Microbes in soil and sand-based rootzones

BY **DAVID A. ZUBERER**

Throughout my career as a university researcher and teacher, I have studied microbes in soils from a number of viewpoints. Mostly my interests have been focused on the roles of so-called beneficial microbes in soil-plant systems ranging from agricultural fields to reclaimed surface-mine sites. More recently, perhaps because of an interest in golf, but perhaps more so because of the need for basic information for turfgrass managers (my job brings me in contact with many students aspiring to work in the sports turf arena), our studies have focused on some of the microbiological aspects of sports turfs on native soils as well as those established on sand-based systems.

As I read various publications, from trade magazines to information on the World Wide Web, I find that there is a wealth of misunderstanding and misconceptions among the general public regarding not only the real functions of soil microbes but also of what it takes to maintain or manipulate them. To read some of the material "out there" one would think that agriculture, including turf management, has been waging "all out" chemical warfare on soil microbes and that we have all but annihilated them in our soils. To try to bring some clarity to the subject, I would like to discuss some of the issues surrounding soil microbes in turf with special reference to sand-based root zones, as that seems to be an area of some confusion.

I would like to address the following questions:

1. Are native soils and sand-based rootzones different?
2. What microbes are in sports-field soils?
3. How many are there? How much biomass?
4. What do they do?
5. What do you need to do for them?

I will try to provide some relevant information from the standpoint of what we know about soil microbes and their activities and I will try to indicate areas where the science is still uncertain.

Are native soils and sand-based root zones different? To some, this is obvious; there are differences in the two systems! But let's take a look from a microbiological perspective. Some of the major ways in which soils and sand-based root zones might differ are listed in Table 1. It is likely that native soils will have a greater content of silt and clay than a sand-based root zone as that is one of the principal reasons for developing the sand base; it cuts down on the finer particles and leads to coarser (more sandy) textures with the presumed advantage of better aeration and drainage. It is also likely that native soils have better aggregate-forming potentials than the coarser sands.

Thus, if managed properly, native soils can exhibit good drainage and will likely have a more variable range of pore sizes. Pore size is critical for air and water retention and finer textured soils, if not well aggregated, tend to drain poorly making the soil environment less suitable for microbes and roots. One might envision that the chemical properties of soils would be more complex than those of the sands although many different ingredients, e.g., zeolites or diatomaceous earth, have been added to sand mixes to improve their chemical properties (cation exchange capacity, etc.).

One might also expect that native topsoil would have more organic matter than a sand mix and that it might be more complex in its chemical composition. Sand-based systems are generally constructed with peat or some other organic material (for example rice hulls) making up as much as 20% of the mix. One should realize that sand-based systems can also accumulate new organic carbon fairly quickly in the surface few inches as roots and microbes grow, die off and decompose. Thus, grasses in sand-based systems become sources of microbial substrates relatively quickly in their early development.

Table 1. Some major characteristics that differ between native soils and sand-based root zones

	Native Soil	*Sand-Based*
Texture	Varies but likely to have silt and clay	Sand of specified particle-size range
Structure	Probably aggregated with a mixture of pore sizes. Mechanical properties may deteriorate when wet	Probably lacks aggregation; pore size less variable. Better mechanical properties than soil when wet
Drainage	Variable, mix of pore sizes. Better water retention. Drainage can be poor depending on texture and structure	Rapid drainage, pore space mostly due to packing of the larger sand particles. Water movement retarded due to perched water table
Chemical properties	More complex, greater cation exchange capacity due to clays properties derived mainly	Less complex; lower cation exchange capacity. Chemical from the organic matter content
Organic matter	Probably greater and perhaps older; more humified	Can be quite high in surface few inches. Different composition during early stages

What microbes are in sports-field soils?

Sand-based rootzones contain abundant populations of bacteria and fungi as well the other major microbial groups; actinomycetes (a specialized group of mostly filamentous bacteria and well known for their ability to produce many of our modern, medically useful antibiotics), algae (and cyanobacteria, formerly known as the "blue-green algae") and protozoans. Bacteria and fungi generally dominate the soil microbial population and this is probably true of sand-based root zones as well (see Table 2). It probably is not inaccurate to say that we know less about the microbial ecology of sand-based rootzones than we do about "normal'" soils. But that is changing as more research efforts are focused on these highly managed systems. However, what we do know is that they tend to function like regular soils once vegetation is established and regularly maintained as a healthy turf. Numerous studies document the abundance of microbes in sand-based turfgrass systems and they indicate that microbial numbers equal or exceed those of turf growing on various soils. Thus, one might expect that microbes in sand-based systems would behave like their counterparts in soil-grown turfs.

