Forestry Commission

Contingency Plan for Oak Wilt (*Ceratocystis fagacearum*)

INTRODUCTION

1. Serious or significant pests require strategic-level plans developed at a national level describing the overall aim and high-level objectives to be achieved and the response strategy to either eradicate or contain an outbreak.
2. The Plant Health Risk Group (PHRG) has commissioned, following identification by the Risk Register, pest-specific contingency plans for those pests which pose the greatest risk and require stakeholder consultation, including this plan for *Ceratocystis fagacearum*.
3. The purpose of these pest-specific contingency plans is to ensure a rapid and effective response to an outbreak of the pest or disease described.
4. Contingency planning starts with the anticipation and assessment of potential threats, includes preparation and response, and finishes with recovery.

Anticipation

5. Researching sources of information and intelligence about the pest, including horizon scanning.

Assessment

6. Identifying concerns and preparing plans.
7. Setting outbreak objectives

Preparation

8. Ensuring staff and stakeholders are familiar with the pest.

Response

9. Implementing the requirements to either contain or eradicate, including work to determine success.

Recovery

10. Identifying when the response strategy has been effective or when the response is not considered feasible, cost-effective or beneficial.
11. The Defra Contingency Plan for Plant Health in England (in draft 2017) gives details of the teams and organisations involved in pest response in England, and their responsibilities and governance. It also describes how these teams and organisations work together in the event of an outbreak of a plant health pest. The Scottish Government has also produced a similar plan (in draft 2017).

Scope

This contingency plan was prepared by the Forestry Commission's cross-border Plant Health Service to be used at country and GB or UK levels. It should be used in conjunction with the Defra Plant Health Contingency Plan (in draft 2017), which provides details of the level of response required and by whom, depending on the scenario. Forestry Commission England's Forest Services division will use OGB17b 'Managing Incidents in the Forestry Commission' for relevant incidents. The Scottish Government (including Forestry Commission Scotland) also has a draft generic contingency plan for dealing with general plant health outbreaks, and the Welsh Government will develop a similar document detailing its management of outbreaks. Where an outbreak becomes of UK- or Great Britain-wide concern, the UK Government's Chief Plant Health Officer will form a management team to co-ordinate the activities in the different countries.

This contingency plan falls into three parts:

- official action following a presumptive diagnosis;
- official action following the confirmation of an outbreak; and
- background information about the pest.

This plan will be updated following new information or changes in policy or contact details. (Last updated December 2016).

Objectives of this plan

- To raise awareness of the potential threat posed by *C. fagacearum*, the causal agent of oak wilt disease, and to ensure that stakeholders are aware of symptoms caused by infection of host trees by this pathogen.
- To provide guidance on actions to be taken when symptoms of infection by *C. fagacearum* are observed.
- To ensure that outbreaks of disease caused by *C. fagacearum* are managed promptly and effectively, with the aim of eradicating pioneer populations of the pathogen.
- To ensure that all relevant Forestry Commission staff and staff of other government agencies and local authorities are conversant with the contents of this contingency plan so that effective and immediate action is implemented.
- To ensure that good communications are put in place so that all stakeholders (including relevant media) are kept fully informed of the scale of the outbreak.

Anticipation and Assessment

1.1 *C. fagacearum* causal agent of oak wilt in the United States of America, is a serious and destructive fungal pathogen of oaks, particularly species in the red oak group (*Quercus* Section *Lobatae*; syn. *Erythrobalanus*).

1.2. The native range of this pathogen is uncertain, but current opinion suggests that the origin was in Central or South America, or Mexico.

1.3. In North America, the pathogen is known to be vectored between trees by various beetle species, including sap-feeding Nitidulidae and oak bark beetles (Scolytinae). In Europe, European oak bark beetle (*Scolytus intricatus*) might be able to act as a vector. *S. intricatus* is widespread in England and Wales, although there are no records of it in Scotland or Northern Ireland. (Figure 5)

1.4 Human transport of firewood in North America has been responsible for outbreaks of oak wilt in areas previously free of the disease.

1.5 Underground spread of oak wilt occurs via common root systems in live oaks and root grafts, which occur predominantly between trees within the same genera, and are especially common among trees in the red oak group.

1.6. *C. fagacearum* is not currently known to be present in Europe. There was a report of *C. fagacearum* killing oaks in Turkey (BOYRAZ and BAŞTAŞ 2001), but no follow-up information about this finding could be found. Previous reports from Bulgaria, Romania and Poland in the past were almost certainly mis-identifications.

1.7. Infections by the pathogen can cause extensive damage, particularly to oak species in the red oak group. However, there is strong evidence that European white oaks, including *Q. robur* (pedunculate or 'English' oak) and *Q. petraea* (sessile oak), are also very susceptible to infection and could be killed by the disease. In addition, North American and European sweet chestnut (*Castanea dentata* and *C. sativa*, respectively), North American chinquapin (*Castaneopsis sempervirens*), and species in the tanoak genus *Lithocarpus* have been found to be susceptible in artificial inoculations. (Rexrode and Brown 1983)

1.8. *C. fagacearum* is not known to be present in the UK, and, given current legislative controls on imports of timber; the risk of its being introduced is low.

Preparation

2.1. *C. fagacearum* is listed in Annex IAI of the EC Plant Health Directive 2000/29/EC.

2.2. It is present on the EPPO A1 list of quarantine pests.

2.3. It has been placed on the UK Plant Health Risk Register with an unmitigated risk rating of 100/125 (high) and a mitigated risk rating of

50/125 (medium). Current mitigation includes regulation, surveillance, preparation of a contingency plan, and increasing awareness amongst stakeholders.

2.4. A Rapid Pest Risk Analysis (PRA) for *C. fagacearum* was published in July 2015.

2.5. EU import controls define how timber of certain members of the Fagaceae (Quercus and Castanea spp.) must be treated before importation, including removal of bark and treatment by pasteurisation (in operational terms, kiln drying) or fumigation. More information can be found in Appendix 1: Import controls.

Legislation

2.6. A list of the legislation which might be relevant in a *C. fagacearum* outbreak is in Appendix 3.

Response

Trigger

3.1. The key indicators which would trigger a response are findings or reports of:

- the presence of an infected tree in a nursery, although there is no evidence that the pathogen can be transmitted via nursery stock or seed;
- the presence of an infected tree in the wider environment; or
- the presence of the disease in a consignment of imported wood, wood products or wood packaging material at the point of entry.

OFFICIAL ACTION FOLLOWING A PRESUMPTIVE DIAGNOSIS

Communication

3.2. In England, a duty officer from Forestry Commission England or the Animal and Plant Health Agency (APHA) will act as a point of contact for incidents, and it is their job to assign a response officer to incidents when they occur. Similar arrangements are expected to be in place for Scotland and Wales.

The response officer investigates and reports back to the Defra Contingency Core Group (CCG), which is an ad hoc group put together in response to a notification, and which is usually chaired by the Chief Plant Health Officer. Country teams in Scotland and Wales will fully manage the outbreak in accordance with their own generic contingency plans, but will provide updates to the CCG for information purposes and for Defra to report to the European Commission (EC).

