BY PETER KONJOIAN AND COLIN BELL

Harnessing Soil Microbes:
Past, Present and Future


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Colin Bell is co-founder, co-inventor, and chief growth officer of Growcentia, parent company of Mammoth Microbes, Ft. Collins, Colorado. Colin completed his Ph.D. in Soil Microbial Ecology in 2009 and took a research scientist position at Colorado State University. His academic publications focus on microbial mediated processes that enhance plant growth. Colin left CSU in 2015 to launch Mammoth, an ag-tech company that develops microbial biostimulants to sustainably increase plant yield and all-natural biocontrol products to prevent pests.

Peter: Colin, thanks for joining me today to discuss this topic. Tell us where our current level of knowledge of soil microbes stands and about your research contribution.

Colin: To understand what we know about plant-microbial interactions, it is helpful to think about the beginning of life on Earth: Plants have co-evolved with soil microbes over hundreds of millions of years. As bacteria colonized Earth and transformed the atmosphere over three billion years ago, they created conditions which made it possible for the evolution of soil fungi 900 million years ago. Together, bacteria and fungi shaped Earth's soil structure and created habitable conditions for the evolution of plants around 700 million years ago.

Overall, soil microbes are commonly thought of as ubiquitous (i.e., everywhere). In a more practical framework, we accept that many of the known microbial groups are present in most terrestrial environments. My academic research included long-term multidisciplinary studies in which biological, chemical, and physical characteristics of soils were measured to elucidate soil microbial and plant responses to climate variability. My current research is focused on plant-microbial relationships within the rhizosphere zone to identify mechanisms that may influence soil microbial taxonomic and functional differences among plant species.

Peter: Okay, soil bacteria came first, then soil fungi followed. After they evolved, the soil became hospitable to plants. It sounds like these microbes may have been taken for granted because of their ubiquitous presence for a long time. Now that research is asking and answering questions about their role in the plant world, what have we learned?

Colin: Soils are abundant with microbial life. For example, there are more microbes in 1 gram of soil than there are people on the Earth! This is important because these tiny soil microbes play a huge role in supporting plant growth. We now understand that bacterial and fungal species work together in clusters (consortia) to support plant growth along the rhizosphere (soil root zone) primarily by delivering nutrients and preventing disease. Soil bacteria and fungi continually increase soil nutrient availability by transforming unavailable nutrients into bioavailable forms for plant uptake.

Soil microbes also can act as a biofertilizer. When microbes die, they release their cellular constituents into the environment, which serve as rich organic nutrients for plant uptake. In nature, plants wouldn't have enough nutrients to grow without the help of soil microbes. Beyond nutrient cycling, microbes produce hormones and other biochemicals to stimulate plant growth. Soil microbes also can prevent pathogen infection by inducing plant systemic disease resistance and by coating root surfaces to physically shield the plant from infection by pathogens.

Peter: Appreciating the complexity of these relationships helps me understand why a number of projects I've worked on with products claiming to enhance crop performance failed to produce consistent results. Applying a single bacterium or fungus to a system is likely to be influenced by the complexity of the soil environment. How are you addressing the consistency versus complexity challenge?

Colin: Growcentia is devoted to developing very effective natural microbial solutions to bring results that enhance plant yield and nutritional value across many crops. My academic specialty in environmental microbiology was focused on understanding the importance of plant microbial interactions in both natural and agriculture environments. Our first technology was developed while I was at CSU. Likewise, we used our deep understanding of soil microbial functionality and how it effectively supports plant success to develop a microbial technology that bridged the gap between nature and agriculture.

Peter: Aha … bridging the nature to agriculture gap. That brings to mind a comment I made 20 years ago while researching ethephon (ethylene) as a plant growth regulator. As we learned how to harness this hormone to stimulate branching and control flowering of ornamental crops, I felt that future reflection would label the work's single hormone focus as quite crude after we eventually learn how all plant hormones interact in their natural setting. A similar consortium to what you describe and a perfect example of how research uncovers simple, main effects before unraveling complex interactions one step at a time.

Colin: That's a great point, Peter, and the reason we developed a patented microbial trait selection platform that allowed us to develop a functionally targeted microbial consortia while optimizing microbial efficacy. This technology maximizes plant performance by targeting specific nutrient cycling functions while optimizing efficacy to achieve extended shelf life and compatibility across many different management practices and crop types. We ultimately patented and licensed the technology from CSU and I left the university to start Growcentia in 2015.

