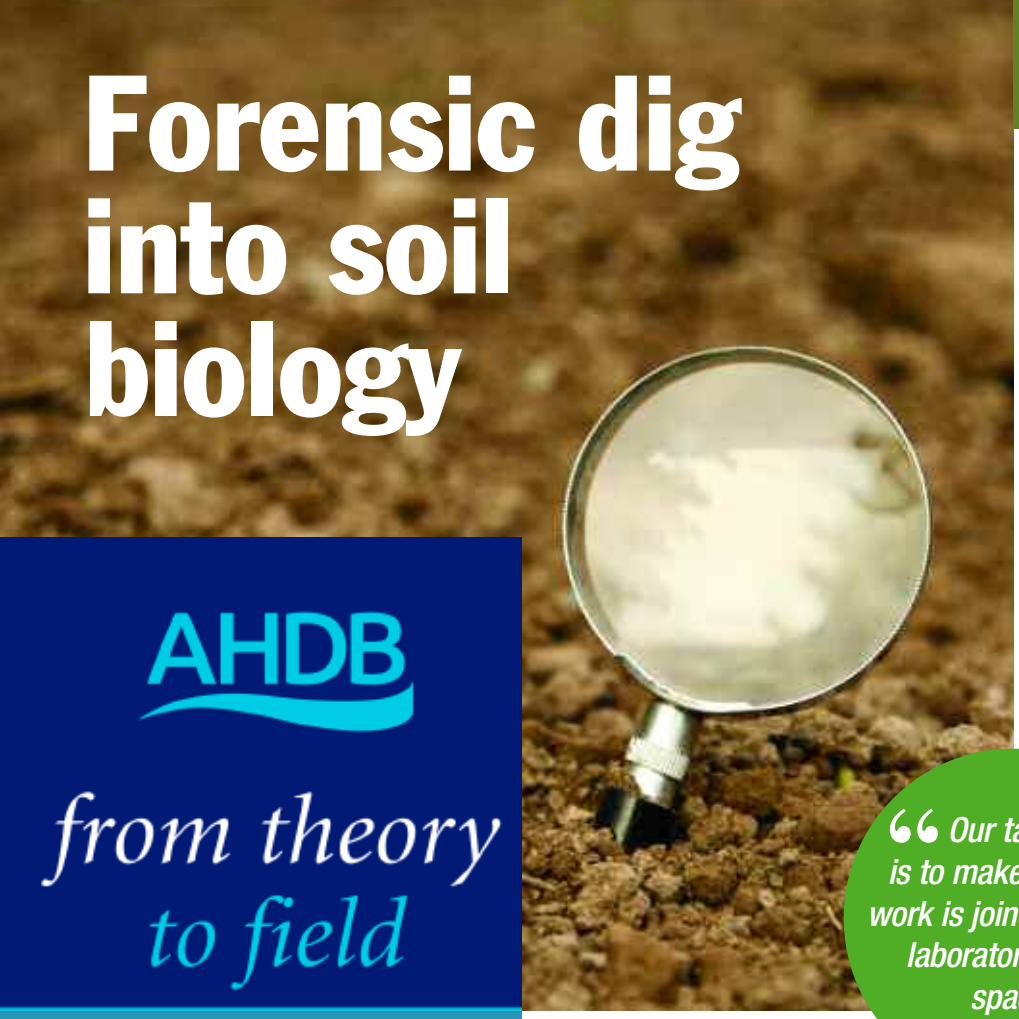
Forensic dig into soil biology



from theory to field

Soil communities play a vital role in maintaining soil health, but are we any closer to finding out more about the make-up and function of the microbiome in the mysterious world beneath our crops? *CPM* gets an update from the Soil Biology and Soil Health Partnership.

By Lucy de la Pasture

Three years ago, an exciting new project was launched to address the knowledge gaps in soil health. Funded to the tune of £1.14 million by AHDB and BBRO, the Soil Biology and Soil Health Partnership project is now in its last 18 months and, from the outset, has been an interactive affair with grower and industry partner involvement at its heart.

"The partnership is explicitly not just research, but rather work to deliver linked knowledge exchange and research on soil biology and soil health by building on work already carried out," explains project leader Dr Elizabeth Stockdale, who's NIAB's head of farming systems research.