3.3. The response officer will gather information, including the location, likely origin, host or commodity, level of damage, extent of outbreak, and risk of spread. The composition of the CCG will comprise plant health officials and specialists from the plant health risk group.

3.4 Based on the information fed back to it, the CCG in England will decide upon the alert status (black, amber or red) to be given to the outbreak, which will determine the level of response. (See Appendix 2 for Alert Status Table.) In Scotland and Wales, the CCG can advise on alert status and the appropriate response. If required, the CCG may request the relevant organisation/s to set up an Incident Management Team (IMT) to resolve the incident.

Holding consignments and movement / planting restrictions

3.5. Until further investigation, a containment notice should be served requiring that no material shall leave the outbreak site, and local operations associated with tree or nursery management will be suspended pending the results of the investigation. (This is a precaution, even though there is no evidence that the pathogen can be transmitted via nursery stock or seed.) The extent of the site will be determined by the IMT Controller.

Preliminary trace forward / trace backward

3.6. It is very unlikely that the oak wilt pathogen would be introduced through the nursery trade: the pathogen has never been reported associated with bare root or containerised nursery plants. Plant health agencies for the member countries of the UK will undertake any surveys required in nursery situations, e.g. Animal and Plant Health Agency (APHA) in England.

3.7. The most likely pathway for entry of the pathogen into the UK is on oak or sweet chestnut wood cut from infected trees and with bark still attached. There are several potential vectors for the pathogen in the UK should live fungus be present on imported oak or sweet chestnut timber. (See Appendix 1.) American and European chestnuts (*Castanea dentata* and *C. sativa* , as well as species of chinquapin (*Castanopsis sempervirens*) and tanoak (Lithocarpus) have all been affected by *C. fagacearum* following artificial inoculation, as have several varieties of apple (*Malus*). (Sinclair and Lyon, 2005; Rexrode and Brown, 1983)

3.8. Depending upon the entry pathway, tracing forwards and backwards to identify suspect material must be conducted to identify other potentially contaminated stock or sites.

Surveying to determine whether there is an outbreak

3.9. An outbreak of *C. fagacearum* is most likely to be detected through specific surveys carried out as part of the annual Protected Zone surveys for oak processionary moth, general surveillance by local authorities or other land managing organisations, or following a Tree Alert report of a suspected sighting from a landowner or manager, a member of the public, or an Observatree volunteer.

3.10. For reliable detection and identification of *C. fagacearum* in host material, laboratory testing must be conducted using EPPO Standard PM 7/1(1) English, Diagnostic protocols for regulated pests: *C fagacearum*. For molecular diagnosis, Internal Transcriber Spacer sequences are available in the various databases (e.g. GenBank). Updated molecular diagnostics

methods for *C. fagacearum* should be consulted (e.g. Wu et al. 2011) or developed further.

3.11. If there is evidence of the presence of *C. fagacearum*, follow-up inspections or surveys in England by APHA for non-woodland situations, and Forestry Commission England for woodlands, should gather the following information. (In Scotland the Scottish Government's Horticultural & Marketing Unit and Forestry Commission Scotland would carry out these inspections and surveys.)

- The likely origin of the infection.
- The geographical location and ownership of the affected site(s).
- Any other biotic or abiotic factors influencing the outbreak, such as public access, presence of watercourses, proximity to major highways. Maps should be included, if possible.
- The extent and impact of the infection in the outbreak area.
- Details of the host species infected at the outbreak site (species, variety, age, proportion of the host in wooded area etc). If known, the presence of potential vectors should also be recorded.
- The precise date when oak wilt was first suspected and detected. This must be recorded, along with the date of confirmation. Images of the symptoms should be included.
- Other possible host trees on the site. Although possibly not infected with *C. fagacearum*, these trees might be suitable breeding habitat for potential vector insects.
- Details of any recent movement of oak or sweet chestnut timber (or bark) which could be colonised by *C. fagacearum* or the potential vectors close to the affected site.
- Information about movements of people, products, equipment and vehicles etc as potential pathways.
- Inspection of oaks in any other known destinations of the potential pathway material.
- Relevant treatments applied to host plants which might affect development of symptoms or detection and diagnosis of the pathogen.
- History of the pathogen on the site, at the place of production, or in the area.
- The likely impacts on biodiversity of any control measure implemented, such as oak felling to control vector spread, and including any duty of care

requirements under the Natural Environment and Rural Communities (NERC) (2006) Act. This applies to England and Wales; Scotland has similar legislation in the Nature Conservation (Scotland) Act 2004.

3.12. Suspect material from infected trees in the wider environment for testing should be either:

(a) triple-wrapped in robust plastic bags; or

(b) double-wrapped in robust plastic bags and the bags placed inside a secure box or vial and sent immediately to the Tree Health Diagnostic and Advisory Service at Forest Research for diagnosis. Suspected vectors should be preserved in alcohol and sent in a similar manner as for suspect tree material. The samples should be accompanied by information about the date when the samples were collected, the location (address, postcode, GPS) and contact details of the person collecting the samples. The address is: Tree Health Diagnostic & Advisory Service, Forest Research, Alice Holt Lodge, Gravel Hill Road, Wrecclesham, Farnham, Surrey, GU10 4LH for England and Wales; and in Scotland: Forest Research, Northern Research Station, Roslin, Midlothian EH25 9SY.

Samples collected from nurseries by staff of APHA's Plant Health & Seeds Inspectorate (PHSI) should be sent to Fera Science Limited for analysis. In Scotland samples would be sent by the Scottish Government's Horticulture & Marketing Unit to the Scottish Government's Science & Advice for Scottish Agriculture (SASA).

Confirmation of an outbreak

3.13. The positive identification of plant pathogens, including *C. fagacearum,* requires molecular diagnostic protocols. See the '*EPPO Diagnostic Standard PM 7/1(1) English, Diagnostic protocols for regulated pests*: *Ceratocystis fagacearum*' for the currently accepted methods for identification of *C. fagacearum*. This document requires updating, because the molecular diagnostic methods reported are not well developed for this pathogen. More up-to-date molecular diagnostic protocols for identifying *C. fagacearum* in soil and infected wood are available. (Wu et al. 2011). Where on-site diagnostic systems have been developed, these may be undertaken by a pathologist or by a suitably trained and competent plant health officer.

Samples should only be removed from the site by trained individuals using safe and appropriate equipment, and operating in accordance with biosecurity guidelines.

OFFICIAL ACTION FOLLOWING THE CONFIRMATION OF AN OUTBREAK

Strategic actions on confirmation

3.14. The following should be done on positive confirmation in England:

- notify Westminster Ministers and senior Defra and Forestry Commission officials;
- set up regular (determined by scale of outbreak) Lead Government Department (LGD) meetings to keep partners aware of the current status, actions and possible future requirements, and to agree a communications strategy;
- notify the Devolved Administrations and the EC; and
- inform and discuss with stakeholders.

