> *"The potential to refine environmental risk assessments is huge."*

Innovation
Innovation Insight

The life detectives

Few organisations worldwide have accrued as much knowledge as Fera on the living organisms in our environment. *CPM* visits its facility near York to find out how original thinking has been applied to cutting-edge R&D to enhance the services it offers growers.

By Tom Allen-Stevens

Just the name of this new structure suggests it is something of wonder. The E-Flows Mesocosm is taking shape in a clearing at the edge of the National Agri-Food Innovation Campus at Sand Hutton near York. It's the latest development at the vast science facility that's home to Fera.

Here, around 350 of the country's keenest minds in crop health and diagnostics are among those who analyse some 90,000 samples every year. Fera has a 100-year history as the government science agency for food, environment and agri-tech and is still 25% owned by Defra. In that time, it's probably accrued more knowledge about the life in the nation's soils, its crops and its food than any other UK entity. More recently, Fera's quietly developed this into a range of diagnostic and analytical services that can offer UK growers a staggering insight into how their crop performs and interacts with the environment (see panels on following pages).

Largest of its type

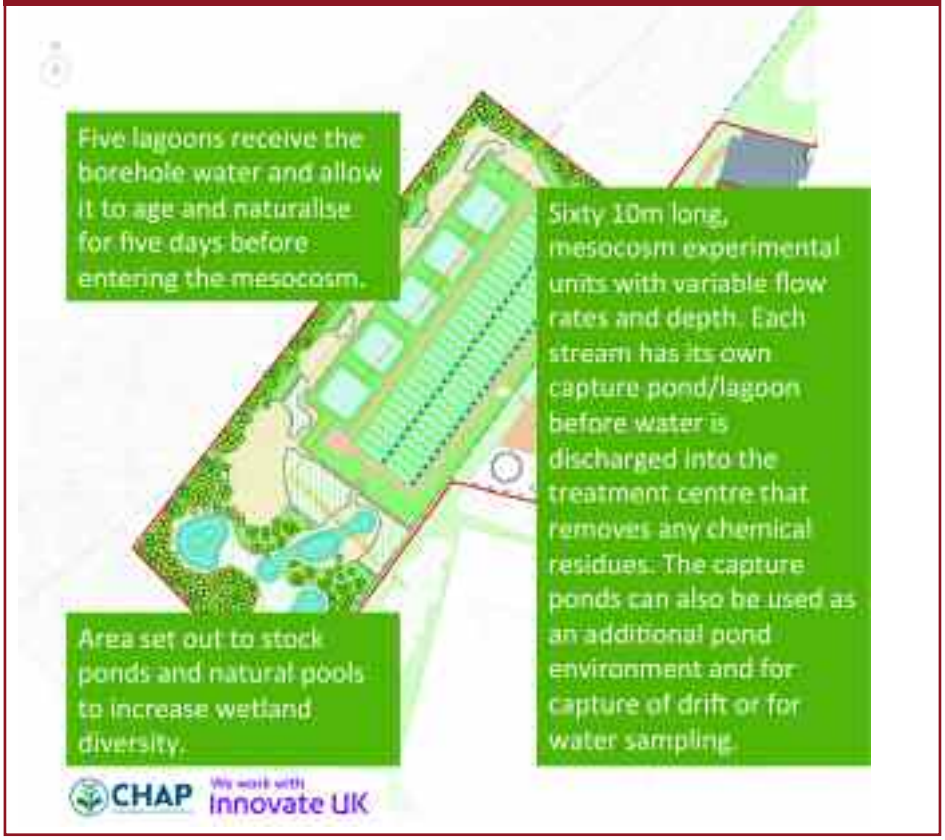
But it's also remained at the cutting edge of R&D, and the E-Flows Mesocosm is a £4M manifestation of this. It's an advanced testing facility — the largest of its type in Europe — funded through CHAP (Crop Health and Protection) under the government's AgriTech strategy, and is due to open this summer. So what exactly will it do?

"It will allow us to carry out realistic environmental risk assessments on aquatic life," explains Dr Rachel Benstead, senior aquatic ecotoxicologist at Fera. "We already get a good understanding from the lab about how plant protection products, for example, interact with aquatic organisms. But they can't be assessed in the natural environment because it's difficult to control and could have unforeseen consequences." So generally, there's a factor built in to scale up any effect that could be as large as 1000 times to ensure there's a good safety margin.

