural fields, if conditions are suitable for plant growth, it is highly likely there is an active microbial population.

ENVIRONMENTAL FACTORS AFFECTING SOIL MICROBES

Soil microbes require what all other living organisms require — a source of carbon and energy, adequate moisture and aeration, and the essential inorganic nutrients and trace elements (Table 1) necessary to build cells. Ideally, the soil should contain about 50 percent water-filled pore space, allowing for a good balance of air- and water-filled pores for growth and activity of aerobic microbes. Too much water limits oxygen exchange through the soil matrix and can lead to the development of anaerobic conditions, sometimes leading to root decline and the formation of black layer. Like all living things, microbes must have an adequate supply of nitrogen, phosphorus, potassium, sulfur, and other

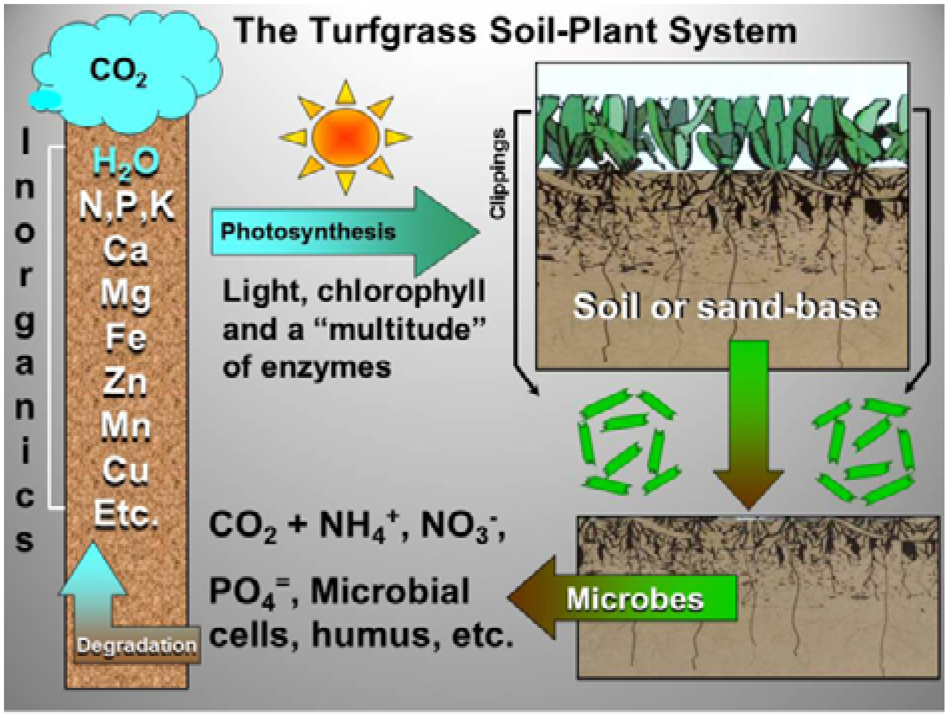


Figure 1. The turfgrass soil-plant system. Plants take up soluble nutrients (N, P, K, etc.) from the soil solution. Carbon dioxide is fixed through photosynthesis and plant biomass is synthesized above and below ground. Grass clippings are removed or returned to the soil. Roots and clippings are decomposed through the activities of soil microbes, and through the process of mineralization organic forms of nitrogen and phosphorus (and other essential elements) are returned to their inorganic, plant-available forms to begin the cycle anew.

SOIL PROPERTY	SOURCE OR DESIRED RANGE
Organic carbon	Grass clippings, root exudates, crop residues, organic wastes, etc.
Moisture	50% water-filled pore space
Aeration	Balance of air and water filled pores
pH	Near neutral (pH 6.0 to 8.0)
Temperature	10-40°C
Inorganic nutrients	Adequate N,P,K,S, etc., and trace metals

Table 1. Principal environmental variables affecting growth of soil microbes.