Incident management and communication

3.15. In situations where the outbreak is in woodland, Forestry Commission England will appointment an incident controller and an IMT. APHA would take the lead for outbreaks in nurseries in England and Wales. In Wales the Welsh Government, with support from Natural Resources Wales, would take the lead in woodland situations. Forestry Commission England's Forest Services will work to the generic Defra contingency plan, which will be enacted in response to a confirmed outbreak. The Scottish Government, including Forestry Commission Scotland, and the Welsh Government will work to their own generic contingency plans.

3.16. Initial efforts will be directed towards eradicating new outbreaks following the procedures set out below. Failing eradication, efforts will concentrate on containment.

3.17. The incident controller will set up a management structure to implement the incident management functions. The outbreak will determine the size

and nature of the management structure. Identification of and liaison with key stakeholders is a crucial part of this process. An example list of such stakeholders would include, but not exclusively: ICF, Confor, Scottish Government, Welsh Government, Natural Resources Wales, Environment Agency, Natural England and other members of the Defra Group, SEPA, Forest Research, Woodland Trust, National Trust, Country Land & Business Association, Scottish Land & Estates, Royal Horticultural Society, National Farmers' Unions and local councils.

Surveillance

3.18. A delimiting survey should be undertaken as soon as possible after the first finding and confirmation of oak wilt in an area. The survey will determine and map the extent of spread to demarcate a regulated area. Two parallel strategies should be adopted in the delimiting survey:

- an **intensive survey** of all oak trees, both native and exotic and, as a precaution, sweet chestnut trees within at least 1km radius of the first tree(s) found to be infected. The 1km radius (3x350m, which is the maximum combined flight and wind aid dispersal distance of potential insect vectors) has been set on the precautionary basis that insect transfer of spores is feasible in Britain or the UK;

- line transects along the north, south, east and west axes outwards to approximately 5km from the confirmed infection site, with visual inspection of oak and sweet chestnut trees at regular intervals (e.g. every 50-100m) and to 50m each side of the transect, to estimate the full extent of spread. Any felled materials (sample branches or leaves of symptomatic trees) must be disposed of using the protocols described under 3.36 below. Open wounds should be treated by applying wound paints. More information is available in 3.34 below.

Where available, helicopter surveillance, using naked eye and binoculars, will be made instead of line transects to survey forest areas to the approximate 5km points as suggested above. Alternatively, unmanned aerial vehicles ('drones') carrying multi-spectral imaging equipment might be useful for detecting declining oak or sweet chestnut trees.

3.19. Vector beetles in the USA are attracted to weakened trees, or trees wounded by, for example, vehicles or construction activities. (Note that the same species are not present in the UK, and it is not known whether native UK beetles can act as a vector.) Survey work, therefore, should pay particular attention to standing trees which have recent wounds, or are affected by other biotic or abiotic problems, whilst also making basic observations on other trees on the transects. Insect vectors might also feed or lay eggs in freshly felled trees and branch material etc. from recent felling or pruning operations (up to 18 months after cutting).

3.20. It is possible to use sentinel logs and/or traps spiked with generic pheromones to attract potential vector insects for testing. Any oak and sweet chestnut trees showing possible symptoms of wilt, including dieback and death, should be examined for fungal spore mats below cracks in the bark, particularly on the main stems and large scaffold branches. The main visual diagnostic symptoms are branch dieback and dark streaks or staining in the xylem. Samples can be removed for laboratory analysis to determine the possible presence of *C. fagacearum*.

3.21. If further trees are found with *C. fagacearum* infection during the surveys, the limits of the survey should be extended to examine all oaks to a distance of at least 1km from the newly discovered infected trees. The line transects must also be further extended to enable trees within approximately 5km of the additional infected trees to be examined. (See above). Using a step-wise process each time new infected trees are found, the surveys must be extended to ascertain the true extent of the affected area. The surveys must be repeated in following years to monitor any further spread of *C. fagacearum*, and to delimit the boundaries of the infections.

Demarcated zones

3.22. A demarcated statutory regulated area should be established as soon as possible after the discovery of an outbreak of *C. fagacearum* to stop the spread of the pest by human-assisted transport. (See 3.24 below.)

3.23. A protected zone of about 1km radius should be established around infected trees, where all oak trees will be assessed for the presence of *C.*

fagacearum. Appropriate measures to prevent the movement outside the affected area of all potentially infected host material must be implemented. These measures should include a prohibition on the movement of untreated host material (including firewood, round wood, sawn wood, wood chips, waste wood, seeds, foliage, bark and arboricultural arisings). All infected trees, and those with recent wounds, within this area should be felled, and the resulting timber burned on site. (**See 3.29 for tree removal requirements within 30m of infected trees**). No wood should be removed from the area. Any felled materials must be disposed of using the protocols described under 3.33 below.

3.24. A buffer zone of about 5km around the infected zone should be established. The infected zone and associated buffer zone together make up the demarcated area. Within the buffer zone, surveillance should be carried out during the growing season from the time when foliage has fully opened to early autumn, each year, at intervals of 8-10 weeks. This should be enough for any new infections to begin showing symptoms. If these surveys identify new infections, the infected and buffer zones must be further extended, to the limits indicated above.

3.25. As a precaution, even though there is no evidence that the pathogen can be transmitted via nursery stock or seed, nurseries within the demarcated area will be inspected for the presence of *C. fagacearum.* They will also have their plant passporting authority for oak and sweet chestnut plants suspended as a precaution until the presence or absence of *C. fagacearum,* both within the nursery and within the demarcated area, can be determined.

3.26. Timber yards within the demarcated area will have their operations which involve oak material (e.g. timber import and/or export) halted until the presence or absence of *C. fagacearum,* within both the timber yard and the demarcated area, can be determined.

Tracing forwards and backwards

3.27. The most likely pathway is untreated oak wood with bark, imported from the USA. Tracing forwards and backwards to identify suspect material, therefore, should be relatively straightforward, provided that the first identification of the presence of the problem was made at an early stage in the invasion process. Surveys will be conducted to identify other potentially infected trees, and to identify oak timber in hardwood timber mills,

transport or storage. The surveys should focus on timber imported from North America.

Any consignment which contains infected timber will be destroyed as specified under 'disposal', below.

Pest management procedures

3.28. Depending on the location of the new outbreak, Statutory Plant Health Notices (SPHNs) requiring actions associated with eradication to be carried out will be issued in England by the Forestry Commission (in woodland situations) or, in England and Wales, by APHA in nurseries and non-woodland situations. Timely issue of and responding to these and subsequent actions is vital if new outbreaks are to be contained and eradicated. It should be made clear at the outset that the costs of any remedial actions required will be borne by the landowner. The Forestry Commission or APHA will also need to consider whether direct intervention funded by government is required to ensure a rapid response to reduce the risk of spread.

3.29. Procedures to be adopted on the diagnosis of oak wilt are given below and are based on the North American experience. (Karrie A. Koch, Gina L. Quram, Robert Venetts 2009).