> "Using microbial technologies will ultimately allow farmers to reduce fertilizer applications while maximizing crop yields."

Peter: You state that the challenge lies in developing the right research tools and techniques to find the right microbe combinations. For the benefit of growers who have tried this category of products, tell us more about how our current level of knowledge explains their success or failure.

Colin: Historically, the two major challenges that farmers have experienced while using microbial technologies in their management practices relate to inconsistent performance (effectiveness) and poor efficacy (short shelf life and/or constrained usage tied to specific crops and soil types). This often makes it difficult for a broad range of farmers to validate a positive return on investment for adopting microbial solutions into their practices.

We believe soil microbes can solve many of the current real-world challenges that farmers face in agriculture production. One of the biggest challenges the agriculture industry faces is delivering adequate nutrients to plants to maximize plant growth without over fertilizing soils, which can have negative environmental impacts.

For example, up to 70% of phosphorus (P) applied to soil can become almost immediately unavailable for plant uptake due to natural chemical binding and chemical transformations inherent with the PO_4 molecule. In practice, most growers apply excessive P fertilizer to soils and growth media in order to deliver ample P for plant growth. Over time, once the soils become chemically saturated by the P build up, the excessive soil P load leaches into the groundwater and ultimately represents a source of environmental contamination.

Likewise, many published scientific studies have cited that using soil microbes as soil additives can help farmers reduce soil fertilizer inputs by maximizing nutrient bioavailability and thus maximizing nutrient use efficiency, allowing the plants to effectively take up the majority of nutrients applied to the soil. Soil microbes can accomplish this through their ability to naturally unlock bound soil nutrients, transforming nutrients back into plant available forms, maximizing soil nutrient availability to significantly increase plant nutrient uptake. This simple function that microbes facilitate can maximize plant growth, quality and yield.

Peter: Your comments on nature's complexity could fill this conversation. At the risk of oversimplifying regarding phosphorus, consider that my father's generation of greenhouse growers used 20-20-20 as their base fertilizer. My base formulation today is 13-2-13 … wow.

Next, what does the future hold for a plant microbe specialist?

Colin: The future success of agriculture production will likely depend on precision biological solutions that sustainably maximize plant growth and yield. Although chemical fertilizers have been a vital component of the first green revolution, which enhanced crop productivity beyond any historical precedence, we are now facing a shifting paradigm in agriculture that suggests that chemical fertilizers are failing us. This is not because fertilizers don't work — they do. Rather, the paradigm shift is challenging the way we think about using chemical fertilizers and stems from information learned since the widespread adoption of chemical fertilizers during the green revolution of the 1950s.

There are three prevailing points to support how microbial technologies will start to displace chemical fertilizers:

1) Fertilizers bind in soils and are very inefficient to deliver to plants and microbes help release soil nutrient sorption.
2) There is only so much fertilizer any plant can use before farmers realize diminishing returns … you simply cannot keep adding fertilizer to induce more plant growth — there is a threshold that is realized. Soil microbes engage with plant roots to stimulate plant physiology and metabolism. Likewise, plants are able to take up more nutrients with microbial applications.
3) The long-term use of chemical fertilizers has been clearly shown to significantly reduce natural soil health, thus diminishing the potential of soil (physical and chemical structure along with soil biology constituents) to support plant growth.

Using soil microbes serves many functions. Besides adding lost carbon back to the soil, microbes function as catalysts to cycle nutrients to maximize their bioavailability for plant uptake. Using microbial technologies will ultimately allow farmers to reduce fertilizer applications while maximizing crop yields — thus maximizing crop nutrient use efficiency. Functionally targeted microbial inoculants represent next-generation green revolution technologies, which will help farmers increase crop production to meet the impending increase in the global food demand, which is currently predicted to surpass current global food production capacities by 2050.

Peter: How soil microbes fit into hydroponic culture is next but we're out of space. Until I get you back for a full discussion, please point us in the right direction with a brief introduction.

Colin: Well, Peter, one challenge when using soil microbes in true hydroponic systems is that not all terrestrial microbes have evolved to thrive in the extreme aquatic environments. When developing our first technology at CSU, we found that out of over 10,000 species collected and identified from natural and agriculture soils across the country, 1:2000 were suitable to persist and function at a high level in hydroponic environments. This simply means that as applied scientists, it is our job to select the RIGHT microbes for the job so they will work optimally for the environment in which they are being applied. Definitely a discussion to be continued.

Peter: Thank you very much for sharing your knowledge with us, Colin. gpn