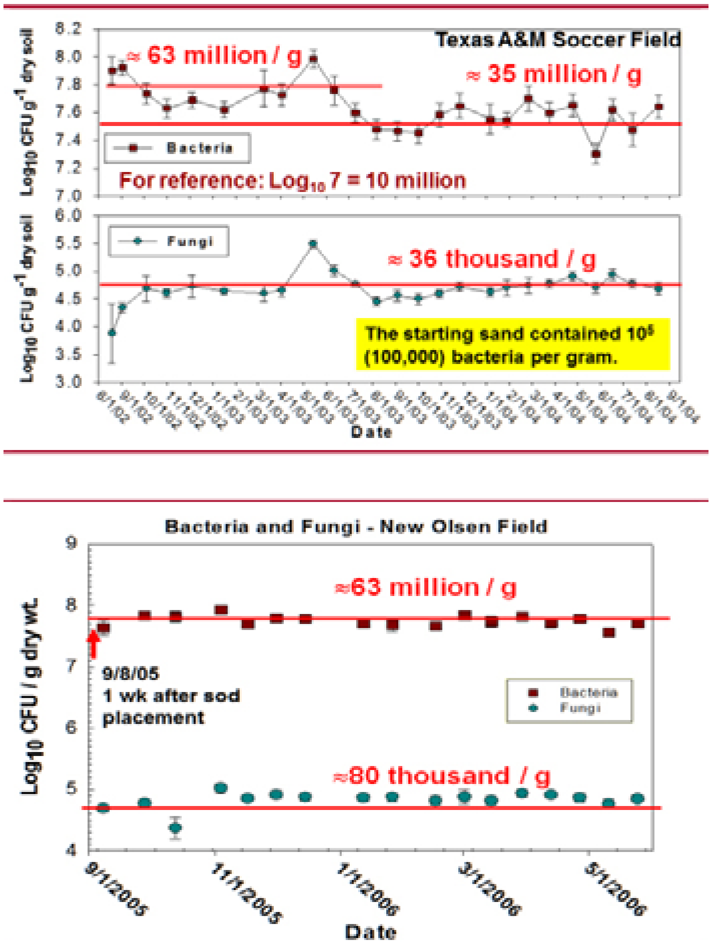


Figure 2. Microbial populations in a newly constructed soccer field (top) and baseball field (bottom) with washed bermudagrass sod laid over an 11-inch rootzone of pure sand. Note the rapid establishment of robust microbial populations and the relative stability of the populations in the months following. These samples were meticulously cleaned of root pieces, etc., before the microbial counts were performed on the rootzone sand.

nutrients to build cells and engage in the myriad of activities essential to soil fertility. A near neutral pH is generally favorable for microbial growth in soils.

The vast majority of soil microbes depend on a source of organic carbon for growth and activity. In the turfgrass environment, that organic carbon (energy source) comes mainly from grass in the form of clippings, roots, root exudates, and sloughed or lysed root cells. It is for this reason that the rhizosphere (the area of soil immediately surrounding the root) is an area of intense microbial activity, with elevated numbers of microbes (as much as 10- to 100-fold increases compared to adjacent soils absent of roots). The grass byproducts become the microbe's food source. It is my contention that to grow "healthy" microbial populations, you must grow good grass. In other words, feed the plants to feed the microbes! Feeding plants by providing a sufficient supply of nitrogen, phosphorus, potassium, and other essential nutrients and maintaining a favorable rooting environment (a balance of air- and water-filled pores, acceptable pH, etc.) for turfgrass should provide a suitable habitat for soil microorganisms. An active microbial population will decompose grass clippings as well as decaying roots and dead microbes. They will recycle the organic nutrients immobilized within these sources and convert them back to inorganic, plant-available forms. This "mineralization" process is one of the most essential functions of soil microbes in maintaining a productive soil capable of supporting plant growth.

ARE TURFGRASS SOILS LACKING IN SOIL MICROBES?

It is not unusual to find statements suggesting that turfgrass soils are "sterile" or somehow lacking in microbial populations and therefore in need of having some microbial preparation added. Some of those statements are based on newly constructed sand-based rootzones or refer to soils that have been recently fumigated for pathogen control. It is true that soils in those cases can have a much reduced microbial population, but they are not sterile and with the establishment of new vegetation, especially if sodded, they will develop robust microbial populations in a short period of time.

In our studies of a number of sports fields (both soccer and baseball) and putting green situations established with dwarf bermudagrasses, we observed bacterial populations ranging from 28 million to 100 million cells per gram of soil. Even newly established turfgrasses on sand-based rootzones showed high numbers of bacteria within one to several weeks after sodding (Figure 2). Bigelow et al. (2002) found that bacterial numbers exceeded 108 colony-forming units (or 100 million) per gram of dry soil within the first six months after seeding a newly constructed green to creeping bentgrass. This is similar to levels recorded in a mature sand-based putting green. The authors further stated, ". . . it seems that microbial population dynamics in these sand-based rootzone mixtures may largely be influenced by the developing turfgrass system, independent of any rootzone amendment." And, "Consequently, if environmental conditions are not favorable for the root system, the indigenous microbial population may decline, at least temporarily." Bear in mind that laboratory plate counts of bacteria generally represent approximately 1 to 10 percent of the population, thus the actual populations may be 10- to 100-fold greater in the soil.

