THE IMPORTANCE OF AERATION

Philip Threadgold looks at the important research work into aeration carried out by Dr Donald McGregor, at Royal Holloway College.

FEATURE

Most of us take for granted the quality of the air we breathe and that oxygen is critical to the maintenance of life on this planet. What fewer people realise is that oxygen and CO^2 are also critical to life in the soil.

Scientists have long regarded the soil as a "black box" into which it was best not to peer too closely. However, modern analytical techniques have opened up this world and enabled us to understand the processes that govern life in the soil.

The predominant life forms in soil are microbes; bacteria and fungi that break down dead plant and animal material and recycle the nutrients making them available to plants. These beneficial microbes also require oxygen to grow, and a build up of CO^2 is detrimental to them too. Without soil microbes, life above ground would not exist.

However, soil is a physical structure, consisting of aggregates, with air or water-filled spaces between them in which most of the microbes live. Any soil can become compacted by pressure imposed by human feet or machinery, meaning that the spaces between the aggregates become fewer, gaseous exchange with the atmosphere is reduced and oxygen content decreased. If this happens, the microbial population will suffer and, subsequently, the above ground community will too.

In sports turf, compaction is a frequent occurrence and machines, such as the Verti-Drain, have been developed to open up a compacted soil, to allow oxygen and water to enter it and CO^2 to leave. No previous study has ever asked about the consequences of aeration for the microbial community. Here we examined how aeration can affect soil microbes, using cutting-edge analytical techniques.

A hidden world beneath the surface

That grey zone where the worlds of turf grass cultivation and microbiology intersect is an intriguing region about which swirls a confusing amalgamation of facts, half-truths, and downright speculation.

Aeration is certainly one of the most common cultivation practices. In this area of study, the research work of Dr Donald J. McGregor, conducted at the Royal Holloway campus of the University of London, breaks new ground in establishing a greater level of understanding. According to Dr McGregor, there is much that we simply don't know about microbes and their interactions with plants and other living things in the soil. This complex set of biological processes make up what he calls "the hidden world" beneath the surface.

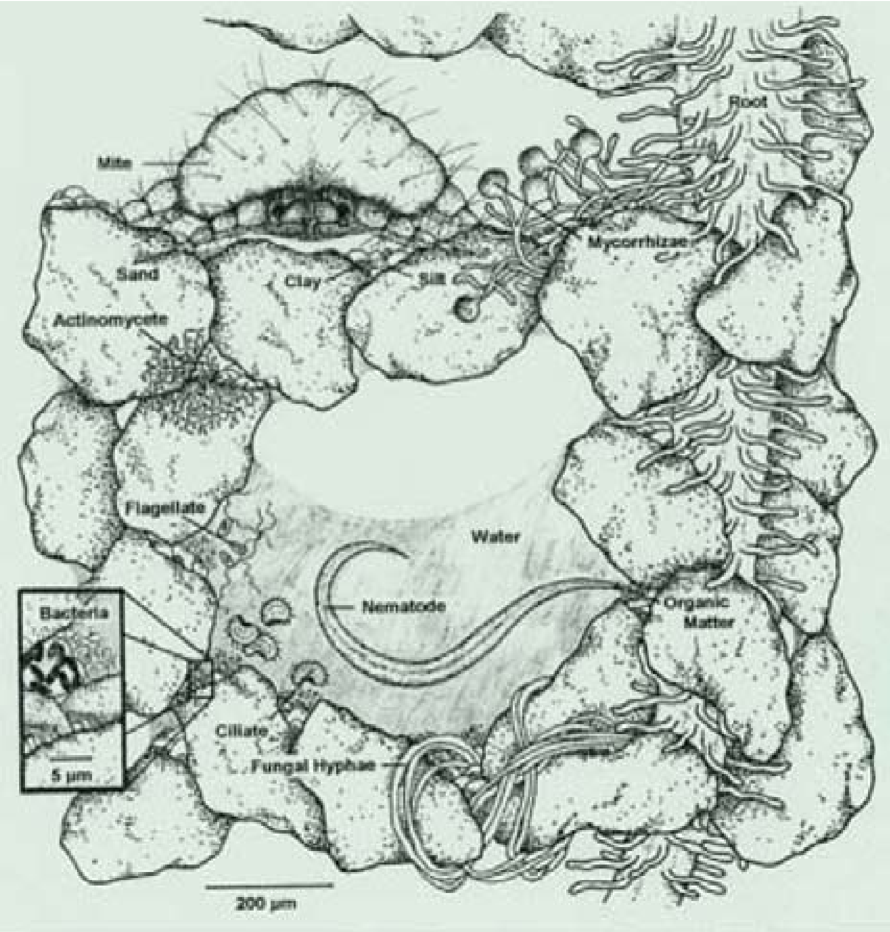
Just a few years ago, it was impossible for aeration equipment manufacturers – and their customers – to know how effective their products were without understanding the composition of microbial communities in the soil around the turf grass. The research work at Royal Holloway marks a turning point in that regard.