The E-Flows Mesocosm creates a range of natural aquatic environments so a more realistic assessment can be made. All manner of macrophytes and invertebrates will be reared in a number of carefully designed wetland habitats on the site. Borehole wayer is fed into a series of five

High hopes for better regulatory evidence: Rachel Benstead surveys the site where the E-Flows Mesocosm is taking shape.

The E-Flows Mesocosm



lagoons. From there, water is pumped along one of 60 10m-long mesocosms, which can recreate anything from a meandering ditch to a torrid brook. It's presented with its environmental hazard, such as a spray boom or point-source contaminant, and the effect is carefully captured and assessed.

"The advantage is that it's highly controllable, so we can replicate the test and know it's scientifically robust," says Rachel. "The potential to refine environmental risk assessments is huge — regulators will be able to make a more informed decision which could have benefits for the availability of products for growers." www.fera.co.uk/mesocosm-studies

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Cutting-edge R&D

It's at the intersect of cutting-edge R&D and practical application that Fera brings in some original thinking. Few organisations worldwide can claim to draw on as much in-house experience in food, agriculture and the environment, and this expertise is frequently applied to develop new technologies which bring the agri-food chain the analytical services Fera provides.

A good example is the use of loop mediated isothermal amplification (LAMP) as a diagnostic or detection technique. ▸

A focus on the root invaders

If you're a potato or sugar beet grower, you're probably aware of two or three species of nematode that can be responsible for yield losses of up to 35%. But did you know there's estimated to be around one million different species of this prolific organism in the world's soils?

"Nematodes are the most numerous multi-cellular animals on Earth, although only around 27,000 species have been formally documented," notes Tom Prior, senior plant nematologist at Fera. "Considering how important they are, they're understudied compared with other microorganisms."

Plant-parasitic nematodes (PPN) are responsible for around £48bn worth of crop damage per year worldwide. Potato cyst nematodes are the most important PPN in temperate Europe, and the nematodes Fera's identification and detection service is most often tasked to assess.

"We offer advice on the biology and pathogenicity of a whole range of PPN commonly found in crops. This is becoming important with PCN as the options for control are now more limited."

Fera houses one of the world's largest nematode collections, and the identification and advice service is where it differs from the standard nematode counts growers get from most providers, says Tom. "We now handle larger, more representative soil sample volumes which improves the accuracy of the nematode analysis."

But it's not just root crops that are at risk. Meloidogyne spp. or root-knot nematodes are the most economically important group worldwide. They can parasitize almost any plant species, inducing galls in the roots through an adverse reaction by the host plant.

"They are present in the UK, more common in sandy soils, although there is a perception that they're unlikely to cause economic damage to host crops. However, symptoms are often assumed to be nutritional deficiency, disease or lack of water — farmers have to take a detailed look at crop roots to assess a problem," says Tom.

Symptoms of nematode damage are often assumed to be nutritional deficiency, disease or lack of water, says Tom Prior.

There are also beneficial nematodes, points out colleague Bex Lawson. "Not all nematodes are harmful, but regular use of chemical sterilants will reduce populations of all species. We can give advice on how to change rotations to maintain a balanced ecosystem." www.fera.co.uk/nematodes

Insight into insect activity

Previously a priority for just a few growers, monitoring insects is now becoming a more mainstream activity across a wider range of crops, notes Fera's Dr Larissa Collins.

"Insect monitoring helps growers target agronomic practice better. It's an essential component of any integrated pest management strategy, but it's becoming particularly important to identify insect pests and understand thresholds as pesticide resistance becomes more widespread."

Fera's insect-monitoring service revolves around the use of yellow water traps. These are placed in the crop, with samples sent back for analysis in prepaid envelopes. "We send back results of samples by 12:00 on the day they're received, so it's a fast turnaround," notes Larissa.

With the loss of neonicotinoid seed treatments, monitoring cabbage stem flea beetle in oilseed rape has become a key use of the service, she notes. "You need four traps per field if you're looking to monitor CSFB against thresholds, although you can pool samples and send in only one per field for processing."