The major role of the bacteria and fungi is to decompose organic materials in the rootzone mix (or soil), including the cells of their recently dead microbial colleagues. It is precisely this turnover of root tissues and microbial cells that releases organically bound N and P as plant-available, inorganic ("mineral") forms. This so-called mineralization process is the essence of what soil microbial activity is all about. Yes, they do bring about other important processes, some beneficial and some detrimental, but their primary benefit is to decompose organic materials, make more microbial cells and synthesize some soil organic matter (humus) along the way. This is why we can use mulching mowers and return grass clippings and the nutrients in them back to the soil where they belong.

Algae and cyanobacteria occur in very small numbers unless a soil is kept overly moist. They can be a problem on closely mown turf, like putting greens, where they may form slick spots if they are not shaded out by the grass canopy. More often than not, they are only problematic in very wet soils. On the other hand, in arid soils they represent a source of new organic matter albeit a relatively small one.

Protozoa probably deserve more research attention in turf systems. Grass roots generally support abundant bacteria and that is where you'll find the protozoa. Soil protozoa are effective "grazers" of soil bacteria and other microbes. In fact, this may be their most important role. By eating bacteria, they not only keep a check on the size of the population but they speed up the rate at which nutrients locked up (immobilized) in those microbial cells are recycled (mineralized) for uptake by plants and other microbes.

Table 2. Numbers and biomass values for the major groups of microbes found in soil

Microbial Group	*Biomass (Wet wt. in lbs/ac; 6" depth)*	*Number per Gram of Soil*
Bacteria **Actinomycetes**	300-3,000 300-3,000	10 Million - 1 Billion
Fungi	500-5000	10 Million - 100 Million
Algae and Cyanobacteria	10-1500 (Bloom*)	100 - 1 Million (Bloom)
Protozoa	50-200	1000 - 100, 000
Viruses	???	10 Billion - 100 Billion

**A bloom is a visible overgrowth of algae on the soil surface.*
Alexander, 1977, Sylvia et al., 2005

How many are there; how much biomass?

There are countless microbes in soils and literally tons of microbial biomass in normal, healthy turfgrass systems, including sand-based systems. Grasslands have long been known to support large populations of soil microbes. Some figures for numerical abundance and microbial biomass of various microbial groups are listed in Table 2. For perspective, one gram of soil is about the size a kidney bean in the palm of your hand.

But what about numbers of microbes in intensively managed, sand-based, sports fields? Are the populations somehow compromised? Research suggests that the answer to this question is, No! Results from multi-year monitoring of microbial populations in sports fields at Texas A&M University showed that bacteria consistently number in the tens of millions (Log10 7.0 = 10 million; Log10 8.0 = 100 million) per gram of sand (Kyle Field, Soccer Field) or soil (Intramural Field) and fungi number in the tens to hundreds of thousands per gram.

The soccer field was first sampled just 2 weeks after washed Bermudagrass sod had been laid on an 11-inch base of pure sand with no organic amendments (peat). The sand used in construction of the field contained only 100,000 (Log10 5.0) bacteria per gram. Thus, we found that microbial numbers increased rapidly (10- to 100-fold) as the grass "grew in" and new roots of the washed sod were the primary source of microbes and the carbon sources to sustain them. Fluctuations did occur during the seasons and they appeared to be most associated with the moisture status of the fields when we collected samples.

However, we observed that populations remained high throughout the year and that they were similar in the sand-based and soil rootzones. We have found similar populations in common Bermudagrass with and without compost additions (15 or 90 tons per acre), sand-based putting greens under dwarf Bermudagrass varieties and even under common Bermudagrass treated with molasses at 16 times the suggested rate of the vendor.

I hope to dispel the notion that sports turf is "lacking soil microbes" and that microbial preparations (microbial inoculants, small amounts of carbon sources like molasses or sugar, etc.) are needed to restore them.

While the numbers of microbes in soil are no doubt impressive, it is the biomass (weight) of the microbes that truly indicates their abundance. Though not all soil microbes are actively growing at any given point in time, a large biomass indicates great potential for the many biochemical activities of the microbes under appropriate conditions for their growth! A healthy stand of grass can literally contain tons of soil microbes! Thus, we know that soils with large active populations do in fact mediate lots of beneficial processes in the soil.

We are only at the beginning of our understanding of the microbial biodiversity in soils and sand-based systems. Molecular biology research from the past two decades suggests there may be as many as 4000-13,000 species of bacteria in a single gram of soil. Moreover, we have managed to culture only a very small percentage of these in the lab. The challenges of understanding and harnessing this diversity are many but they must be understood in order to determine if we can actually manipulate soil microbial populations to our benefit under "real world" conditions!

