Fera plant health and seeds inspector collecting samples.

Fera

The future of tree health

Ancient mainstays of our woodlands, hedgerows and parklands are at risk from a surge of pests and diseases – but a new research programme is bringing experts together from many fields to find solutions.

Chalara fraxinea – the fungus behind ash dieback – was first spotted in the UK in early 2012 in a consignment of trees from the Netherlands. It had already spread widely, and it's now almost certainly present throughout much of Britain.

It's already devastated European ash populations across the Continent since arriving in the early 1990s. Some trees can resist it, but most can't. Ash accounts for around 13 per cent of UK broadleaf cover, so dieback could change the landscape as profoundly as Dutch elm disease did a generation ago. Right now there's no defence and no cure.

A major research programme is helping us understand and control this woodland catastrophe, and perhaps even prevent the next one; in an increasingly globalised world, the flow of new pests and diseases is only likely to increase. Tom Marshall spoke to some of the scientists working under the Tree Health and Plant Biosecurity Initiative.

Tariq Butt

Scientists investigate a pine processionary moth pupation site in Turkey.

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Harvested logs from infected larch trees.

POPULATION BIOLOGY TO CONTROL DISEASE

Chalara is spreading fast – but what will its long-term effects be? Will it fizzle out, reduce the ash to a minor hedgerow shrub, or even drive it to extinction? It all depends on how the fungus and its host's defences evolve.

Professor James Brown of the John Innes Centre is focusing on the fungus's pathogenicity – its capacity to harm its host. Some *Chalara* strains are deadlier than others, but does this extra investment in pathogenicity weaken the fungus in other areas, like reproducing or surviving cold winters? If there's a high cost to being deadly, there's a good chance the ash population will make a long-term recovery as tree defences evolve.

Brown also wants to understand the fungus population's genetic structure, to see how natural selection acts on that population – the more genetic variation it contains, the faster it can evolve to beat ash trees' defences.

'Understanding variation in the fungus's pathogenicity will tell us about the long-term prospects for the ash population developing resistance,' says Brown. If the fitness cost turns out to be very high, we might be able to rely on natural selection alone – though in practice we may want to speed up the process. Brown's project could show how to breed more resistant ashes or manage woodlands to encourage the spread of disease-resistant genes.

It may also help contain the disease in the shorter term. The group is examining a related but harmless fungus that arrived in the 19th century and is now widespread in UK ashes. If the two fungi are close enough to share genes and diseases, viruses that infect the naturalised fungus could be transferred to the newcomer to slow its spread.

Professor Ismail Karaca

Pine processionary moth caterpillars building their nest.

GENOMICS FOR MORE RESISTANT TREES

The European ash may be in trouble but Dr Richard Buggs at Queen Mary, University of London thinks the solution could already be in the ash family's genes. Some close relations aren't bothered by the ash dieback fungus at all – for example in Manchuria it's been around for a long time but doesn't seem to harm living trees.

Buggs has already sequenced the European ash genome (see www.ashgenome.org) and now he's doing the same for 35 different ash species from all over the world. His research group will analyse the results to identify which genes confer disease resistance. We may be able to transfer those genes into the European ash, with regular breeding techniques or even using genetic modification (GM) technology.

Social scientists are investigating what people think of the different options, and which they'd be prepared to accept. 'We don't want to spend many years creating a wonderful new genetically modified disease-resistant ash tree, only to find the public isn't willing for us to plant it,' Buggs says.

He'd like to make sure the ultimate result is resistant not just to *Chalara*, but also to the emerald ash borer – an even deadlier threat that's moving across Eurasia and could reach the UK in the next decade or two. It would be tragic if scientists could deal with the danger dieback poses to our ashes just in time for a new pest to arrive and finish them off.

JIC Bioimaging

Dr Elizabeth Orton of the John Innes Centre working with the ash dieback fungus.

Brian Bell/Science Photo Library

Spraying against ash dieback disease.

