

FDI Feature Interview

19th April 2016

The Importance of Understanding the Role of Soil Microbiological Ecosystems: Dr Peter Keating

Key Points

Healthy soils contain complex ecosystems that contain many species, including highly diverse populations of microorganisms.

The rhizosphere is the narrow region of soil directly associated with plant roots and the accompanying microbiological ecosystem.

Microorganisms living in the rhizosphere are functionally important to plants.

Species-rich soil ecosystems with many interactions are more stable than soils with degraded soil ecosystems.

A general awareness of the importance of diverse soil ecosystems is still in much need of improvement.

Introduction

The terms microorganisms or microbes refer to the vast range of living organisms that are too small to be visible to the naked eye. They include, but are not limited to, bacteria, some types of fungi and viruses. Microbes can be found in all parts of our planet where life is possible. The study of microorganisms is called microbiology.

The importance of microbes in soil is fundamental. Without them life on the planet would not be possible. Microbes play essential roles in maintaining soil fertility through recycling nutrients and influencing their availability to plants, improving soil structure, supporting healthy plant growth and degrading organic pollutants. The functions and processes microbes perform or facilitate in our soil are incredibly complex and there are still significant gaps in our understanding of soil ecosystems. Filling these gaps presents a major challenge for the scientific community and for pastoral, agricultural and horticultural producers and land carers.

Until relatively recently science did not have the tools to research and fully appreciate the scale and complexity of microbiological activity in soil. Advancements in DNA technology, however, are now progressing research into the enormous biodiversity and complex ecology of soil microbial ecosystems.

Dr. Peter Keating, Managing Director of the Australian company, Bioscience, believes that understanding and maintaining the health of soils can provide the agricultural and horticultural industries with a foundation for sustainable practices and increased productivity. Dr Keating and his staff believe their approach is unique and holistic, taking into consideration the structural, chemical and biological properties of soil to build an integrated, soil fertility picture. The Bioscience laboratories in Forrestdale, Western Australia, are equipped to undertake the full range of analyses. They have invested in leading edge technologies to focus research on the link between soil microbiology, soil carbon and plant productivity, while retaining traditional methods of soil nutritional profiling, structural testing and microbiology analysis.

FDI has taken the opportunity to interview Dr Keating on the topic of soil microbiology, soil microbiological ecosystems and his research into the analysis and maintenance of healthy soils and soil biological fertility.

Commentary

FDI: What is soil Microbiology?

PK: Soil microbiology refers to the study of microscopic organisms that populate the soil. These microorganisms include bacteria, fungi, algae, protozoa and viruses. Each of these groups has different characteristics and carries out different activities in the soil it lives in. Importantly, these organisms do not exist in isolation; they interact with their living and non-living environment and these interactions influence soil fertility as much or more than the activity of a single species.



Figure 1. A section of one of the Bioscience laboratories at Forrestdale, Western Australia.

Source: <http://www.biosciencewa.com> .

I prefer, however, to discuss soil microbiology as a component of broader soil ecology which aims to understand the role played by organisms in a community and the abundance and

distribution of those organisms. Ecology is defined as a branch of biology that deals with the relations of organisms to one another and to their physical surroundings.

An ecosystem is defined as a biological community of interacting organisms and their physical environment. It is important to note that healthy soils contain complex ecosystems with highly diverse populations of microbes. For example, recent research estimates that one gram of a typical soil sample contains 10,000 species of bacteria or 10^{10} bacterial cells per square centimetre. These species-rich soil ecosystems contain many interactions and are more stable than those soils with less diverse ecosystems. They are also more resilient to environmental change. This stability occurs because a diverse community will contain species that are similar but not identical in both their requirements and their effects.

Soil microbes usually occupy subtly different habitats within the soil. Some bacteria even have resistant spores that can remain in soil for long periods, while waiting for a burst of food availability. When conditions become suitable, the number of microbes that can consume available food will grow rapidly. Soil conditions can be highly dynamic and at times volatile, and changes in conditions can be aggressive or even hostile to microbe populations. In healthy soils, with large numbers of species types, there is a far greater likelihood of essential microbial roles being maintained by replacement species when environmental conditions change.

Some microbes, bacteria in particular, have the capacity to communicate with each other by a process known as quorum sensing whereby a population of microbes is able to coordinate behaviour in response to changes in the environment. As environmental conditions often change rapidly, bacteria need to respond quickly in order to survive. These responses include adaptation to availability of nutrients, defence against other microorganisms which may compete for the same nutrients and the avoidance of toxic substances.

The latest research techniques are allowing us to discover soil microbes that could not previously be studied. As a result, light is being shed on the complexity of the interactions and the essential functions performed by them.

The unique soil microbial ecosystem associated with the immediate vicinity of plant roots is called the rhizosphere. The rhizosphere is the narrow region of soil that is directly influenced by the roots and associated soil organisms. Soil which is not part of the rhizosphere is known as bulk soil. Plant rhizosphere soil contains a very different community of bacteria and fungi compared to bulk soil. Many rhizosphere bacteria require living plants to survive and reproduce, whereas many rhizosphere fungi live in mutually beneficial association with plant roots. Plant and microbial relationships and processes enable and enhance plants to manufacture chemicals that reduce damage and increase resistance to pests, diseases or environmental stress. Protozoa and nematodes that graze on bacteria are also more abundant in the rhizosphere. Thus, much of the nutrient cycling and disease suppression needed by plants occurs in the region immediately adjacent to roots.

FDI: What role does microbiology, soil ecology and soil ecosystems play in providing healthy, sustainable agriculture?