DO WE NEED TO ADD MICROBES TO TURFGRASS SOILS?

With the exception of establishing new putting greens from seed on a pure sand-based rootzone, I can think of few areas where one would need to add exogenous microbes (beneficial bacteria) to a soil. Even the sand used for building greens or sports fields is not sterile. In the soccer field study above, we found 100,000 bacteria per gram in the sand used to construct the rootzone. A new construction site might afford the opportunity to intro-

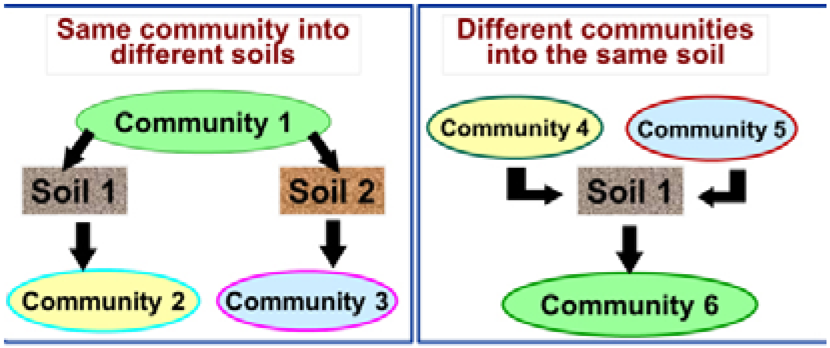


Figure 3. Results from a "community swap" experiment show that soil is an overriding factor influencing microbial population dynamics. More specifically, when the same microbial community was inoculated into two different soils, it developed in a different way in each soil (on left). Conversely, when different communities were inoculated into the same soil, they developed in the same way. The authors of this particular study concluded that ". . . it appears that the soil physico-chemical conditions determine what specific microorganisms thrive in that soil and so determine microbial community composition" (Griffiths et al., 2007).

duce selected microbes, but figuring out which ones to add would be a daunting task, to say the least. Recent research based on modern molecular techniques suggests that there may be as many as 4,000 to 13,000 species of bacteria in a gram of soil (that's about the size of a kidney bean in the palm of your hand). Some researchers suggest a number ten times greater. Most of the bacteria in soil have yet to be obtained in pure cultures, so we know relatively little about them or how they might be of use to us. Given that current state of affairs, if one wanted to inoculate a newly established putting green, a prudent practice might be to add back a small amount of pathogen-free soil from the surrounding area. Those microbes would likely be better adapted to the prevailing environmental conditions.

Microbiologists can now determine the composition of microbial communities using relatively new sophisticated molecular techniques. Those techniques are proving fruitful in understanding the factors that control the composition of microbial communities in different soils. Using such techniques, a group of researchers in Scotland (Griffiths et al., 2007) conducted what might be referred to as a "microbial community swap" experiment (see Figure 3). In this experiment, they added the microbial community from one soil into two new soils and found that those soils produced two new distinct community structures. Conversely, when they inoculated the communities from two different soils into a common soil, they obtained one new community as a result. In short, what they found was that it was the soil physico-chemical factors that exerted substantial control over the developing communities and not the composition of the added microbes. Such findings highlight the challenges of trying to change the soil microbial population by adding a few new bacterial species via a microbial inoculant. Similar results were reported in a study testing the effects of adding compost to a soil on the composition of the microbial community (Saison et al., 2006). The authors in that study concluded that the compost did indeed alter the composition of the microbial community of the compost-amended soil, but they ascribed the change in composition to the changes in the physical properties of the soil and not to the microbes added with the compost. More recent research has shown that soil pH is one of the main drivers of soil microbial community composition, among other environmental and plant factors. As such, it is a parameter easily monitored by turfgrass managers and one that is relatively easy to control.