Elizabeth Orton

Ash sapling showing the symptoms of dieback.

BIOLOGICAL PEST CONTROL

Professor Tariq Butt of Swansea University specialises in biological insect control – killing pests using other organisms. He's an expert on *Metarhizium anisopliae*, a fungus that's raised killing insects to a fine art. Unlike chemical pesticides, it's lethal to the intended victim but harmless to other insects and the wider environment.

This could be critical to our trees' future, because damaging invasive insects are already loose in our woodlands, and others are likely to follow.

The initial focus is the pine processionary moth, now found across much of Europe although not, for the moment, in the UK. Its caterpillars stunt tree growth, potentially devastating timber profits.

They're also covered in stinging hairs that can detach and blow on the wind, causing swelling and extreme pain and making it risky just to walk in the woods. They can even cause blindness if they get in a victim's eyes; two of Butt's collaborators in Turkey have already been hospitalised after a fieldwork accident.

The researchers are working on lures to get moths into *Metarhizium* traps. One idea is attracting males with female pheromones; another is using tree signalling chemicals to make females think they've found the perfect spot to lay their eggs.

Similar techniques should work on many pests, like vine weevils and the Asian longhorn beetle. Butt is working with forestry companies and other organisations including the Food and Environment Research Agency (Fera) and the Forestry Commission.

'We take trees for granted, but if major species start disappearing from the landscape it will have a huge psychological impact on us all,' says Butt. 'Even if we eventually find solutions that lets them return, a landscape full of saplings just won't be the same.'

Fera

Using the Genie system to detect ash dieback in the field.

THE ECONOMICS OF ASH DIEBACK

Planting woodland is a long-term gamble; it's not like sowing a field of wheat, where the risks are short-lived and if the crop fails you may be able to recoup your losses next year. The chances of eventual profit have to be weighed against many risks – from a drop in the price of wood to disease destroying the plantation.

Dr Adam Kleczkowski of the University of Stirling is leading a team of mathematicians, forest ecologists and economists to understand how disease affects foresters' decision-making, and how ash dieback is changing this. For example, will they stop planting ash – or could they plant more, hoping for a crop before the disease reaches them? We don't know, and we need to if we're to grasp the disease's long-term effects.

'More diseases will appear, and to deal with them we have to stop reacting afterwards and start preparing before problems occur,' Kleczkowski notes. 'We have to be more proactive in finding solutions.' And with around half of UK forests in private hands, we need economic solutions as well as political ones.

Kleczkowski plans to identify the forces affecting the spread of tree pathogens including ash dieback, and use these to improve models of economic decision-making so they account for the presence of disease. This should illuminate the behaviour of foresters and woodland managers faced with trade-offs between disease risk and other factors.

All this will deepen our understanding of dieback's economic dimensions, and of how it affects already-complex decision-making. Some of its costs are easy to measure – lost carbon credits, destroyed timber crops. Others, like reduced enjoyment of woodlands, are subtler; the scientists will carry out experiments asking people to choose between different outcomes to get a clearer idea of how much they value these intangible benefits.

At the project's end, Kleczkowski aims to have a list of potential anti-disease policies, ranked by cost-effectiveness. This will include things we already do and potential ideas for the future; it will help policymakers plan the war on plant pathogens for the long term.

Crown copyright: Forestry Commission

Citrus longhorn beetle.

AN ECOSYSTEM APPROACH TO TREE HEALTH

Dr Stephen Cavers at the Centre for Ecology & Hydrology leads a project that focuses on pest and disease resistance in the Scots pine. The UK's only native pine, it's economically valuable and ecologically priceless – the cornerstone of the rare Caledonian pinewood habitat, sole remnant of the primordial forests that once covered Britain.

Like several other species, Scots pines are under severe pressure from red band needle blight, a potentially fatal disease which has become a widespread and serious threat in Britain. But this is only one of several challenges they face in the coming years, from insect pests to climate change. The project will investigate how natural genetic variation can help the trees cope.