Aphid monitoring is where the service comes into its own, however. The results feed back species of aphid identified, which can help growers assess the risk of virus infection. "For potato growers, it's important to know which species you have and whether it can colonise the crop," she adds.

That makes a difference when it comes to what sort of virus is transmitted. Persistent viruses such as potato leaf roll virus have to be ingested and pass through the gut before the vector can transmit it to other plants. Non-persistent viruses, such as PVY and PVA stay on the mouthparts and can be transmitted within minutes by winged aphids just testing plants to find out if they're suitable hosts. "We found new vectors of PVA," notes Larissa.

One recent development has been in carrots. Viruses in the crop cost the industry around £20M/year, she notes. "Aphid numbers have been growing in recent years, and pesticide resistance is making them more of a problem."

In Feb this year, willow-carrot aphids in a sample Larissa collected were found to be resistant to lamda-cyhalothrin by Dr Steve Foster at Rothamsted Research. "We now know there are resistant aphids, but we don't know what level of resistance we're dealing with."

Larissa Collins notes it's becoming particularly important to identify insect pests and understand thresholds as pesticide resistance becomes more widespread.

And as the prevalence of resistance builds, the role of beneficial insects becomes all the more important, she adds. "The service can give you information on your beneficial populations as well, although more work is needed to assess the impact of these on pest thresholds."

www.fera.co.uk/insect-monitoring

▸ "LAMP methodology amplifies DNA but uses different chemistry to PCR — the current standard," explains Catherine Harrison, molecular biologist at Fera.

"The advantage is that the Genie III, the unit that does the analysis, is small and can be taken out into the field. It also takes just a couple of minutes to prepare a sample and it gives you a result in half an hour."

Fera has developed LAMP techniques to identify infected plants that may need quarantining at the UK border, and to detect Chalara fraxinea in the 2012 ash dieback outbreak in the UK. More recently the units have been used to analyse septoria isolates in a project funded by Innovate UK. "We're using the technique to analyse spores, looking for mutations known to confer resistance to fungicides," she says.

The overall aim for CHAP is to provide a real-time surveillance, forecasting and diagnostics platform to support

Sky-high sight of what the eye can't see

The use of unmanned aerial vehicles (UAVs) or drones in agriculture has come on in leaps and bounds in recent years. But they could soon be used to spot *Septoria tritici* in a wheat crop before it's even visible to the naked eye.

"We've been experimenting with different types of camera," explains Lee Butler of Fera's UAV services. "We're getting good results identifying stressed crops using multi-spectral cameras, but currently we can't tell from the imagery what's causing the stress.

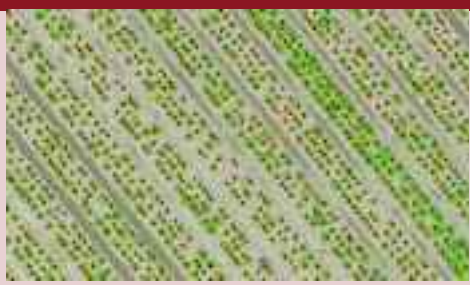
"The next step is to investigate the use of hyper-spectral cameras, that give information on 47 bands of light reflected by a crop. Initial studies in the lab indicate there's some really exciting potential here."

It's part of a joint project with Newcastle University, RAL Space (Rutherford Appleton Laboratory) and two Chinese partners. Working with a hyper-spectral camera in the lab, the team has successfully identified spectral signatures that denote plants in the latent stage of septoria infection.

"RAL Space are developing a camera we can mount on a drone so we can take the project out into the field," says Lee. "Of course, when it comes to spotting it in the field, there are a whole load of other conditions that will come into play, so we're a long way from being able to build a reliable remote septoria-prediction tool."

What they have developed, however, and are already using in the field is a fly-over service that can make accurate yield predictions for crops such as potatoes. "We teamed up with Strawsons and applied some original thinking to how drones are used. We've developed software that can count individual plants in the crop's early stages with remarkable accuracy," he says.

During the study, not only did the UAV accurately count the number of established potato plants, but helped identify a planting problem. "The software picked up irregularities in planting in the first 10m of each run, leading to a 10% drop in potential yield. This was traced back to a problem with the potato planter that probably wouldn't have been spotted otherwise," notes Lee.