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"Our aim is to improve on-farm understanding of soil health by sharing current academic and industry knowledge, as well as developing and validating indicators of soil biology and soil health in research trials and on-farm," she says.

The partnership has already delivered a soil health score card which has been developed to give an indicator of the three main principles of soil health — physical, chemical and biological — using indicators which were determined during the first phase of the project, explains AHDB's Dr Amanda Bennett.

Biological function

There are three projects involved in testing the theory in practice — from theory to field — to assess whether the descriptive models for soil biological function, which were developed in the initial phase of the project, hold true in the real world. As part of this, the scorecard has been evaluated to make sure it makes sense both in terms of benchmarks and its usability.

One of the remarkable things about the research being carried out in the Soil Biology and Soil Health Partnership is that is envelops work from the practical level all the way to the more blue-sky science that's looking at the DNA of soil biology, explains Elizabeth.

The biological function of the soil is widely acknowledged as a linchpin of overall soil health, yet very little is known about the interactions between soil communities and how these may be affected by management practices, she says.

"Our target is to make sure the work is joined up from laboratory to the spade. The molecular science is a high-cost element of the work, but it will help us to understand how soil management affects soil biology and soil-borne diseases.

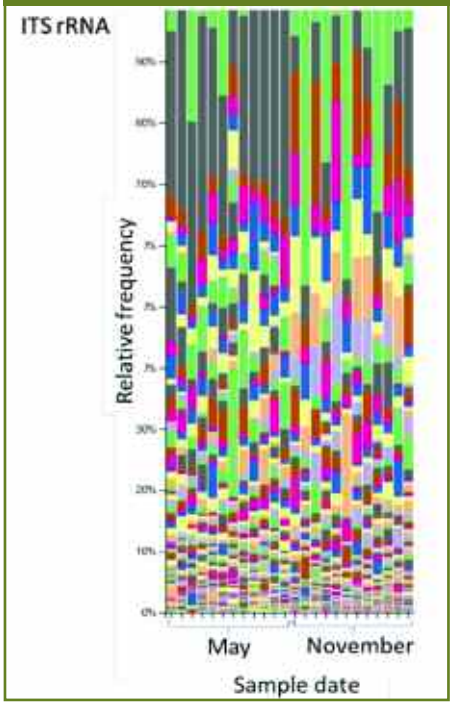
"Within the programme of research there are two very integrated projects evaluating and developing the more innovative measures of soil-borne disease risk and overall soil biological health using molecular measures. This is the cutting-edge innovative science — but grounded within the practical application of the research into measuring soil health and establishing links to management practices," she explains.

The molecular science is being led by Dr Joana Vicente at FERA, with key inputs from SRUC and University of Lincoln and its two associated PhD students. The aim of the work is to demonstrate the value of molecular methods to quantify the effects of management on soil health across a range of existing (long-term) trial sites and to better understand the link between soil management approaches and minimisation of soil-borne disease risk.

"A key step is to assess different approaches to soil extraction of DNA and then to consider the different ways of summarising the huge wealth of information generated into measures that can support ▸

Looking at the DNA present in the soil tells us there are lots and lots of organisms present, but the science isn't there yet to identify exactly what they are, says Elizabeth Stockdale.

Fungal DNA samples



No clear differences in fungal DNA (using ITS rRNA primers) were seen between contrasting cultivation practices in samples extracted from a long-term (>13 years) experiment. Fungal species shown in the stacked bars (each colour in sequence is a different species).

Source: University of Lincoln (Soil Biology and Soil Health Partnership), 2020.

▸ management decisions," explains Elizabeth.

"Next the work will explore the causal links between management and soil-borne disease control by providing some insight into the relationship between pathogen populations and the diversity and function of the overall soil microbiome.

"At the end of the project, we will explicitly consider whether molecular testing for pest and pathogen diagnosis and/or soil health is ready to go and can be integrated with the soil health scorecard to provide information on the soil biological community," she comments.

Molecular work

So what has the molecular work found so far? Importantly, the work has illuminated the fact that the methodology used to sample soil and extract DNA, together with the target sequences for DNA amplification are very important.

"Different methods can give very different answers; from our work it looks like different extractions target different parts of the microbiological community," explains Elizabeth.

The work has also identified a big information gap in the soil biology database that will need to be filled before DNA analysis can provide a real picture of what's actually making up the communities living in the soil.