'Tree health depends on many different things, not just the particular pathogens,' says Cavers. 'Today, with climate change and new pests and diseases on the way, it's important to study it from several different angles simultaneously.'

The way a tree looks and grows depends on genes – its genotype – and the local environment. As natural selection acts, some genotypes do better than others. Yet if the environment changes – for example, if the climate gets warmer or we move seeds from one place to another – then once-successful genotypes can become stressed and susceptible to disease.

Individuals within a species vary in their ability to cope with these complex environmental pressures. This variation could point to solutions, if we know enough about how trees relate to their whole ecosystem – including pests and diseases.

For instance, assessing the tree's microbiome – the tiny organisms living on and in its leaves, which may act like a human's beneficial gut bacteria – will reveal if and how it affects disease risk.

Cavers will also consider how Scots pine is grown and managed, working with landowners, foresters and others to increase awareness of tree-health issues, and find ways to apply science to tree management. 'We want to produce guidelines on how to use natural variation to minimise the impact of disease on many tree species,' he adds. 'By looking at many health issues together, we think we can come up with helpful guidance for conservationists, foresters and the general public.'

BETTER BIOSECURITY THROUGH TECHNOLOGY

An interdisciplinary group led by Dr Rick Mumford of the Food and Environment Research Agency (Fera) is building technologies to help stop pests and pathogens at the border, or at least detect them before they spread too far.

Insects and fungal spores can get to the UK naturally, but many arrive in plant shipments, so monitoring imports is essential. Two technologies will help inspectors at ports: an electronic 'nose' that can detect volatile chemicals emitted by many infected plants; and cameras that pick up subtle disease-induced changes by looking beyond the spectrum of visible light. Both can detect many problems long before they are visible to the naked eye.

Other projects aim to give early warning of pests and diseases in the wild to improve our chances of stopping them getting a foothold. 'Monitoring imports is vital, but it's a thin blue line around the country,' Mumford notes. 'If a new disease gets through it can be several years before we find out, and in that time it can spread a long way. We need better surveillance technology.'

His group aims to create systems that capture fungal spores and test for the DNA of known pathogens; detectors to pick up the genetic material of waterborne diseases like sudden oak death; and smart insect traps that catch invasive species with customised lures and then transmit images to base for identification. The researchers are working with citizen-science experts at the Centre for Ecology & Hydrology to create risk maps to guide trap placement, drawing on the expertise of amateur entomologists.

Many of these technologies have already been developed in areas like homeland security, where they're used to detect explosives, drugs and other illegal items. Others are widely-used scientific instruments. The challenge is turning them from research tools into portable devices that are easy for plant inspectors, foresters and others to use in the field.

WHAT DO WE REALLY THINK OF TREE HEALTH?

The arrival of ash dieback has triggered heated debate in the media and beyond, and many of us now know enough about tree health to report sightings and take steps to avoid spreading disease.

But there's still a lot we don't know about public understanding of tree-health risks – and about the social, cultural and economic factors that shape it. Dr Clive Potter at Imperial College London is exploring how people encounter tree pests and diseases in different contexts, and assessing the role the media and other communication channels play in informing people of the risks they pose.

They'll study public reaction to, and involvement with, three recent outbreaks in the UK – ash dieback, sudden oak death and the oak processionary moth. Their findings will help build public trust in initiatives like Defra's Plant Health Risk Register, which assesses threats to UK flora. They'll also help policymakers and risk managers find better ways to communicate with the public, making the issues relevant and help people understand how they can make a difference.

The Tree Health and Plant Biosecurity Initiative is funded by the Biotechnology and Biological Sciences Research Council, Defra, the Economic and Social Research Council, the Forestry Commission, NERC and the Scottish government. They are investing £7m in projects lasting up to three years to address threats to UK tree health, under the auspices of the Living With Environmental Change partnership.