ASH DIEBACK – THE BIOLOGY AND SPREAD OF *Chalara Fraxinea/Hymenoscyphus Pseudoalbidus*

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Ash *(Fraxinus excelsior)* is one of only about 30 major tree species native to the British Isles. It is thus a significant component of native woodlands being important in woodland regeneration and succession dynamics. Ash is often a component of mixed broadleaved woodlands and pure ash stands occur naturally in the uplands. Britain has a number of Special Areas of Conservation which are designated because of the tilio-acerion woodlands of ash and other species. Ash is the second most planted broadleaved tree of managed woodlands making up about 5.4% of Great Britain's woodland cover. Its good ability to regenerate naturally means that it is also an important and valued hedgerow and urban tree.

As with other trees, dieback is known to occur in ash and work has been done in the UK over the years to determine its extent, severity and causal mechanisms (Hull & Gibbs, 1991). However from the early 1990s onwards more serious and spreading ash dieback was reported across mainland Europe. Dieback was first noticed in or around Latvia and Poland in c 1990, since then it has spread westwards being reported in Germany in 2002, Denmark in 2003, Belgium in 2010, Northern France in 2012. Symptoms were leaf wilt then necrosis, defoliation, cankers on branches and stems resulting in crown dieback. Affected trees usually die although the period between early symptoms and tree mortality can be several years. In 2006 the causal agent of this new ash dieback was identified as the fungus *Chalara fraxinea* (Chalara) which was considered to be new to science (Kowalski, 2006). Three years later it was suggested that Chalara was a stage (the asexual form or anamorph) in the life cycle of the cup fungus *Hymenoscyphus albidus*, which had been known since 1851. *H.albidus* is a saprophytic ascomycete which lives on ash leaves without causing harm and indeed being responsible for leaf decay and nutrient release from fallen leaves on the forest floor. It is indigenous across Europe. However as a result of the spread and severity of Chalara-related ash dieback across Europe with some 60 to 90% of trees infected in many countries, Chalara was added to the European & Mediterranean Plant Protection Organisation alert list in 2007. In 2009 Forest Research published on its website a description of symptoms and the UK forestry and land management sector were asked to be alert for symptoms.

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> . . . identified as the fungus *Chalara fraxinea*. . .

Molecular studies conducted in 2010 showed that the pathogen responsible for ash dieback (Chalara) was not the anamorph of *H.albidus*, but was the asexual phase of a newly identified fungus *Hymenoscyphus pseudoalbidus* (Queloz et al 2010). *H.pseudoalbidus* is identical to *H.albidus* in appearance and the two can be distinguished only by DNA analysis. However it appears that only *H.pseudoalbidus* has the pathogenic asexual phase now known as Chalara. The lag between arrival of the disease and the identification of the causal agent and the time taken to sort out its taxonomy have been factors in the lack of action over this new ash dieback as it spread across mainland Europe.

We know that Chalara has a life-cycle which is unique but not unlike that of a number of other ascomycetes. The cup fungus or fruiting body (apothecia) of *H.pseudoalbidus* is c 3mm across and grows on the midrib or rachis (central stem of the compound leaf of ash) of fallen leaves. Each midrib may have many fruiting bodies and each produces a large number of ascospores over a period of about two weeks at some time between July and October. Spores are shed from the fruiting body around dusk and are small (17 x 4μ) floating freely in the wind. When sufficient spores are intercepted by ash foliage and twigs, they develop as Chalara infection which grows slowly, the leaves

. . . a systemic infection which discolours the wood . . .

wilt and develop areas of black necrosis. The fungus spreads down the shoots infecting the inner bark and xylem causing lesions and shoot dieback. In branches and eventually the main stem, Chalara spreads as a systemic infection which discolours the wood. It may take several years for the tree to die but the discolouration of infected wood reduces its value. Mortality occurs more quickly on saplings. Chalara persists over winter on fallen leaves on the forest floor until the fruiting bodies of the sexual phase *(H. pseudoalbidus)* are produced in the following summer. Critically, spread of the infection is by two mechanisms – the movement of windblown spores and transportation of young plants with infected foliage. The disease has spread in Europe at rates of c 20 to 30 km per year and this is mainly associated with the first of these two mechanisms; windblown ascospores. These life cycle details have important consequences for the control of the outbreak and the longer-term prospects for adapting ash silviculture to the presence of Chalara in Britain.