When *C. fagacearum* infection is first found, the initial goal of the management programme should be eradication. As a precautionary, pre-emptive approach, a clear-cut zone should be established with a minimum radius of 30m around oak trees in which definitive *C. fagacearum* infection has been diagnosed. All susceptible trees and plants, including oaks and sweet chestnut, in this clear-cut zone must be felled and burned as close to the site of felling as is feasible. Felling and burning of the tree and other plants must be carried out from the outside of the zone towards the centre. Trees must be felled and removed during the autumn or winter to minimise the risk of spread by sap beetles the following year. If the material cannot be burned *in situ*, any timber greater than 1.5cm in diameter must be wrapped in heavy-duty black plastic and tightly sealed before being moved to the burning site. This procedure will minimise the risk of insect vectors leaving the felled timber and other debris.

3.30. Parts of the host tree/plant, within the 30m clear-cut zone, to be examined in detail include branches of 1.5cm diameter and greater showing any dieback symptoms: clean transverse cuts through this material should be examined for the presence of staining in the xylem tissues, which would be indicative of a wilt-type infection. The large scaffold branches (arising from the main stem) and the main stem itself should be closely examined for the presence of longitudinal cracks in the bark, which can be indicative of fungal sporulation mats. Ideally, the bark should be stripped from scaffold branches and main stems on the felled material, to determine whether sporulation mats are present. Sapwood tissues should be removed from the main stem and sent for diagnosis. Any larvae of bark-boring beetles present should also be sampled and sent for identification. (See 3.12.).

3.31. After sampling, susceptible felled trees must be destroyed on site (burnt) or wrapped in plastic before being moved under official licence for processing. Potentially infected trees should NOT be used for firewood, because sporulation mat production can occur on felled timber, and the timber attracts bark beetle vectors.

3.32. Pheromone traps can be used to collect potential insect vectors of *C. fagacearum*. The traps should be placed outside buffer zones (to help determine whether the disease could have been carried out beyond the buffer zone), and sampled after the flight time of the potential vectors, between July and September in each year. Diagnosis must include identification of insects present, and diagnosis of any new *C. fagacearum* infections. If surveying finds further evidence of oak wilt expansion, buffer zones must be extended accordingly.

3.33. The European oak bark beetle (*Scolytus intricatus*) is relatively widespread in England and Wales, although there are no records of it in Scotland or Northern Ireland. Controlling insect vectors with insecticides is not likely to be practicable due to the wide area which would need to be treated, and the collateral damage which would be done to non-vector species.

3.34. Within the demarcated zone, oak pruning should be avoided between April and June. (O'Brien et al., 2000). When pruning or other damage to oak trees is unavoidable, many authors recommend immediately applying wound paints or dressings. (French and Juzwik, 1999; Wilson, 2001, 2005; Camilli et al., 2007) Wound paints and dressings can be effective by either reducing the attractiveness of fresh wounds to nitidulid beetles or

preventing the entry of Ceratocystis spores into the vascular system of wounded trees. (Camilli et al., 2007)

3.35 Natural spread by transfer through root grafts or common root systems is well documented (e.g. Gibbs and French, 1980; Cooke, 2001), but typically only results in expansion of localised disease foci. Whitford et al. (2007) suggest that in Wisconsin oak savanna an average distance between mature red oak trees of less than 9m assures continuous root-to-root transmission of the disease. For that reason the installation of trenches at least 1.2m deep will prevent continual tree-to-tree spread of the fungus through interconnected live oak root systems. (PRA) This protection method could be considered in urban situations where oak trees of high amenity value are present.

Disposal

3.36. Conditions must be imposed on the movement of susceptible plants (as a precaution) and wood within and from demarcated areas, including the buffer zone. Infected trees within the infected zone must be felled and burnt on site, together with all oak and sweet chestnut trees within 500m of infected trees (or as near to the site as is feasible). Fumigation of the logs with a currently approved proprietary product is an alternative to burning. (See current lists of suitable chemicals.) With suitable site preparation, burning can be carried out within the demarcated area. Alternatively, a licenced processing facility may use the timber as fuel, with suitable precautions taken during transport of the timber. If burning, Environment Agency or SEPA guidelines must be followed. All woody materials, including waste wood and debris, should be destroyed in the same way. All equipment used in the disposal of *C. fagacearum*-infected trees should be cleaned thoroughly between sites, following standard biosecurity protocols.

3.37. For previous plant pest and disease outbreaks in England, Forestry Commission England used incineration contracts agreed with the Environment Agency, allowing it to exceed the usual 10 tonnes-per-day limit. Such contracts could be used in a *C. fagacearum* outbreak. A site-by-site agreement with the Environment Agency or SEPA is good practice for disposal by burning.

3.38. Heat treatment in a licensed treatment facility may also be used, following the specifications of ISPM 15. Composting treatments have not been used to treat wood infected by *C. fagacearum* in the USA. Although chipping of timber from affected trees has been used, this process is not considered suitable, because living pathogen could persist in the wood, and be vectored by insects attracted to the fragmented spore mats.

Public outreach

3.39. It is crucial to have public support for the management programme and to help with general surveillance. Engaging the public and key stakeholders will require the provision of timely, balanced and accurate information about monitoring and control. It can also provide opportunities for the public to participate in monitoring and reporting suspect trees using the reporting tool Tree Alert. The voluntary tree health surveillance network, Observatree, could also be deployed. Information, subject to available budget, can be made available through newspapers, radio, TV, publicity materials, the internet and social media, and should be targeted locally, especially within the infected and regulated areas and, where appropriate, regionally and nationally.

3.40. It is important to provide:

- information about the location and size of the infected and regulated areas, and statutory and voluntary responsibilities; and

- indications of changing or enlarging distribution, management options, pathways by which the pest might have arrived and could be dispersed, the prospects for British forestry and the host species more generally, and what people can do to help, especially in terms of monitoring.

Managing this level of public engagement can require a central administration office capable of handling a large number of enquiries and able to provide general and specific information. Liaison with communications and press offices from devolved administrations will be required for cross-border outbreaks.

Review measures in the case of prolonged official action

3.41. If attempts to eradicate the outbreak prove ineffective, efforts should shift to containment, with the focus moving from outbreak management for eradication to a plan for containing the outbreak. If continuing action is required within the demarcated area over a prolonged period, a review of the management programme should be undertaken regularly (e.g. annually) to determine the success and cost effectiveness of the measures in the longer term. This review will involve consultation with stakeholders and should include:

- evaluation of the effectiveness of current measures;
- evaluation of the economic impact and cost effectiveness of continuing existing measures;
- consideration of further measures to strengthen containment and eradication actions;
- consideration of statutory obligations and impact on import and export procedures;
- consideration of alternative approaches or the cessation of statutory action; and
- consideration of the impacts on biodiversity from control methods.