In a very real sense, microbes are a turf manager's best friends.

"Microbes are the foundation of everything we see around us; without them we would not exist," claims Dr McGregor.

"If anything goes wrong in the environment, the microbes are an early indicator. They will show subtle changes before anything else."

Anyone with an interest in healthy turf grass is familiar with the basic processes that make up what we'll call the soil habitat. What biologists are discovering, however, is that this habitat is ful of surprises. Did you know, for example, that the characteristic "fresh smell" we've all sniffed right after it rains is the scent of chemical secretions from mysterious microbes called actinomycetes,



A pictorial representation by Kim Luoma

organisms that seem to be halfway between bacteria and fungi? Even today, no one is sure exactly what these microbes do. One thing we are sure of, when it comes to microbes, is that some are aerobic and others are anaerobic, and that only the aerobic ones show a strong benefit to turf grass.

But microbes are only part of the picture. They exist in the soil structure right alongside earthworms, organic matter, plant roots and other living and once-living things – the so-called "biota" in the soil. Within this biota we find incredible diversity – aerobic and anaerobic, acidic and basic, wet and dry, and the list goes on. This diversity – and the interdependence of the life forms involved – is the very core of understanding this soil habitat. It is the interactions of these elements that influence all aspects of turfgrass health, and which have a strong relationship with practices like aeration.

When you stop to consider what microbes are capable of, in a biological sense, the effect is mind-boggling:

- Enhancement of plant growth
- Enhancement of drought resistance
- Disease protection
- Reduced need for fertilisers
- Control of Poa annua without using chemicals

And those examples are just biological. Microbes do even more when you examine their roles in the chemical and physical processes of the soil habitat:

- Breakdown of organic compounds
- Breakdown of cellulose and lignin
- Formation of humus
- Soil stabilisation
- Nutrient cycling
- Nitrogen fixation

It's fascinating to contemplate that all this activity is going on beneath the surface but let's not forget that the appearance of the turf plants is also affected. In fact, it is the highly visible condition of the grass, whether it appears healthy or unhealthy, that gives an indication of a healthy and productive soil habitat – or the lack of it.

The complex interdependent concept of the 'soil habitat' provides a scientifically useful basis for turfcare professionals seeking answers to cultivation challenges.

Aeration isn't new. For most of this century, mankind has been poking holes in the soil based on the belief that it helped the grass grow.

Aeration is really the technique, not the machine, and there are a great many ways to aerate, each with its own advantages and disadvantages. What turf professionals have known for years is that machines like the Verti-Drain work, but no one could provide the scientific reason why.

Clearly, aeration was a popular cultivation practice, but how rooted was it in biological processes? When a Verti-Drain tine breaks the soil surface, penetrates down to a desired depth, and performs its "heaving" motion, what is happening from a biological standpoint, and how and why does that affect turf health?

Dr Alan Gange and Dr Donald J. McGregor

This dilemma recently attracted the attention of the academic community, specifically Dr Alan Gange and Dr McGregor at Royal Holloway, where the Department of Biological Sciences sees some 40 faculty members and 400 students routinely explore timely issues in biology, ecology, zoology, biochemistry, and molecular biology.

While Royal Holloway isn't the first institution to delve into research on microbial activity, it has taken on the task with a rather unique twist. Rather than simply counting the number of microbes in the soil, their research involved analysing the composition of the soil's microbial community – exploring in the process whether or not aeration had an effect on that community, in particular, the "good" aerobic microbes with the potential to benefit turf plant growth.

"I've given lots of turf talks in the past, usually on environmentally friendly products which are designed to increase microbial populations," noted Dr Gange.

"What really caught my attention was when people told me that many of these were not all that effective. It led me to believe that one could probably get the same effect, increasing the

Verti- Drain

good microbes in the soil, by simply aerating it. So I approached Redexim Charterhouse, to see if they were interested in helping us determine if that statement were true."

According to Dr Gange, this is the only study done that attempts to link aeration to the numbers and diversity of the microbial community in the soil.

"Ecologists couldn't look at the diversity of the microbes before because the technologies were not really available until the last few years," he said.

"So, we've had 10 years of just counting the numbers of microbes without anyone profiling the composition of that community in the soil. And no one's made the connection to aeration before."

While Dr Gange may have started the ball rolling, it was Dr McGregor who chose to do the research for his thesis "The Effect of Cultivation on Microbial Communities in Sports Turf Soils". The research experiment took three years to complete and nearly six months to analyse and write up.

Beneath the surface

Anatomy of an experiment: Aeration and Microbes

With some assistance from Dr Gange, Dr McGregor conducted two trials: one on two clay-based football fields at the school, and the other at the sand based turf at Liphook Golf Club, in Hampshire.

Feeling a little like an "environmental detective", Dr McGregor designed the experiment in a way that entailed dividing the football pitches into individual plots, some of which were aerated while others were not.