In 2009 the Forestry Commission conducted a limited survey of ash in GB to look for Chalara infection and did not identify the disease as being present. Chalara was first found in the UK in February 2012 in a forest nursery which had imported young trees from the Netherlands. Since then it has been found in a number and variety of locations in Britain – initially all these were sites which had received young ash plants from nurseries in the last five years. A Pest Risk Assessment (PRA) on Chalara was published and a formal consultation on its management was held during September and October 2012. However infection was found in an established woodland in late October 2012 and by the end of October it had been found to be present in over 40 woodland sites in East Anglia and Kent. The UK Government took emergency measures on 29th October banning the import of

. . . ash in GB may survive the arrival of Chalara . . .

ash and imposing movement restrictions in the UK. A rapid survey of ash was conducted by the Forestry Commission in the first week of November 2012 with three sites being inspected in every 10Km grid square of GB. During November as samples from this survey were analysed the presence of Chalara across Great Britain and Northern Ireland has become more clearly understood. By 28th November the disease was known to have been present in 17 nurseries, 105 recently planted sites and 135 sites in the wider environment (woodland, hedgerow and amenity trees). In addition to the rapid survey an important source of information is the observations of the forestry and land management sector and the wider public. At the time of writing the Forest Research Disease Diagnostic and Advisory Service has received a large number of enquiries about ash health. These reports are

. . . banning the import of ash . . .

investigated and some result in the identification of infected sites.

For nurseries and recently planted sites there are good prospects for elimination of the infection by destroying infected material. The wider environment sites will inevitably prove more difficult to manage. However these sites are clustered on the east side of England (131 sites) and Scotland (only four wider environment sites at November 28 2012), and ascospore production will not occur from the fallen leaf litter of these sites until May 2013 giving a short window during which a control strategy or plan can be drawn up based on the best available evidence. The Chalara control plan will be published in early December 2012 along with supporting biosecurity and operational guidance.

There remain a number of important gaps in our knowledge of the biology and epidemiology of *Chalara fraxinea / Hymenoscyphus pseudoalbidus* which need to be addressed as quickly as possible to inform the control

. . . the relationship between it and its host . . .

plan and its implementation. Critical questions are: How common are incidences of ascospore arrival from Europe with sufficient inoculum potential to infect trees in the UK? Will such incursions diminish in frequency and intensity of inoculum potential as ash dies in Europe and Scandinavia? Do the conidia (spores) produced by the asexual phase (Chalara) result in spread of the disease as well as the ascospores produced by *H.pseudoalbidus*? How will the fungus and the relationship between it and its host (ash) now evolve? Can we deal with the recently planted sites which are infected before they become sources of infection in established woodlands? If so can we develop and implement the control strategy so that it is more effective in slowing the spread of Chalara?

There is some evidence to suggest that ash in GB may survive the arrival of Chalara. There are a number of fungal pathogens present in our woodlands which can be tolerated through good biosecurity and appropriate management (forest operations). For a small number of fungal pathogens biocontrol systems have been developed. Lastly it is known that there is a range of susceptibility of different ash species to Chalara, *Fraxinus excelsior*, *F.angustifolia* (narrow-leaved ash), *F.nigra* (American black ash) are the most susceptible. *F.ornus* (flowering ash from mainland Europe) and *F.pennsylvanica* (Green ash) are of moderate susceptibility while *F.americana* (American ash) and *F.mandschurica* (from North eastern Asia) are the least susceptible. In addition, observations in Europe have shown that some 1 to 2% of *F.excelsior* – our native ash – show some level of useful resistance. Useful meaning resistance which could be exploited in a breeding programme. The Future Trees Trust (www.futuretrees.org/) is an organisation with a range of partners in the UK and The Irish

Republic which has made real progress in broadleaved tree breeding and which has a number of ash collections that will make an excellent starting point for the breeding of Chalara resistant or tolerant *F.excelsior*.

. . . resistance which could be exploited . . .