While we are on the subject of adding microbes to the soil, let's consider the issue of dilution during application of non-traditional soil amendments or microbial inoculants. The label recommendation for many non-traditional soil amendments is to apply one gallon of product per acre of turf or agricultural field. One can gain a perspective on the dilution of such products upon application by viewing Figure 4. Realizing that one gallon per acre equates to about 1.75 drops of product per square foot, it should follow that a product would have to contain a very active compound or microbial assemblage to be effective in such small quantities. For those products advertising delivery of "natural" beneficial bacteria, it should be remembered that turfgrass soils can literally contain up to several tons of microbial biomass per acre. A soil with 10 million bacteria per gram (a typical value) contains about 200 billion cells per square foot (assuming 2 million pounds per acre and a 6-inch soil depth). Adding a few "new" microbes is not likely to have any impact. Establishing introduced

Dissecting the one-gallon-per-acre application rate:

One U.S. gallon equals about 3800 milliliters

One milliliter = 20 drops

Thus one gallon ≅ 76,000 drops

One acre = 43,560 square feet

$$\frac{76{,}000 \text{ drops}}{43{,}560 \text{ ft}^2} = 1.75 \text{ drops / ft}^2$$

Applying one gallon of a product to one acre of land equates to delivering 1.75 drops of product per square foot of land area.

Figure 4. Many non-traditional soil amendments on the market are recommended to be applied at a rate of one gallon per acre of turf. A few simple conversions and calculations helps put this into perspective when it is realized that this application rate delivers approximately 1.75 drops of product to one square foot of turf. Factor in that many of these products are already quite dilute suspensions of various bacteria or unconventional nutrients and one can see that only a miniscule amount of "active ingredient" or microbial cells is delivered through such an application.

bacteria in a soil-plant system to bring about favorable changes remains a formidable challenge for researchers and practitioners alike, and this remains an active area of ongoing research.

DO WE NEED TO FEED THE MICROBES TO FEED THE PLANTS?

Over the years, particularly with the growth of the Internet, I have seen various recommendations for managing soil microbial populations in turfgrass soils. Among those recommendations is applying sugar or molasses to stimulate soil microbes to somehow benefit the turf. Specifically, one recommendation is to add five pounds of sugar per acre to "feed the microbes to feed the plants." To investigate that particular recommendation, we conducted a laboratory study to determine what effects adding a similar rate of glucose (a readily available carbon source for microbes) would have on soil respiration, a measure of overall soil microbial activity. Using a soil from the Texas A&M University research station, we found the results shown in Figure 5 (top). We found no difference in the respiration rates of the soil amended with the equivalent of six pounds per acre of sugar compared to the unamended soil. To explore the concept further, we used the same soil and exposed it to increasing levels of glucose. The results of that trial (Figure 5, bottom) indicated that we had to add the equivalent of somewhere between 60 to 600 pounds per acre of glucose to elicit a measureable respiratory response to the carbon addition.

In another study, we examined the effects of molasses on the numbers of bacteria and fungi in bermudagrass turf treated with 0, 1, or 16 pounds per 1,000 square feet of commercially available molasses. That study, done in collaboration with Drs. Tony Provin and Gene Taylor, both of Texas A&M University, yielded the results shown in Figure 6. We found no differences across the three treatments. Molasses did not affect the numbers of bacteria or fungi in the molasses plots. It is possible that had we sampled immediately after application, we might have detected a transient increase, but that