"These were pitches that were used by the college football team on a regular basis, and so were subjected to normal or above-normal real world stresses, like any other sports turf," he said.

He added a degree of complexity by aerating at certain times of the year.

"Some areas were aerated in spring only, others in summer only, autumn only, winter only, while other plots were aerated in all four seasons," he said.

A control group of plots on the football pitches were not aerated at all.

Like the football pitches, the test area at Liphook was divided into individual plots, with each one coded for a schedule of aeration at different times of the year.

A comprehensive series of measurements were then taken – of pH, water content, gas content, atmosphere, compaction, and make up of the microbial population and community structure – on all the plots at regular intervals before and after aeration, the exact timing of which depended on the technique and the weather conditions.

Soil samples were taken and returned to the lab at Royal Holloway for analysis. Some tests were done in the field, including those measuring the degree of compaction with a penetrometer.

Static and dynamic changes

According to Dr Gange, a variety of soil properties were constantly exerting varying degrees of influence on the soil microbial community, and the turf grass.

Some of the properties were inherent to the soil such as: texture (clay, sand, etc.), pH level, and other things relating to the physics of the soil. Other soil properties were dynamic in nature including: gas content, water content, and the most dynamic of all, compaction.

"You get compaction, you aerate to relieve it, and then it's played on and gets compacted again," notes Dr McGregor.

Key findings

Among the factors that influence microbial activity in the soil are: temperature, water, and oxygen – all of which exerted transient changes on the microbial community.

The importance of water and oxygen in influencing microbial communities bears out the value of compaction relief through aeration. In this experiment, there are a number of benefits that were found to have a direct connection to the use of the Verti-Drain for turfgrass aeration -

Soil Physical Characteristics: The effects on the soil are the most significant result of the treatment, where it reduces compaction in all seasons on both clay and sand-based sports turf, and significantly improves oxygen levels.

Microbial Structure: Microbial community structure is affected by treatment, but the strength of the response is season dependent and qualitative in nature. The main effect of the aeration was to change the microbial community structure in favour of more aerobic microbial groups, a factor that is believed to have a profound influence on organic matter dynamics and nutrient supply in sports turf soils.

Aesthetic Characteristics: Changes in the soil and in the microbial structure also yield improvements in appearance. In this era of televised golf and football games, the visual appeal of the sports turf is often the target of commentary, and viewed as a key indicator of the health and condition of the turf.

Dr Gange stresses that oxygen is a huge consideration, in that unchecked compaction will prevent root growth by causing a shortage of oxygen in the soil and preventing it from being able to filter water down to the root zone.

"Once a root zone becomes anaerobic, anaerobic bacteria will flourish, and generally they are toxic to plant life," he says.

Dr McGregor believes that the key is the prevalence of macropores versus micropores.

"The larger the size of the pores, the more 'connectivity' between pores and the greater the ability of the soil to permit gas exchange and water percolation. This may be the real reason why aeration works in a beneficial way in microbial communities," says Dr McGregor.

"These larger pores also help prevent run-off of water and make irrigation more efficient."

Clays, which have more micropores and fewer macropores, tend to have more physical barriers set up in the soil structure that may prevent bacteria from getting to the organic matter to degrade it.

"When you Verti-Drain you're loosening up the soil so you encourage this connectivity of pores," he adds. Also, clay soils require a greater frequency of aeration than sand based soils.

In the experiment, oxygen concentrations varied from area to area – likely because pore size and connectivity differed from one area to another. And from season to season, oxygen varied because of differences in the biota, including roots, earthworms, bacteria, and other life forms. It is this interconnectedness that reinforces the concept of "soil habitat" to explain the dynamic aspect of such interactions.

"This experiment indicates that encouraging development of microbial communities, particularly aerobic ones, is in the best interest of the average turf plant. Aerobic microbes are more metabolically productive.

"The chemical reaction that goes on within the respiration system of an aerobic microbe creates more energy, whereas an anaerobic microbe does not use oxygen and cannot achieve the same level of efficiency. The soil habitat is literally a healthier one with such an enriched energy budget," said Dr McGregor.

The greater the number of aerobic microbes in the community, the greater the level of biological processes: decomposition and nutrient cycling go hand in hand with remineralisation.

"Enhancement of plant growth is also going on, and it can be either direct or indirect," Dr McGregor says.

"And the natural competition between microbes, aerobic versus anaerobic, can have a useful effect against pathogens that could harm turf plants, since some microbes in the soil produce antibiotics that are antagonistic to the pathogens."

One of the most important findings of Dr McGregor's work is the revelation of the transient benefits of the Verti-Drain on microbial communities.

"The benefit doesn't last when compaction returns. Sports turf is subject to compaction on an ongoing basis, and so the benefits of aeration are only sustainable when the activity is routinely repeated. Without it, microbes can go into a kind of hibernation if they are deprived of the necessary access to oxygen and water."

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About the Author

Philip Threadgold is a director of Astute Consultancy Ltd.

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