The risk from tree pests and pathogens is growing with the expansion of international trade and the transport of live trees and timber products. The arrival of Chalara has proved to be a further reminder of the importance of proactive work to protect trees, woodlands and the natural environment from plant pests and diseases. Good biosecurity measures and an effective plant health regime are clearly essential. For woodlands, trees and the natural environment there is an ongoing need to manage established and emerging pests and pathogens. However effective our border controls, new pests and pathogens are likely to arrive occasionally, and we know that pathogenicity can develop through evolutionary change to non pathogenic, indigenous fungi. Fungi and invertebrates will remain as components of forest ecosystems. Tree species selection, regeneration methods, silvicultural systems and woodland management overall need to be undertaken in ways which optimise resilience to pests and pathogens.

. . . new pests are likely to arrive occasionally . . .

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ASH TREES – EFFECT OF CHALARA FRAXINEA

CHALARA ASH DIEBACK IN CONTEXT

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***Chalara fraxinea* is one of many organisms which threaten our trees, crops, gardens and ecosystems. In 2012 it was found established in woodland in eastern England, probably through aerial spread of spores from the continent. It has also been introduced on infected young plants. It is likely that Chalara originally arrived in Europe on imported plants from the Far East.**

There are standards and legislation to reduce the risk of such organisms spreading. These are currently under review to see how they can be made more effective, while continuing to facilitate safe trade. Under the Sanitary and Phytosanitary Agreement (SPS) of the World Trade Organisation countries may take measures to protect human, animal or plant health. Standards agreed under the International Plant Protection Convention (IPPC) set out how risks should be assessed, how risk management measures are selected and applied, and the form of phytosanitary certificate to be used for trade. The "phyto" represents a statement from the plant health service in the exporting country to the importing country that a consignment of plants or produce meets import requirements and is free from quarantine pests.

Symptoms of ash dieback, with some regrowth from new shoots

A quarantine pest is defined by the IPPC as "A pest of potential economic [including environmental] importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled". "Pest" covers fungal and bacterial pathogens, viruses and nematodes, as well as insects.

Low grade wooden packing material, with bark attached, has proved an effective pathway for

> . . . eradication campaigns for pests of arable crops . . .

moving pests around the world, and difficult to regulate at a national level. International Standard 15 requires wooden packaging material to be treated (usually by heating) and branded with an internationally recognised mark. The recent outbreak of Asian longhorn beetle in Kent is likely to have been caused by import of infested wooden packaging material before this standard was implemented.

International standards do not set out lists of quarantine pests: a quarantine pest in one region is often unregulated in some other part of the world. This may be because it originates there, and natural enemies limit its impact, or its host plants have evolved resistance over many years. Pests introduced into new areas can be very damaging. However, once they are widespread they no longer meet the definition of a quarantine pest and regulation may no longer be appropriate. Hundreds of years of food imports and plant collection have brought to the UK many pests which are now well established. Farmers, growers, foresters and gardeners manage them routinely, though at a continuing cost.

The European and Mediterranean Plant Protection Organisation (EPPO) has fifty member countries, including all EU Member States. Unlike the IPPC, EPPO does list the pests it recommends for regulation by its members, and maintains an "alert list" of new threats drawing on reports from member countries, from other Regional Plant Protection Organisations, scientific literature and other sources. EPPO has a small secretariat and relies for much of its work on panels of experts drawn from member countries. Much of the EU plant health regime derives from horizon scanning and risk assessment carried out by EPPO over its sixty year history. More recently the European Food Safety Authority, an EU agency, has established a plant health panel, which considers scientific questions and risk assessments referred to it by the European Commission.

Countries of the European and Mediterranean Plant Protection Organisation

The EU Plant Health Directive (2000/29) sets out lists of regulated pests, and measures applied to imports of plants and plant produce from outside the EU.

For some types of plant which represent a risk of moving specific pests within the EU, it prescribes the use of plant passports. These are issued under official supervision by the nursery where the plants were grown. Amendments to the detailed lists in the Directive are considered each month at a Standing Committee on Plant Health, at which all Member States are represented.

Risks are very different in different parts of the EU, and some regionalisation is permitted. Areas which are free from a pest can apply for protected zone (PZ) status, and take measures to stay free, even if the pest is present in the rest of the EU. The UK has more PZs than any other Member State, including for Colorado beetle and 11 forestry pests. Some PZs only cover Northern Ireland (with the Republic of Ireland) because the pest is already established in GB.