3.42. In circumstances where eradication efforts have proved ineffective, other methods for the management of ongoing outbreaks of oak wilt disease should be considered to contain the disease, in consultation with stakeholders. These methods, which are widely used in affected areas in the USA, include:

- survey work, usually in response to woodland or tree owners reporting the problem;
- full diagnosis of the problem, based on visual survey work and the application of diagnostic laboratory methodology to suitable materials from affected trees;
- felling and burning trees already showing wilting symptoms when positive diagnosis is obtained; .
- use of root-cutting equipment to sever any possible connections at root grafts between infected trees and surrounding uninfected trees. The

distance from the affected trees at which root cutting is carried out should be determined by a professional disease expert;

- continued monitoring of the affected sites at least annually, to determine whether the pathogen has 'jumped' the root cutting. Should this have occurred, it will be necessary to repeat the felling and root cutting, following suitable expert advice;
- use of prophylactic fungicide injection to reduce the chance of infection of oak trees of very high aesthetic or amenity value and where the probability of root-to-root transmission is high.(Juzwik et al. 2011). The fungicide selected must be determined following consultation of the current approved lists for the EU, and the procedure must be carried out by an approved contractor. In the USA, Alamo, a formulation of the systemic fungicide triazole propiconazole, has been used for this purpose. Treatments are most effective if a tree known to be under threat from infection from nearby infected trees is injected. Wilt symptoms in the crowns occurred in 40% of treated red oak trees within three to five years after injection, necessitating further injections, which gave another year of disease suppression. (Peacock and Fulbright 2009). In white oaks (*Quercus alba*, *Q. microcarpa*), fungicide injections have protected trees from further infections for five years. (Eggers et al. 2005). Similar measures have been used over many years against Dutch elm disease; and
- use of root cutting equipment to sever root-to-root grafts at the same time as fungicide injection. Although these procedures do not eliminate oak wilt in some instances, they considerably slow the progress of the disease. This enables the retention of oaks in the area until alternative species have attained sufficient stature to reduce the landscape impacts resulting from the loss of oaks.

Criteria for declaring a change of policy and reviewing the contingency plan

3.43. This and other contingency plans will be reviewed annually to accommodate any significant changes in pest or pathogen distribution, dispersal, refinement of surveillance techniques, legislation changes or changes in policy. There will be a move towards containment when and if policy makers in the country or countries affected deem that eradication is no longer practicable. The criteria for determining such a break point could

be based on a proportion of host species lost, a set number of hectares lost, number of individual outbreaks, resources needed, or a combination of these. However, this will be determined by the policy makers in the country or countries affected. Further details can be found in the Defra Generic Contingency Plan.

In circumstances where statutory action is no longer considered appropriate, stakeholders should be consulted and a timetable and mechanism agreed for the removal of statutory measures and for the dissemination of information about managing the pest as appropriate.

This Contingency Plan will be reviewed and stakeholder views sought on proposed changes if new information is presented which significantly affects the approach to the management of an outbreak.

Recovery

4.1 A site can be deemed as recovered from an outbreak if, after five years of monitoring, there are no indications of oak wilt in remaining *Quercus* spp at that location within the infected and buffer zones. Five years is used in the USA as the time limit for eradication efforts. The clock is reset if an infection centre appears in the eradication zone within that time.

Appendix 1: Pest background information

Identity of organism and quarantine status

Species name:	*Ceratocystis fagacearum* (Bretz) J. Hunt
Synonyms:	*Endoconidiophora fagacearum* Bretz
	Chalara quercina Henry
	Thielaviopsis quercina (Henry) A.E. Paulin, T.C. Harr. & McNew
Common name:	Oak wilt (a fungal pathogen)
UK risk rating:	Unmitigated 100/125; Mitigated 50/125
EU status:	*Ceratocystis fagacearum* is on the EPPO A1 list, EU Annex designation I/A1 (1992), Commission Decisions 83/87/EC, 2000/780/EC, 2005/359/EC, 2005/359/EC and (2006/750/EC).
UK status:	Not present

Hosts

There are approximately 600 species of *Quercus* known, of which 16 are listed as susceptible to damage by *C. fagacearum* infection by EPPO. It is known, however, that all 58 North American native oak species are susceptible to damage. The most susceptible species are red oaks (*Quercus* section *Lobatae*), all of which are native in North America. The two UK native species of oak, *Quercus robur* and *Q. petraea,* are white oaks (*Quercus* section *Quercus*), but are known to be susceptible to the pathogen, dying within one year of inoculation with *C. fagacearum.* (Pinon et al. 1997). Other oaks planted in the UK include members of the sections *Cerris* (e.g. *Q. castaneifolia, Q. cerris*, *Q. trojana*) and *Mesobalanus* (e.g. *Q. frainetto, Q. macranthera, Q. pyrenaica*).

Tree species in several other genera within the Fagaceae have been reported to be susceptible to *C. fagacearum* in artificial inoculations, including *Castanea dentata* and *C. sativa, Castaneopsis sempervirens*, and species in the genus

Lithocarpus. (Rexrode and Brown 1983). The North America bush chinquapin (*Castanea pumila*) and a species of Chinese chestnut, *C. mollissima,* have been found as additional natural hosts, dying rapidly after infection. (Bretz and Long 1950)

Symptoms

The disease is first seen when dieback begins in the crown of infected trees. In red oaks, symptoms begin to appear within weeks of infection, when yellowing of the leaves occurs, particularly along the veins, followed by 'scorch', typically starting at the tip of the leaf. There is a clear demarcation line between the dead and live tissues. Leaf symptoms, however, can be patchy, even on a single leaf, with brown zones, olive-green patches, and areas of the leaf which maintain a healthy colour. The affected branches of red oaks develop a false autumn colour within a short time as the tree wilts from the top downwards.

Brown staining is usually visible in the outermost sapwood of affected branches cut through a cross-section, which is a typical plant response to the presence of a wilt pathogen. However, this symptom is not seen consistently in infected trees.

Elongated cracks are sometimes present on the trunks of infected dying trees, due to turgor pressure exerted by the formation of fungal sporulation mats under the bark. A fruity smell might be detected adjacent to the cracks. The presence of these mats is a definitive feature of the presence of *C. fagacearum.* Timing and frequency of sporulation mat formation varies, influenced by when the infection first occurred and, probably, with local environmental conditions. They only form when sapwood moisture content is between 37% and 45%.

Infected red oaks can die within four to six weeks. North American white oaks, however, have been known to recover from infections, or take many years to die. Even in white oaks which recover, whole branch systems may be killed, but the remainder of the tree lives on for many years.

Symptoms on white oak in North America are more cryptic and the pathogen less damaging. Death is uncommon, with only partial canopy dieback. Fungal sporulation mats and resultant bark cracking are not usually seen in white oaks.