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www.fera.co.uk/remote-sensing-and-mapping

decision-making in UK crops, explains senior plant pathologist Dr Judith Turner.

"We have a lot of tools that monitor crops for disease and pests and have individual risk models, which all provide interesting information. But they're not yet delivered in such a way that would give growers the confidence to use them when making decisions on pesticide applications."

The three-year, £3M project is due to complete next year and will bring the fruits of these new diagnostic techniques and modelling into a new decision-support platform developed as a major upgrade to CropMonitor (www.cropmonitor.co.uk). This is the service that has brought growers accurate information on a range of wheat diseases since 2003.

"A lot of the work we do in terms of detection delivers results after the event. But fungicide strategies are geared towards preventing disease. The platform we're developing uses models and real-time analytics to accurately predict disease risk."

At the heart of this is new automated spore-detection technology. These units will be deployed at sites across the UK and not only take in fungal spores but analyse them, using LAMP methodology, sending data back to feed into the platform. Growers then get a traffic-light risk assessment that indicates whether their varieties are at risk.

Validation shows the model rarely misses a high-disease scenario, but is currently too cautious, notes Judith. "A lot of the models are based on work with susceptible varieties, and spore data are not yet used in the algorithms — that will vastly improve accuracy."

Once fully operational, the service will provide real-time risk information for cereals and oilseed rape to all growers free of charge on a national and regional basis, whilst local risk forecasts will be available as a subscription service.

"The service will continue building its accuracy and capability. There's also soil-borne pests and pathogens — we're just developing improved diagnostics for these and in time will develop models that will forecast risk. There's a lot of potential to considerably reduce and target the use of pesticides," she concludes.

www.fera.co.uk/in-field-diagnostics ■

The new service will provide real-time risk information for cereals and oilseed rape to all growers, says Judith Turner.

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CPM would like to thank Fera Science for kindly sponsoring this article, and for providing privileged access to staff and material used to help put the article together. For more information, visit www.fera.co.uk

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Original thinking... applied

Sorting the health wealth from the soil spoil

They say there are more living things in one teaspoon of soil than there are people on the planet. Fera's Soil Health Unit can give you a snapshot on a tiny proportion of that life at present, but it's gearing up to bring growers a whole lot more.

Fera is one of the partners in the £1M Soil Biology and Soil Health Partnership, funded by AHDB and BBRO (see article on p41). The project is one year into its five-year study and senior phytobacteriologist Dr John Elphinstone is ambitious for what it can achieve. "The aim is to come up with a method of measuring good and bad soil health that can be easily and cost-effectively used on a practical basis.

"Measures for a soil's physical and chemical nature are already pretty well established — we can easily assess texture, organic matter, nutrient levels — but we're missing studies on the biology. We're applying some original thinking to provide an assessment of a soil's biodiversity through an analysis of its fraction of soil-borne organisms."

The core service Fera currently provides consists of tests for soil-borne pathogens — these include for beet necrotic yellow vein virus that causes rhizomania, for powdery scab and spraing, for example. There's also brown rot, ring rot, blackleg, clubroot and verticillium.

"Most of our current tests use PCR assays to detect the presence of a known target organism," John explains. "That's fine when you know what you're looking for. When you're looking to carry out an assessment of the life of a soil, this will involve new techniques, so we're evaluating the technology that would be suitable for in-field testing."

He has three core goals for the project: to develop a sampling procedure, to establish a method of extracting material of sufficient quality to assess its DNA, and then to develop methods and molecular markers to measure what's there.

"There are methods of metabarcoding that use universal PCR assays and next-generation high-throughput DNA sequencing to amplify certain DNA markers so you can identify what groups of organisms are present according to their unique DNA sequences. We know this technology works in the lab, but will it work in the field and across all soil types and conditions?"

While John has decades of experience studying soil organisms, the challenge in this project for him is deciding on which of the many tens of thousands of species he should focus on. "It's the ultimate kid in a sweetshop scenario — there are so many organisms we could develop markers for. This project is about identifying the important ones that will become key indicators of a soil's health."

www.fera.co.uk/soil-health

Like a kid in a sweet shop, John Elphinstone is excited about what the new project could reveal about the soil's biota.