Within the UK the Plant Health Act 1967 allocates responsibility for forest trees to the Forestry Commissioners and for other plants to the Agriculture Departments: Defra in the case of England. It does not define "forest trees". Defra's Food and Environment Research Agency (Fera) carries out research, risk assessment, diagnosis, import and export inspections and eradication campaigns for pests of arable crops, nurseries and gardens. Fera's Inspectors operate across England and (under a concordat with the Welsh Government) in Wales.

Many pests affect both forest trees and other plants, and in practice Forestry Commission and Fera work closely together. The five year programme to reduce the level of inoculum of *Phytophthora ramorum*, by removing hosts such as rhododendron from woodland, has been a joint endeavour. When an outbreak of Asian longhorn beetle was detected in Kent in March 2012 Fera and Forestry Commission collaborated on the basis of the different capabilities of the two organisations, without letting discussion of remit become a distraction. We are cautiously optimistic that the outbreak has been eradicated, but further survey work over several years will be needed to confirm that.

Steps have been taken over the last two years to formalise governance of plant health. A Plant Health Strategy Board has been established, chaired by Defra, and comprising representatives from Fera, Forestry Commission, JNCC, and the Devolved Administrations. Alongside the Plant Health Strategy Board an Advisory Forum has been convened, with stakeholders representing different sectors. The Forum has helped to develop and promote UK lines on review of the EU plant health regime. A Risk Management Workstream commissions and prioritises pest risk assessments, consults on appropriate measures based on the assessment, and prepares UK positions for the Standing Committee.

There are around 250 pests listed in the Plant Health Directive and a further 25 on EPPO's Alert List. New pests are listed after a process of pest risk assessment (PRA) according to international standards. Fera publishes 10-15 PRAs each year as part of an ongoing process of consultation on new risks.

Damage now believed to have been caused by *Chalara fraxinea* was observed in Poland in the early 1990s but it was not until 2006 that the causal agent was isolated, 2010 that its identity was clearly established, and 2012 that a PRA was carried out. The reasons for those delays need to be

Asian Longhorn Beetle – cautiously optimistic that an outbreak in Kent last year has been eradicated

understood in order to learn the right lessons about how the European and UK plant health regimes can be improved. It is also important that experience with other pests is taken into account in learning and applying lessons from Chalara. Successes in preventive work tend to be inconspicuous. Research has been commissioned to quantify the benefits associated with the current plant health regime, as a baseline against which the impact of necessary improvements can be assessed.

In October 2012 Defra's Chief Scientific Adviser, Professor Ian Boyd, was asked by the Secretary of State to convene an Expert Task Force to advise on Defra's response to recent tree and plant disease outbreaks. Interim recommendations were published at the beginning of December, and the final report will be available this spring.

Two areas where progress should be achievable are early detection of outbreaks and assessment of risks from new trades. The first of these is a technical issue, the second about strengthening the EU and international regime.

Outbreaks detected early can be dealt with at lower cost, and with more chance of successful eradication. Fera and Forest Research are working with partners in other countries to improve detection through

Colorado beetle – continuing exclusion from the UK is a longstanding success of citizen science.

technology: remote sensing, acoustic signals (larvae munching inside trees), and spore trapping. We have found that by going back through old pollen traps we can detect DNA from Chalara spores. In future that approach might give us early warning about a pathogen, even when symptoms have not yet been seen. Citizen science has a lot to contribute. Colorado beetle has been kept out of the UK for over a hundred years partly by ensuring that enough people know what it looks like, and report findings.

One of the key shortcomings of the current EU plant health regime is that new trades in plants from other continents develop without any form of risk assessment being carried out. It is often only when a problem has been found on such a trade that measures are put in place, and this is too late. A more precautionary approach would require that trades of which there is no significant experience are subject to an assessment before they start. That will be one of the main points for negotiation when the Commission publishes formal proposals very soon.

ASH TREES – EFFECT OF CHALARA FRAXINEA

ASH DIEBACK: Resources at Royal Botanic Gardens, Kew available to research the disease

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and

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Images of *Fraxinus excelsior* Copyright RBG,Kew

BACKGROUND

. . . dying in large numbers in Poland . . .

