Quorum Sensing in the Soil Microbiome

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In human society, a **quorum** is the number of members of an organisation that must be present in order for decisions to be made or any business to be transacted. In the microbial world, the term **quorum sensing (QS)** refers to **density dependent coordinated behaviour** that regulates gene expression in the microbial population and/or in the host plant or animal.

Quorum sensing was first described in the 1960s in relation to the expression of bioluminescence in the marine bacterium *Vibrio fischeri.* When free-living in the ocean, *V. fischeri* is non-luminescent, but when populations reach a critical population density they 'shine' ... but only in the dark. The bacteria know 'how many' of them there are - and they also know it's dark. The latter is fair enough, but the former is intriguing.

When the activation of bioluminescence in marine bacteria was first discovered it was thought to be a quaint peculiarity - something novel - but of no great significance. However, in the last decade, research into quorum sensing has grown exponentially. It is now recognised that quorum sensing is utilised by all microbes in all habitats - in water, on land, in plants, on plants, in the soil and in animals and humans.

Microbes can't see, think, or hear. Instead, they communicate using chemical signals, called auto-inducers, to coordinate their behaviour. All bacteria - and fungi - and viruses - have the capacity to know how many others are in their vicinity - both of their own species and of other species. There's also inter-kingdom signalling, whereby microbes not only know how many others of their own kingdom are close by, but also how many living things from other kingdoms are present.

It is well known that ants and bees and other social insects use signals to communicate. A single bee behaves very differently to a colony of bees. The 'decisions' made by the colony are made collectively and cooperatively. Similarly, a single bacterium behaves very differently to a colony of bacteria. And even a colony of one kind of bacteria behaves very differently when it is the only colony - compared to when there are multiple colonies of many kinds of bacteria. Throw fungi and archaea and viruses into the pot and these voiceless millions can achieve awesome outcomes. It's all about getting their collective act together. Once the soil microbial community begins to function as a coordinated 'super-organism' (not unlike a colony of bees) it can perform tasks that individual microbes cannot achieve alone.

By detecting biochemical signals, soil microbes can determine how many different kinds of plants are growing in a particular soil. Once the diversity of plants and hence the diversity of functional groups of microbes reaches a certain threshold - or 'quorum' - everything changes. The lights come on, not

unlike the bioluminescent marine bacteria that suddenly 'shine brightly' in a dark ocean.

Quorum sensing in the soil microbiome enables multi-species crops and pastures to function more effectively than monocultures. Researchers have long known that there's more than physical complementarity involved - but until recently have not been able to determine the 'other factors'.

Quorum sensing also helps explain how biostimulants improve plant health, even at very low concentrations (indeed, the lower the better, it seems). Effects are more pronounced when two or three different types of biostimulant are combined, at one half to one third the recommended rate. The multitude of biochemical signals mimic plant and microbial diversity, resulting in the production of growth stimulating and plant protection hormones.

Current research is providing fascinating insights into how quorum sensing underpins the virulence and pathogenicity of disease-causing organisms. The good news is that once the configuration of the signals produced by pathogens has been determined, they can be scrambled and rendered ineffective by a process termed ‘quorum quenching’ (QQ). Quorum quenching is proving to be more effective than antibiotics and fungicides, which kill everything, good or bad.

In soils, both QS and QQ are important for the function and resilience of plant communities, not only in the face of biotic stresses (eg pests and diseases) but also in regards to promoting health, abundance and resilience in the face of abiotic stress (such as drought, frost and nutrient deficiencies).

There is much to be gained by applying our understanding of quorum sensing in the agricultural space. Quorum sensing and inter-kingdom signalling are the only processes that adequately explain the extraordinary results we see (such as abundant nutrient availability and enhanced drought tolerance) once plant diversity - and hence microbial diversity - reach a critical threshold, or tipping point. Quorum sensing also underpins the beneficial soil health effects associated with yearlong living groundcover, as green plants are essential to the maintenance of microbial activity.

The flip side to quorum sensing is that when there are not enough microbes to form a quorum, nothing happens. No matter whether it is in the human or animal gut - or in the soil - when microbial populations do not attain a quorum some very important genes (that plants, animals and people require for immunity, for example) get switched off. The lights go out ... which is precisely what's happening today in human, animal, plant and soil health.

We need to figure out how to turn the lights back on ... and fast.

Christine Jones, November 2018
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