Figure 1: Red oak cracked bark - Joseph OBrien, USDA Forest Service; Bugwood.org

Figure 2: Oak wilt symptoms - Paul A. Mistretta, USDA Forest Service; Bugwood.org

Figure 3: Affected oak tree - Joseph OBrien, USDA Forest Service; Bugwood.org

Life cycle

As a typical vascular wilt pathogen, *C. fagacearum* is restricted to xylem vessels in the current sapwood during the active disease phase of the life cycle. The fruity odour of the sporulating fungal mats attracts insects and other animals. Insects, particularly sap beetles (Nitidulidae) in North America, feed on these mats and pick up spores on their exoskeletons, subsequently acting as vectors by carrying the spores to healthy trees. North American oak bark beetles might also emerge from infected trees with spores on the exoskeleton.

There is also an underground component in disease spread, because the pathogen can pass from tree to tree via root grafts. Root grafting is particularly common in the red oak group, but also occurs in white oaks, and even between red and white oaks, although more rarely. Some stands of red oaks contain a limited number of clonal trees, because shoots can arise from the roots. Root grafts are known to occur between individual trees of the European *Quercus* species. (Pinon et al. 1997)

An illustration of the life cycle in North America is presented in Figure 4.

Vectors

In North America, the main vectors for *C. fagacearum* are thought to be Nitidulid beetles - *Colopterus truncatus* and *Carpophilus sayi*. These beetles feed on the sporulation mats, then transmit the pathogen to healthy trees when feeding on sap from wounds caused, for example, by machinery. *C. truncates,* considered a universal vector in the mid-western and mid-Atlantic states of the USA, is distributed from southern Canada to Chile in South America.

The oak bark beetles *Pseudopityophthorus minutissimus* Zimm. and *P. pruinosus* Eichh. (Coleoptera: Scolytidae) are more common vectors in the southern range of the disease in North America.

The most suitable vector for *C. fagacearum* in northern Europe is predicted to be the European oak bark beetle, *Scolytus intricatus* (syn. *S. picicolor*), which is widespread in England and Wales, although there are no records of it in Scotland or Northern Ireland. (Figure 5) *S. intricatus* breeds in the bigger (scaffold) branches and main trunks of dead and dying oak trees. Logs cut from felled oaks are also suitable material for oviposition (egg-laying) and breeding for up to 18 months following cutting. The galleries which the insect forms under the bark are perfect for sporulation of the pathogen, and when adult beetles emerge, the sticky spores become attached to their exoskeletons. Following emergence, the adults maturation feed in twig crotches, in a similar fashion to that of elm bark beetles, and the pathogen could, therefore, be transmitted to healthy trees via these feeding wounds.

A factor mitigating spread of *C. fagacearum* by *S. intricatus*, however, is the timing of maturation feeding, which occurs during late wood formation in summer, as opposed to early wood formation in the elm situation. The susceptibility of North American oaks to infection by the pathogen is greatest during early wood formation in spring.

S. intricatus adult beetles can fly up to 100m in the absence of wind, although wind can carry them much further.

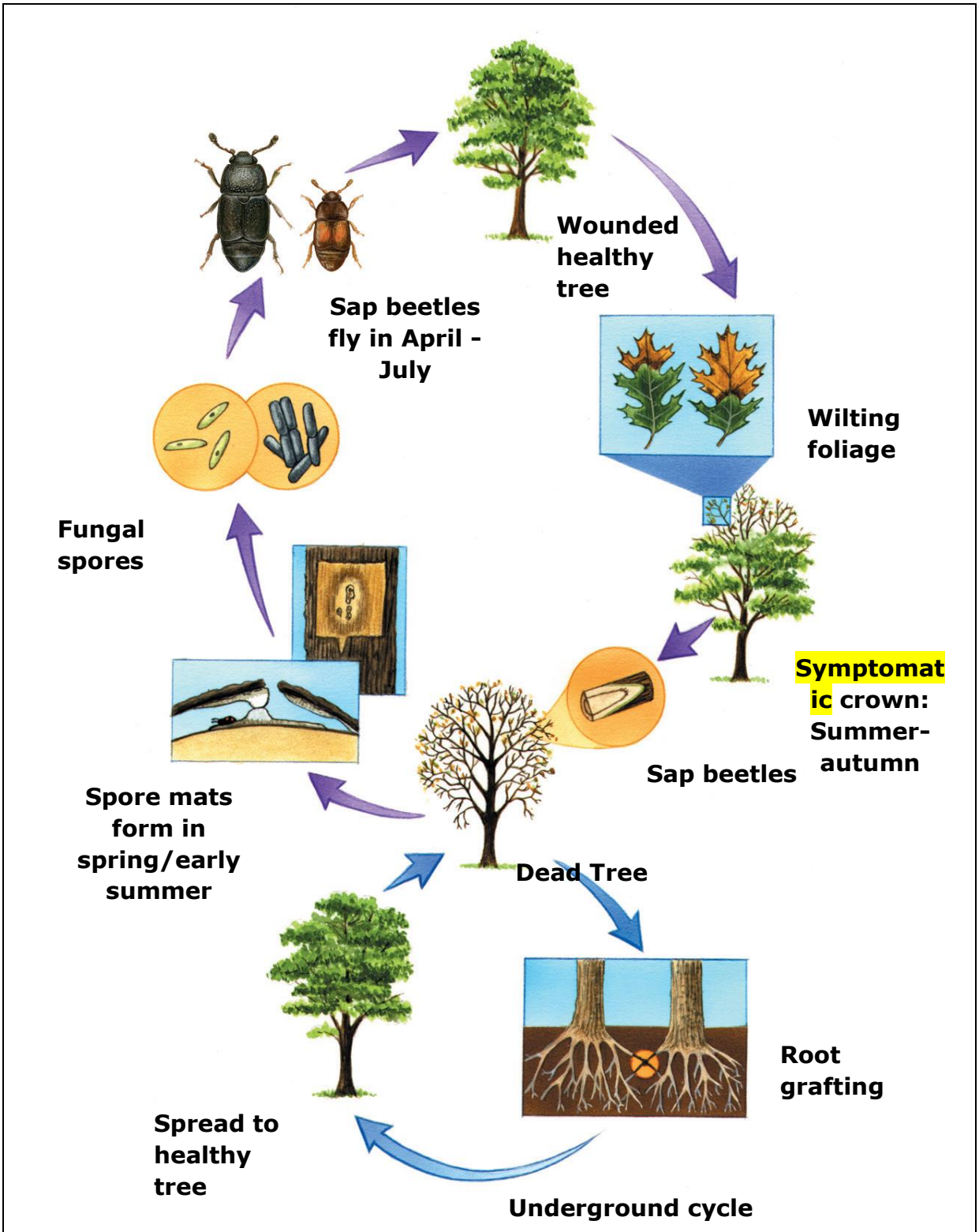

Figure 4. Life cycle of oak wilt in the USA. (Courtesy of the USDA Forest Service).