Chalara dieback of Ash is caused by the fungus *Chalara fraxinea* and was first recorded in the UK in February 2012 and is thought to have entered UK in a consignment of nursery stock imported to an English nursery from the Netherlands. It has since been found in several locations in England, Wales, Scotland and Northern Ireland. It is believed that many sites have had imports from the continent of young ash transplants over the past 5 years. However, there have also been an increasing number of cases of ash dieback in trees which have no links to the nursery trade. Thus it is important that we have a better understanding of how the fungus is being dispersed so that measures to control the spread of the fungus are informed by sound scientific evidence. There is a lot to learn about the life cycle of the fungus, how it is spread and why trees vary in their susceptibility to the fungus.

. . . variation in susceptibility . . .

Ash trees suffering with *C. fraxinea* infection have been found in many parts of Europe since they were reported dying in large numbers in Poland in 1992. These have included forest trees, trees in urban areas such as parks and gardens, and also young trees in nurseries. It is potentially a very serious threat to ash trees in the UK. As it has caused widespread damage to ash populations in parts of Europe, including estimated losses of between 60 and 90 per cent of Denmark's ash trees since 2007; the consequences of it entering the natural environment in Britain could be as serious. Experience on the continent indicates that it kills young ash trees very quickly, while older trees tend to resist it for some time until prolonged exposure causes them to succumb as well.

Researchers in Europe have shown that the common ash tree *Fraxinus excelsior* and the narrow-leaved ash *F. angustifolius* are the most susceptible to the fungus, as is the American black ash, *F. nigra*. Other species of *Fraxinus* vary in their susceptibility. Understanding why there is this variation in susceptibility, especially why some individual trees of *F. angustifolius* appear to be resistant, whereas others are very susceptible should provide clues as to how to control the fungus.

RESOURCES AT ROYAL BOTANIC GARDENS, KEW

The Royal Botanic Gardens, Kew has a diverse collection of over 500 ash trees at both the Kew Gardens and Wakehurst Place sites that currently show no signs of ash dieback. The ash collection at Kew Gardens comprises 43 different species of *Fraxinus* from Europe, Asia and North America. This includes 18 different cultivars grown for their horticultural merit. For those that know the gardens, the majority of the trees are growing either side of Princess Walk. At Wakehurst Place there are 16 different species of *Fraxinus* and the damp woodland areas of the Loder Valley Nature Reserve and other outlying woodlands have a high proportion of ash amongst the native vegetation.

These living collections, as well as over 2,700 herbarium accessions (dried plant samples) at Kew, provide a rich resource to further our knowledge about the factors that influence the susceptibility of ash to attack by the fungus. For example, the herbarium collection contains 293 specimens of *Fraxinus* that include samples from "wild" populations from different parts of Europe. A key to the importance of these collections is that they are taxonomically verified (that is they are the correct species) and the providence for them is known. So if resistant traits are identified then researchers can go back to the area the plants came from and hopefully collect more material and evaluate whether the plants in these areas are still resistant.

. . . these collections are taxonomically verified . . .

Often the traits associated with resistance to fungal pathogens are present in nature. It is our ability to identify them that can take time! A fungus becomes a pathogen on a plant because it shuts down in some way the plant's natural defence mechanisms or exploits some other weakness in the plant. This seems to have happened with *Chalara fraxinea*. Although our knowledge about plant-fungal diseases has increased since Dutch elm disease devastated the elms in Britain, every pathogen usually requires a new solution. It takes time to mobilise resources to tackle a new disease and this is why the collections at Kew are important. The collections are there to be used. Currently, Kew is looking at how the horticultural and scientific staff at Kew can work with others to maximise the use of these important collections. As part of these collaborations the Millennium Seed Bank Partnership, which is run through Kew's Seed Conservation Department at Wakehurst Place, will be working with the Forestry Commission and others to collect seeds from different populations of ash so that the seeds can be screened for the presence of any resistance traits. Having seeds available from resistant plants will enable plants to be grown that could decrease the spread of the disease. Currently there are no collections of wild populations of viable ash seeds that represent the diversity of elms in the UK.

Meanwhile staff at the Kew sites will be actively monitoring the collections for any signs of the disease.

. . . The collections are there to be used.. . .