Between 100,000–200,000 DNA sequences were obtained for both bacterial and fungal groups from each soil sample from the organic matter additions trial at Harper Adams. Although most of these soil microorganisms can be identified at higher taxonomic levels (e.g. phylum, class or order), fewer can yet be accurately assigned at the levels of family, genus or species and even fewer linked directly to soil function.

Earthworms are used as an indicator of the biological function of the soil, but the project is seeking a better understanding of soil communities to assess other benchmarks for soil health.

"In other words, we can tell that there are lots and lots of organisms present, but the science isn't there yet to identify exactly who — or what they are up to — at least we can only do it for a very small percentage of the organisms present."

Meta-barcoding procedures (DNA finger-printing) can be used to investigate the effect of soil management on the overall bacterial and fungal soil microbiomes, but initial findings suggest that the extraction method has a much bigger impact than management on the characteristics of the microbiomes.

"Only where we've done some fancy analysis to screen out the impacts of analysis do management differences show up, even between treatments with long-term organic matter inputs (manures, composts) compared with plots with no added organic

No blueprint for a healthy soil

Making the connection between pure science and practical management is one of the most important parts of the Soil Biology and Soil Health Partnership, believes Dr Simon Bowen, BBRO's head of knowledge exchange.

"The underpinning innovative work in the project is linked with a very hands-on practical approach. It's helping us identify the impact of management practices on soils and that's key to unlocking the yield potential of sugar beet," he says.

"In BBRO's Beet Yield Challenge (BYC) we've consistently found soil health is the biggest factor influencing the ability of a crop to fulfil its potential. But in practice, managing soil health is complicated."

In Simon's view, the project has highlighted that there's no blueprint for a healthy soil. "There isn't an off-the-shelf template to apply to the soil. From soil type to soil type and field to field, the solution may vary. That means benchmarking the health of the soil is an essential first step and the scorecard has made this possible.

"It's no surprise that sugar beet growers who achieve more of their potential yield are those who assess and develop a soil-improvement plan on a field-by-field basis. Sometimes this is refined at an intra-field level with some basic precision management," he comments.

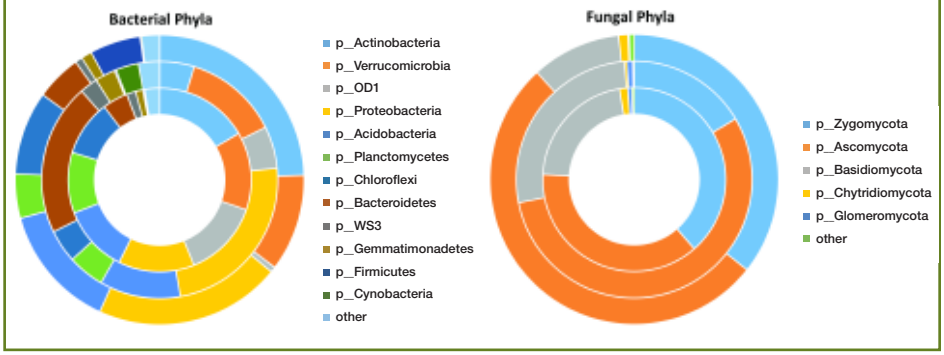
The BYC and Soil Biology and Soil Health Partnership have also helped to identify three key areas of focus for sugar beet crops, adds Simon. These are measuring and managing pH; use of organic manures; and improving soil water infiltration and drainage.

Recent seasons have presented some serious weather extremes, with a drought in 2018 and heavy rainfall last year. The rapid change from very wet to dry soils during soil preparation and drilling of beet this spring has resulted in some challenging seedbed conditions which may affect crop establishment, he points out.

"Another season, another challenge to our soils. It emphasises the importance of getting soil management right. Our understanding of how to improve the soil ahead of these events and how to reach into the soil health improvement toolbox is key. In many cases this will be a long-term fix using a range of strategies including rotational changes, use of cover crops, regular manure application and reduced tillage operations."

Simon Bowen says the BYC and Soil Biology and Soil Health Partnership have helped identify three key areas of focus for soil management.