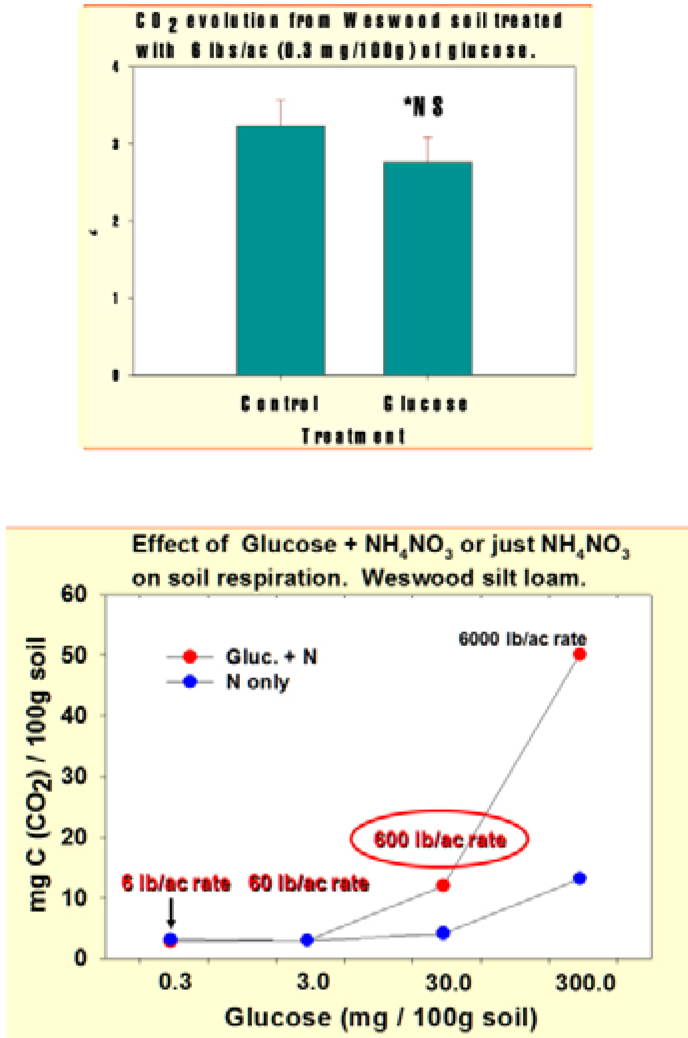


Figure 5. Soil respiration, a measure of soil microbial activity, was not stimulated at either the 6- or 60-pounds-per-acre rate of glucose added to soil. Not until 600 pounds per acre of glucose was added was a measurable difference observed. Data points are means of three replicate 100-gram soil samples.

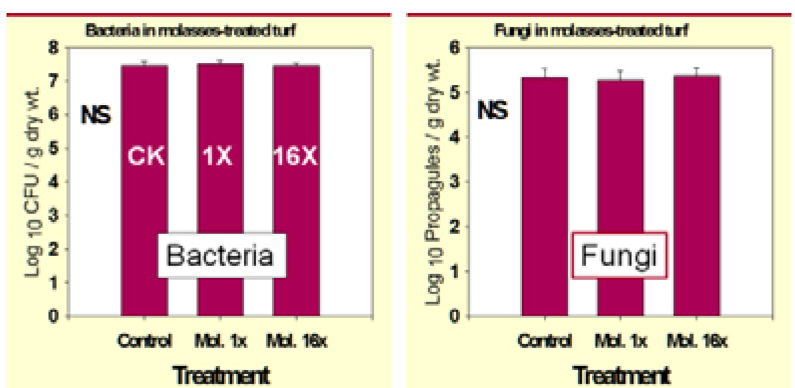


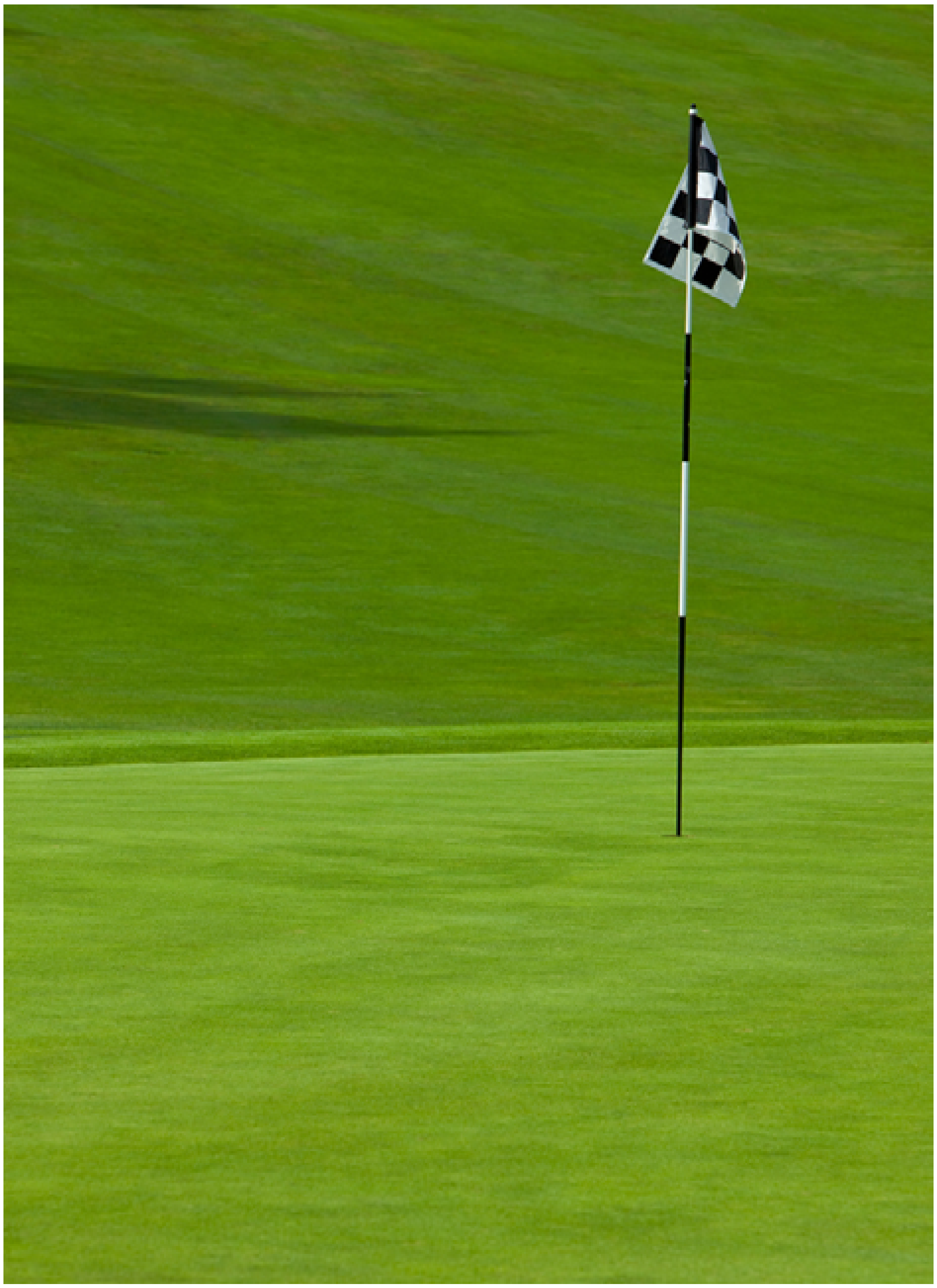
Figure 6. No statistical differences were evident in bacterial and fungal populations in bermudagrass sod treated with molasses at 0, 1, and 16 pounds per 1,000 square feet. Soil samples were collected a few weeks after the application of the molasses treatments. Data are the means of three replicate, composite samples collected from the sod with a soil corer to a depth of four inches.