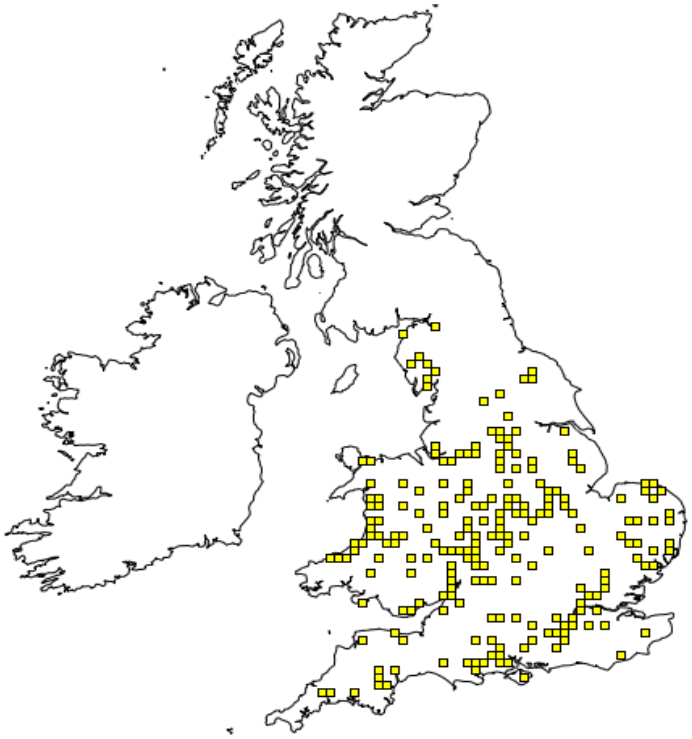

Figure 5: Known distribution of *Scolytus intricatus* (oak bark beetle) in the UK, based on findings at a resolution of 10 x 10km squares. Courtesy of the National Biodiversity Network database https://data.nbn.org.uk/Taxa/NBNSYS0000025525/GridMap

Several other insects bore into oak bark in Europe, but their potential to act as vectors of *C. fagacearum* is unknown. Examples include the oak pinhole beetle (*Platypus cylindrus)*, which attacks stressed trees and could, therefore, find the sporulation mats of the pathogen attractive. This beetle acts as a vector of plane wilt in Greece. Populations of the bark borer *Agrilus biguttatus* are increasing in the UK and are associated with trees affected by acute oak decline. The flat-headed borer, *Agrilus biguttatus*, and another ambrosia beetle, *Xyloterus domesticum*, might also attack stressed oaks. The propensity of longhorn beetles (e.g. *Anoplophora* species; Cerambycidae) to vector pathogens has received little attention.

Distribution of the organism

Although long believed indigenous to North America, the origin of the pathogen is now considered uncertain. It has been suggested that *C. fagacearum* might be indigenous to Central or South America, or, if it is native to North America, its

origins lie in Mexico. (Juzwik et al. 2008). Despite being widespread in the mid-western states of the USA, the pathogen has not yet been reported in Canada.

The current known distribution of the pathogen is shown in Figures 6 and 7.

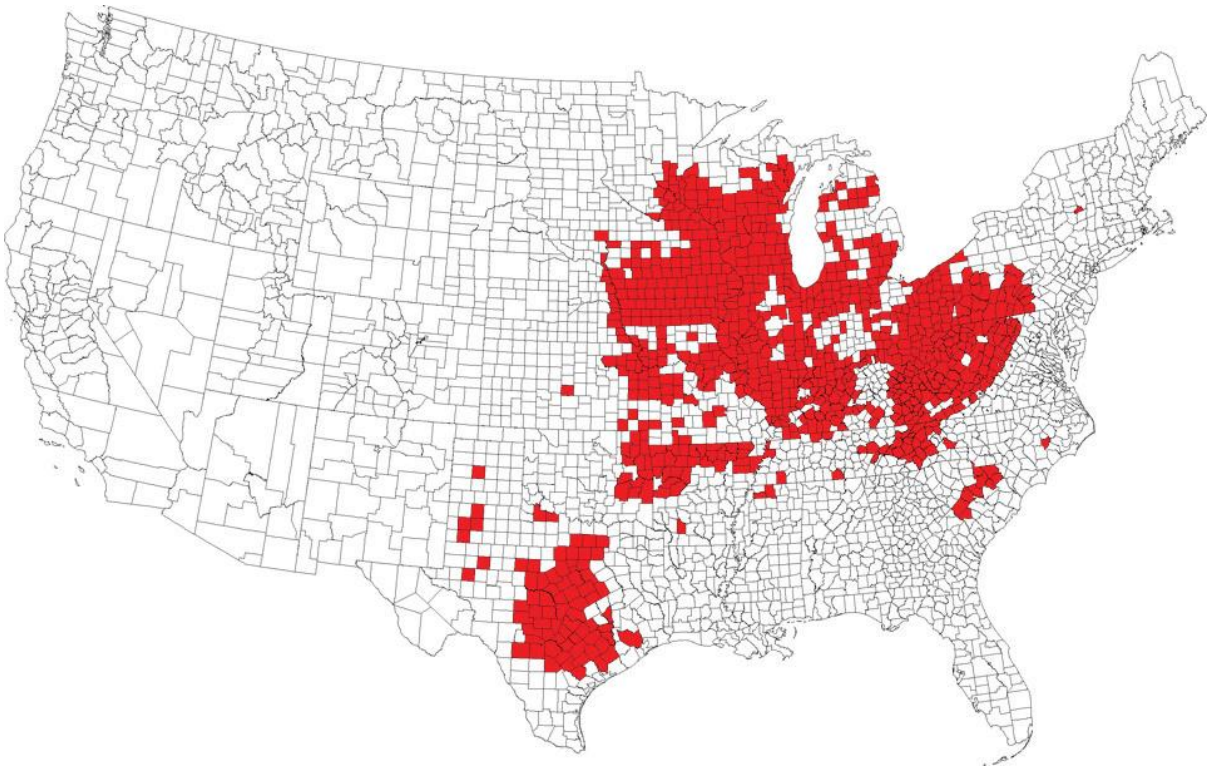

Figure 6. Distribution of oak wilt in the USA (2010). USDA Forest Service http://na.fs.fed.us/fhp/ow/maps/ow_distribution05.gif (modified by Juzwick et al. 2011)