DNA extraction technique affects results



Each ring represents the types and abundance of biodiversity at phylum level (a high level) in different DNA extraction methods

Source: University of Lincoln (Soil Biology and Soil Health Partnership), 2020.

materials (except crop residues).

"It suggests that these communities are tough (resilient) but we also need to remember that changes in a few organism types can make a big difference to function e.g. adding or losing Rhizobia (N-fixers)," she adds.

On the plus side, a number of qPCR assays have been validated for detection and quantification of a wide range of plant pathogenic soil-borne fungi. For example, relevant qPCR assays have now been validated for *Sclerotium cepivorum* (causes white rot in alliums), *Phytophthora asparagi* (spear and rot root in asparagus), *Stemphylium vesicarium* (leaf blight in onions) and *Gliocladium catenulatum* (biocontrol fungus).

"This means that the DNA finger-printing analyses can quickly pick out and count some of the key target species," explains Elizabeth.

The molecular work has also found there are still unanswered questions which are crucial for management-based decision making using the information from molecular tests. "There's a need to better understand the relationships between detection of pathogens in soil and the risk of disease development so that the benefits of soil health monitoring can be clearly demonstrated. Knowing how many 'bad' organisms are present may or may not tell you about whether you need to abandon a site or put mitigation steps in place," she says.

Attribute*	Control	FYM (23 years)	Slurry (23 years)	Green compost (13 years)	Green/food compost (6 years)	Food-based digestate (9 years)
SOM (%)**	3.0	4.1	3.6	4.0	3.7	3.4
pH**	6.4	7.0	6.4	7.0	6.2	6.5
Ext. P (mg/l)**	56	73	53	60	59	65
Ext. K (mg/l)**	80	311	194	187	140	167
Ext. Mg (mg/l)**	44	87	75	63	66	48
VESS score	2	2	2	1	2	2
Earthworms (Number/pit)	11	13	9	11	9	13

Investigate
Monitor
No action needed

*A soil health score card recording the status quo for the Harper Adams University trial site. **Attributes that showed a statistically significant difference between treatments (P<0.05).*

Research roundup

AHDB Project No 91140002, 'Soil Biology and Soil Health Partnership' is part of the AHDB's GREATsoils initiative. It runs from 2017 to 2021 at a cost of £858,869 (BBRO £140,934). It's a cross-industry partnership led by NIAB (Scientific partners: ADAS, FERA, GWCT, ORC, SRUC, Natural England, University of Lincoln. Industry partners: BASF, Frontier, Innovation for Agriculture, LEAF, NRM, Wye & Usk Foundation).

More information and new soil management publications can be found at *ahdb.org.uk/greatsoils*

From Theory to Field is part of AHDB's delivery of knowledge exchange on grower-funded research projects. *CPM* would like to thank AHDB for its support and in providing privileged access to staff and others involved in helping put these articles together.

Amanda Bennett comments the molecular research work has highlighted a skills gap, with few ecologists to classify the taxonomy of the soil.

"If conditions are ideal for disease organisms to act, does population size relate to disease occurrence? What about interactions with soil type or weather etc. Never mind the underlying soil health or activity of the rest of the biological community."

Elizabeth believes that molecular tools aren't yet of great value at the on-farm level for the reasons she's outlined but, in the future, it will be possible to link soil organisms with soil function.

"At the moment we can't make good sense of molecular data. It's a bit like a crime scene where there's good DNA collected, but that alone doesn't point to who committed the crime if the culprit isn't on the police's DNA database," she explains.

Even though the make-up of the microbes that contribute to the biological function of the soil remain largely a mystery, Elizabeth believes that doesn't take away from what we already know about soil health. The interactions between the physical, chemical and biological properties of the soil is what drives good soil health.

"For example, if the soil lies wet when it could be drained or the soil structure could be better, then the biology won't be functioning properly because the soil can't breathe. Regular additions of organic materials through crops and manures are also important not just for structure but to feed the organisms in the soil."

Amanda suggests the molecular work has highlighted a skills gap which can now be addressed by training more soil ecologists. "There are only a few people in the UK who can identify the soil mesofauna and the work has highlighted that soil DNA analysis is only as good as the database that underpins it.

"The Soil Biology and Soil Health Partnership has already produced a lot of useful tools and information and it still has 18 months left to go. Above all it has helped demonstrate that there's no one-size-fits-all strategy when it comes to soil management." ■