was not the intent of the study. There were also no observable differences in the performance of the turfgrass even at a 64-pound application rate.

The results of these two short studies suggest that adding small amounts of carbon has little or no effect on microbial numbers or activity. Perhaps a note of caution is due here. Adding too much available carbon to a soil can be problematic as soil microbes can quickly deplete the soil atmosphere of oxygen and the ensuing anaerobic conditions can lead to root death and other problems.

SUMMARY

Much research recently has demonstrated that turfgrass soils are not much different from agricultural soils or native grasslands in microbial functions. While land-use and management can bring about changes in microbial communities, it remains to be demonstrated definitively whether there are significant negative impacts from such changes.



Well-established agronomic principles are the best practices for managing soil microbes.Growing healthy turf will provide the necessary resources for soil microbes to thrive.

The turfgrass environment is a favorable one for growth of soil microbes, a characteristic shared with other grassland habitats. It also appears that trying to change soil microbial populations in a meaningful way remains a difficult challenge for those seeking to do so by adding microbial preparations or novel soil amendments. Soil microbial populations demonstrate a high degree of resilience, and changes in the community will most likely be accomplished through greater attention to altering the soil environment to be a more favorable habitat.

In my opinion, after 35-plus years of "soil microbiology watching," the best practices for managing soil microbes are those that adhere to well-established agronomic principles. Maintain adequate soil fertility and a favorable soil environment through judicious use of aerification techniques, soil testing, and ongoing monitoring for changes in soil properties. In short, growing healthy turf will provide the necessary resources for soil microbes to thrive.

REFERENCES

Griffiths, B. S., P. D. Hallett, H. L. Kuan, A. S. Gregory, C. W. Watts, A. P. Whitmore. 2007. Functional resilience of soil microbial communities depends on both soil structure and microbial community composition. Biology and Fertility of Soils. 44(5), 745-754.

Saison C., V. Degrange, R. Oliver, P. Millard, C. Commeaux, D. Montange, X. Le Roux. 2006. Alteration and resilience of the soil microbial community following compost amendment: effects of compost level and compost-borne microbial community. Environmental Microbiology. 8(2): 247–257.

C. A. Bigelow, D. C. Bowman, and A. G. Wollum II. 2002. Characterization of soil microbial population dynamics in newly constructed sand-based rootzones. Crop Sci. 42:1611–1614.

DAVID ZUBERER, Ph.D., *is a professor of soil microbiology in the Department of Soil and Crop Sciences at Texas A&M University, College Station, Texas.*