PK: A healthy, fully functioning soil, now and in the future, is a key to maintaining sustainable food production. Soil microbiological ecosystems either preform or facilitate a number of key cycles such as the nitrogen, water and carbon cycles. That said, all of the activities and interactions described above are just as important for agricultural plants as in any other environment. It could be argued that the understanding of the agricultural system is more important but also more difficult as it is inherently more disruptive than natural ecosystems.

Agricultural production aims to reduce the number of plant and animal species down to those that directly or indirectly contribute to crop productivity. It is important not to do the same to the microbial community in the soils supporting that agriculture. Unfortunately, some agricultural practices are not conducive to the maintenance of high levels of biodiversity and active ecosystems. Agricultural soil problems such as acidity, structural decline, salinity and erosion which, in themselves will reduce agricultural productivity can also adversely influence the biodiversity of microbes. In agricultural practice it would be ideal if the impact of a management practice to produce a commercial product was to be considered in parallel with its capacity to maintain and/or increase soil biological fertility.



Figure 2. Image of the root zone or rhizosphere which contains a unique microbiological ecosystem associated with plant roots. Source: www.biosciencewa.com .

The relationship between the size, diversity and activity of microbial populations and soil 'quality' is unclear. It is also unclear how these relationships fluctuate through the seasons, with crop rotations, and the scale (temporal, spatial) on which they vary. As a result, it is difficult to predict the effects changes in agricultural practice, land use, climate change, and the

introduction of novel plants, microbial inoculants and pollution will have on soil quality. As discussed above, a single group of microbes is unlikely to perform with maximum efficiency under all these circumstances or conditions. A genetically diverse population, therefore, is needed to provide continuation of critical and important soil processes.

As an aside, one thing my research experience into soil microbiological ecosystems has shown me is the pointlessness of trying to control individual species. It is very difficult to selectively eradicate or promote an individual species of microbe. Efforts will usually either fail or damage the health of the system by adversely affecting beneficial species as well. The greatest benefit can be gained by ensuring the soil provides the best possible environment for all beneficial microbial life to thrive and which will in turn control harmful microbes. Plant pathogenic microbes as well as harmful and parasitic microbes will be controlled by responses in the ecosystem. This is not to say that benefits cannot be achieved by microbe inoculation. We have achieved beneficial results through direct seed inoculation at planting.

FDI: How can microbial diversity be measured, analysed and studied?

PK: The latest genetic analysis techniques are allowing us to discover soil microbial life that could not previously be studied and, in some cases, we are identifying species that we didn't even know were present and active in the soil. The first DNA profiling of soil microbiology was only conducted in 2007, and we have been doing it here at Bioscience for about five years. I believe that Bioscience was the first commercial laboratory in Australia to offer soil DNA analysis. Up until that time it was difficult to study soil microbes that could not be grown in the laboratory. The range of bacteria, for example, that will grow in the laboratory is relatively small and the same can be said of other microbe types, such as fungi. As stated previously, many only survive in the rhizosphere. Soil DNA analysis is providing a much better insight into microbiological activity and diversity. It also provides a good indication as to which members are dominant at the time of sampling.

Using a systematic approach, we have developed analytical methods which provide rich information on how soil biology changes in space and time, and how this influences plant productivity. We archive all of the soil DNA we have extracted, and we now possess one of Australia's largest collections. The majority of our samples come from farms, where the history of crop productivity and soil chemistry is recorded, but we can compare it to a wide range of natural and pristine environments, and to paddocks which have problems like disease, acidity or water repellent soils.

At Bioscience we have invested in state of the art DNA technology to investigate soils. An important insight gained from this approach is recognising the enormous biodiversity of soil microbes, and the huge part they play in Earth ecosystems. The genetic potential of soils was long known to medicine, where so many important drugs were discovered and which, once understood and developed, prolonged life. Finding a vast new extent to the domain of soil biology creates a new challenge.

Bioscience is not daunted by this challenge. Our leading scientists have more than 50 years of combined experience in soil and life sciences using DNA methods and other advanced

technology. Our approach relies on the well-established principles of ecology to focus on the dynamics of the system rather than on individual players.

FDI: How well is this understood by the farming community, soil scientists, policy makers and academic institutes?

PK: Unfortunately, I don't believe the importance of soil microbes making healthy biological ecosystems is widely understood and appreciated. Although more farmers understand the significance of a particular organisms, there are many aspects of soil biological fertility we still do not understand. The field has been under researched and the research that has been conducted has tended to focus on harmful microbes rather than the overwhelming benefits of healthy soil biological ecosystems and how to maintain them in agricultural production. Science is often not adept at communicating important finding beyond the scientific community. As a result, primary producers have had to make decisions based upon experience and instinct which have been the foundation of many very successful agricultural properties but may also have unforeseen, long-term sustainability problems. The key will be the demonstration of production improvements over the long-term.

FDI: What can be done to improve this understanding?

PK: My experience is that once we have established the integrity of what we are saying, we need to engage those professionals whose business it is to communicate: marketers, journalists and educators. The facilitation of the communication is possibly best managed by private enterprise and government. The former, with the aim of conducting good business, while the later, is responsible for the sustained management of a strong agriculture industry and the environment. When we combine sound scientific knowledge, with good business practice and the determination to responsibly manage the environment for future generations, then genuine change for the better can be achieved.



About the Interviewee: Dr Peter Keating has over 25 years of practical experience as a commercial scientist in a vast spread of biological, chemical and engineering applications, as well as maintaining a career as research scientist and inventor. He has extensive knowledge of Western Australia's flora, fauna, waterbodies, aquifers and geology as well as the state and federal regulatory framework.

Any opinions or views expressed in this paper are those of the individual interviewee, unless stated to be those of Future Directions International.

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