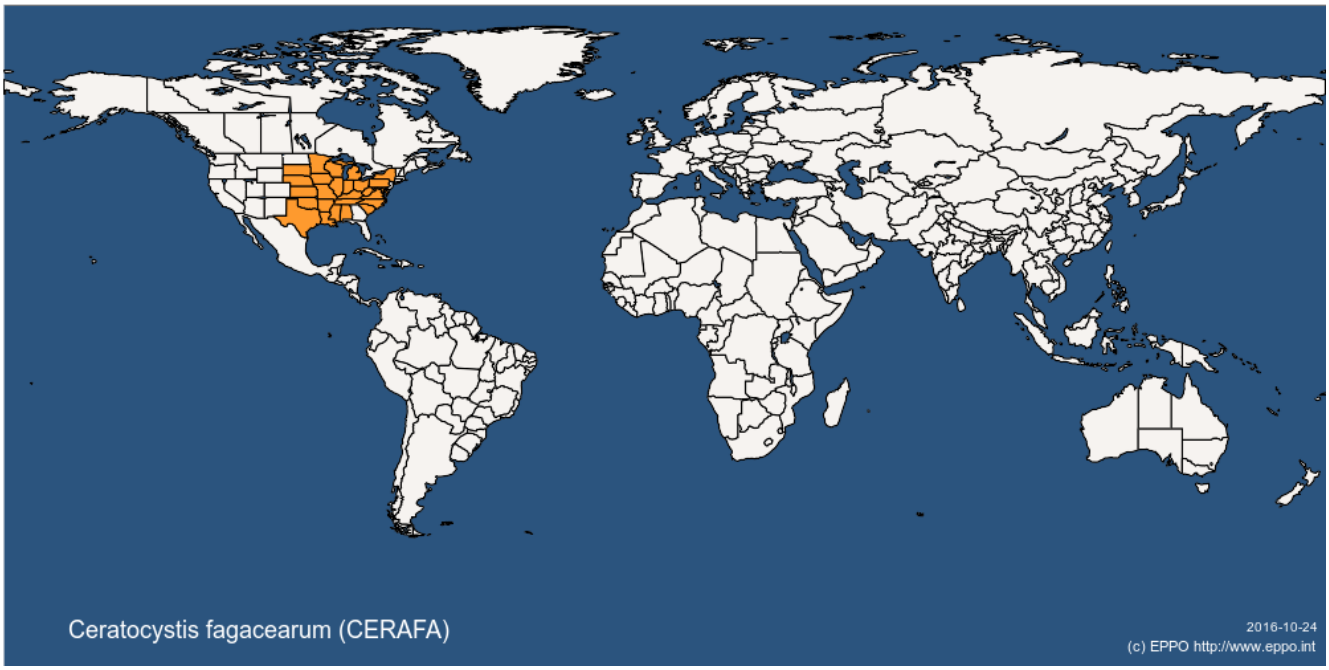

Figure 7: Distribution of *C. fagacearum* as of October 2016 - (EPPO PQR database)

Damage, impact and control

Mortality of oaks in North America, initially centred on Wisconsin, was first noted in the late 19th Century, but was not considered a potentially serious problem until the 1930s. Some of the apparent increased occurrence of the disease in the first 40 years of the 20th Century might have been due to recognition of the problem rather than spread of the pathogen. Notable new outbreaks, however, have included the first record in Dallas in 1961, and in 2008, oak wilt was confirmed causing mortality of *Quercus rubra* in Schenectady County, Scotia, New York.

In contrast to North American white oaks (*Quercus* Section *Quercus* [syn. *Lepidabalanus*; *Leucobalanus*]), European white oaks appear to be highly susceptible to infection and damage by *C. fagacearum*.

Main pathways

The main pathway for spread of *Ceratocystis fagacearum*, other than via root grafts, is through insect transmission, described in 'Vectors' above). The extent to which human-aided transmission contributes to spread of the disease is

unclear. Logs with sporulation mats might be transported, either for sawn-timber production or firewood, clearly presenting a danger. It is also unclear whether logs would provide suitable habitat for survival of *C. fagacearum* during shipping across the Atlantic, for example. It is unlikely that adult insect vectors would survive the journey, but larval and pupal stages might, and potentially then transmit any live fungal propagules to oak trees in the vicinity of receiving ports.

There is no evidence that the pathogen can be transmitted via nursery stock or seed: no natural infections have been reported in nurseries producing containerised stock or bare root plants of *Quercus*.

Import controls

Controlling imports of oak timber into the EU, in a general sense, is specified under Plant Health Directive 2000/29/EC, implemented in Great Britain by The Plant Health (Forestry) Order 2005. This Order provides the '*principal instrument for managing the import of trees, wood, wood products and bark*', and specifies '*Oak* (Quercus) *originating in the USA*' as a commodity.

The specific requirements related to import of *Quercus* timber are summarised at http://www.forestry.gov.uk/forestry/INFD-9NRKTT#oak. Before importation into the UK, any oak timber from the USA and Canada must be squared to remove the rounded surfaces, be bark-free, and be dried to less than 20% moisture content. In addition, it must be disinfected by an 'appropriate' heating treatment, such as hot air or hot water, or kiln dried and labelled as such. Other woody material arising from oaks, such as chips, wood waste or scrap, must be similarly treated. No bark of oaks is permitted.

Some European countries have allowed the importation of bark-covered oak logs from the USA for veneer production. (EC derogation decision 2005/359/EC, extended to 2020 in 2010, by the EC derogation EC 2010/793). However, this does not apply to any UK ports.

Other oak wilt pathogens

It is important to note that two other pathogens are causing oak wilt on a number of *Quercus* species in the Far East.

In Japan, *Raffaelea quercivora* Kubono & Shin. causes mortality on *Quercus crispula* and *Q. serrata*, and also attacks other species of Quercus, as well as *Castanea*, *Castanopsis* and *Lithocarpus species.* The main vector in Japan is the ambrosia beetle *Platypus quercivorus* Murayama (Coleoptera: Platypodidae), which transports the pathogen between host trees in mycangia.

In Korea a second pathogen in the genus *Raffaelea*, *R. quercus-mongolicae,* is attacking oak species, including *Quercus mongolica, Q. aliena* and *Q. serrata*; the main vector is thought to be the ambrosia beetle, *Platypus koryoensis,*

Symptoms on infected trees are difficult to distinguish from those caused by *C. fagacearum*, underlining the importance of thorough diagnostics of any suspected outbreaks.

These pathogens have yet to be added to the EPPO A1 list or the UK Risk Register.

Appendix 2. Alert Status categories – (based on alert status levels for draft Defra generic contingency plan).

ALERT	STATUS	COMMAND LEVEL
White	Plant pest or disease with potential for limited geographical spread	Instigation of incident management plan involving operational command at appropriate level, and implementation of Standard Operating Procedures or scientific advice where applicable
Black	Significant plant pest or disease with potential for limited geographical spread	Instigation of incident management plan, usually involving joint tactical and operational command at appropriate level. Implementation of plant pest/disease-specific response plans where applicable
Amber	Serious plant pest or disease with potential for relatively slow, but extensive, spread leading to host death and/or major economic, food security or environmental impacts	Instigation of incident management plan usually involving joint strategic and tactical command, and plant pest/disease-specific response plans where applicable
Red	Serious or catastrophic plant pest or disease with potential for rapid and extensive geographical spread leading to host death and/or major economic, food security or environmental impacts	Instigation of incident management plan involving strategic, tactical and operational command, and implementation of plant pest/disease-specific response plans where applicable

Appendix 3: Relevant legislation

Domestic:

The Waste Management Licensing (Scotland) Regulations 2011
The Environmental Permitting (England and Wales) Regulations 2010
Natural Environment and Rural Communities Act 2006
Nature Conservation Act Scotland 2004
Plant Health (Forestry) Order 2005
Plant Health Act 1967
Forestry Act 1967

European:

EC Council Directive 2000/29/EC
EC Commission Decision 2010/723

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