What do soil microbes really do?

The fact is that they do all sorts of things in the soil when active, but mostly, they just "hang around" waiting for something to eat. Contrary to what some might think, soils are not seas of organic soup. Rather, they tend to be limiting in supplies of organic carbon to feed microbes and the competition for that carbon is fierce. This is one reason why the rhizosphere, the zone of soil immediately around a plant root, is such a "hot spot" for microbial growth. Roots, as it turns out, give off organic carbon in a variety of forms (sloughed cells, exudates, etc.) that are exploited by the nearby microbes.

WE ARE ONLY BEGINNING TO UNDERSTAND MICROBIAL BIODIVERSITY IN SOILS AND SAND-BASED SYSTEMS

So, one of the things that microbes do in soil is to reprocess these materials into available forms (i.e., mineralization) and into microbial cells and humus (recalcitrant, stable organic matter). They are also involved in many other processes too numerous to describe here in detail. For example, many soil bacteria can fix atmospheric nitrogen (N_2) in order to grow in areas where available soil N is scarce. Note, that I said where N is scarce! They're "smart enough" not to rely on N_2 fixation when soil N is sufficient because the process of biological N_2 fixation is energetically very "expensive" for them.

A common misconception is that one can apply small numbers of nitrogen-fixing bacteria to turfgrass and they will supply nitrogen for the plants. While some N_2 fixation might occur, it is unlikely that one could achieve a healthy stand of turfgrass on such miniscule amounts of nitrogen. Perhaps more likely than N_2 fixation in turfgrasses is the process of denitrification, the microbial conversion of plant-available nitrate to gases such as nitrous oxide (N_2O) and dinitrogen (N_2). This process occurs when soils become saturated and oxygen is depleted within the soil/sand matrix. Then, denitrifying bacteria convert the nitrate to gases that escape from the soil taking with them one of the most expensive turf management inputs, namely, fertilizer nitrogen.

These are just a few of the processes brought about by microbes in soil.

The discussion above about the abundance and functions of soil microbes leads us to the final question: What do you need to do for soil microbes?

This is probably the question that generates the most confusion among turfgrass managers as this is an area where I see a lot of information not based on the science of what we know about soil microbes. It is in answers to this question that we find much misinformation! A common misconception about soil microbes is that using synthetic fertilizers and other management inputs (pesticides, etc.) somehow kills the soil microbial population leading to "dead" or "sterile" soils. The Internet abounds with information (in some cases posted by well-meaning individuals and, in others, by persons selling miracle cures) that is just patently false! Take the following statement gleaned from the Internet for example:

"Chemical fertilizers will eventually destroy even the best soils by killing the beneficial organisms that plants rely on to gather nutrients and moisture. Growers are then forced to pour on larger and larger amounts of expensive petroleum-based fertilizers to maintain yields, but the overdoses create unbalanced "dead soil." (Anon.) A recent search of the World Wide Web for the term "dead soil" returned 96,000 hits.

While it is true that fertilizers may inflict some harm on microbes directly exposed to granules or to anhydrous ammonia, the overall effect of fertilizer applications is to markedly increase microbial numbers and activity in soil through increased plant growth. We have known this for decades! As I mentioned earlier, the majority of soil microbes require organic carbon to grow and produce new cells. In grass systems, the vast majority of organic matter is produced from decomposing roots and leaves. Fertilization increases the amount of organic substrates available to soil microbes by increasing its source, the grass plants themselves. Thus, rather than producing "dead soil," judicious use of fertilizers invigorates soil microbes by allowing plants to produce more resources for them!

Remember though, all management inputs must be used carefully and correctly. Too much of a good thing can produce negative consequences. Excessive fertilizer applications will likely lead to enhanced runoff and leaching and the undesirable environmental consequences that go with those processes.

So, do you need to add "beneficial microbes" to the soil to make it function properly? That's highly unlikely. Many studies of turfgrasses, whether in sports fields, golf courses or home lawns, have shown that soil microbial populations are not compromised by normal management practices. The best thing that you can do to "manage" the soil microbes under your care is to grow a healthy stand of turf and pay close attention to the condition of the soil or rootzone supporting it. Paying attention to the agronomics of grass culture, fertilization, aerification, drainage, etc., will insure that the microbial populations are not being adversely affected. ST

David A. Zuberer, Ph.D., is with the Department of Soil and Crop Sciences, Texas A&M University, College Station, TX. He can be reached at d-zuberer@ag.tamu.edu.