CAPS Datasheets provide pest-specific information to support planning and completing early detection surveys.

Hymenoscyphus fraxineus (T. Kowalski) Baral et al.

Scientific Name

Hymenoscyphus fraxineus

Synonyms:

Chalara fraxinea
Hymenoscyphus pseudoalbidus

Common Names

Ash dieback, ash decline, chalara dieback of ash

Type of Pest

Fungal pathogen

Taxonomic Position

Class: Leotiomycetes, **Order:** Helotiales, **Family:** Helotiaceae

Pest Recognition

This section describes characteristics of the organism and symptoms that will help surveyors recognize possible infestations/infections in the field, select survey sites, and collect symptomatic material. For morphological descriptions, see the Identification/Diagnostic resources on the AMPS pest page on the CAPS Resource and Collaboration website.

Figure 1. Mature *Fraxinus excelsior* (European ash) showing extensive shoot, twig, and branch dieback from *H. fraxineus* infection. Photo courtesy of Andrin Gross.

Ash dieback, which is caused by *Hymenoscyphus fraxineus,* results in the wilting and death of leaves and shoots of infected trees (Fig. 1). Shoot and leaf dieback is visible during summer months (Woodland Trust, 2021). *Hymenoscyphus fraxineus* affects susceptible trees of all ages (Schumacher, 2011), although saplings and young trees are particularly vulnerable (Grosdidier et al., 2020; Husson et al., 2012; Kjær et al., 2012). Older trees infected with *H. fraxineus* can regenerate parts of their crowns, but the presence of another pathogen can accelerate dieback symptoms and hasten tree death (Madsen et al., 2021).

Symptoms

Trees infected with *H. fraxineus* exhibit a wide range of symptoms, including brown spots on the leaves and leaf stalks, wilting and premature leaf shedding, brown-to-orange bark necrosis on shoots, dead shoots and branches, a proliferation of epicormic shoots (shoots that appear from dormant buds on an existing tree branch or trunk), bark cankers, and wood discoloration (Bakys et al., 2009) (Fig. 2, 3, 4). Collar lesions have also been reported (Fig. 5) (Enderle et al., 2013; Husson et al., 2012; Skovsgaard et al., 2010) and are correlated with infection intensity (Bakys et al., 2011). However, in many field surveys for *H. fraxineus* in Europe, collar lesions are seldom seen and occur under specific site conditions (Langer, 2017).

Figure 2. Small necrotic lesions on shoots of young *F. excelsior* (European ash) prior to budburst. Photo from Kirisits et al. (2008).

When infected leaves remain attached, necrosis can sometimes progress into shoots as the fungus invades more tissue, producing characteristic diamond shaped lesions where branches meet the trunk. The inner bark appears brownish-grey under the lesions (Woodland Trust, 2021).

Figure 3. Canker caused by *H. fraxineus* on *F. excelsior* (European ash) (left) and canker with bark removed (right). Photos courtesy of H. Solheim. Norwegian Forest and Landscape Institute, Aas, Norway. www.eppo.org.

Easily Mistaken Species

Ash yellows (‘*Candidatus* Phytoplasma fraxinii’) can cause a witches’-broom like symptom that could be confused with symptoms caused by *H. fraxineus* (CABI, 2021; Sinclair et al., 1996). Ash yellows is present in the United States (Sinclair and Griffiths, 2000). As with most fungal plant pathogens, molecular identification or morphological identification by a trained identifier is necessary to confirm presence of *H. fraxineus*. Detailed morphological analyses, combined with molecular work, are important to distinguish this fungus from related fungal species (Baral and Bemmann, 2014).

Figure 4. Leaf vein necrosis (top), and leaf spotting and wilting (bottom) in infected ash hosts. Vein necrosis tends to extend toward the petiole. Photo credit: Ottmar Holdenrieder, Andrin Gross.

Biology and Ecology

Hymenoscyphus fraxineus is heterothallic and therefore requires two opposite mating types to reproduce sexually (Gross et al., 2012b). This type of life cycle promotes the diversity of the pathogen over time (Downie, 2017). The sexual stage of *H. fraxineus* develops on fallen leaf litter infected during the previous year (Gross et al., 2014a). Ascospores are produced by apothecia that develop during the summer months and are small (mostly up to 3 mm in diameter, rarely 8 mm), white-stalked fruiting bodies that form on infected leaves and petioles and become black due to fungal tissue growth (Gross et al., 2014a) (Fig. 6). Ascospores are dispersed into the air and can infect the current year's new flush of ash leaves (Gross et al., 2014a).

Sporulation usually occurs from June to early September but may occur earlier or later in favorable conditions (Forest Research, 2021). Studies have shown that the optimal in vitro growth temperature of *H. fraxineus* is around 68°F (Kowalski and Bartnik, 2010). This favorable temperature is found in most of Europe, which has allowed this pathogen to spread rapidly to susceptible hosts across the continent. Some research indicates that asexual conidiospores may also cause infections (Fones et al., 2016); however, other researchers think conidia can only serve as spermatia (male gametes) during

Figure 6. Pseudothecia (fruiting bodies) on an infected petiole (left). *Hymenoscyphus fraxineus* teleomorph on an ash petiole (right). Photo credit: Ottmar Holdenrieder.

ascospore formation and are unlikely to have a role in direct infection (Gross et al., 2012b; Gross et al., 2012a; Kirisits et al., 2009; Gross et al., 2014a). Survival of *H. fraxineus* above 95°F is limited, which could reduce its impact in areas where it may encounter these high temperatures during the summer months (Grosdidier et al., 2018).

During autumn, infected leaves and rachises drop from the tree and the fungus overwinters in leaf litter in the main leaf stems (Gross et al., 2014a). *Hymenoscyphus fraxineus* can also grow into woody material on infected trees and overwinter there (Downie, 2017). The life cycle is completed in about a year but can repeat and extend for many years under suitable conditions where hosts are present (Grosdidier et al., 2020; Gross et al., 2014a).

Known Hosts

Most *Fraxinus* species are thought to be susceptible to *H. fraxineus* (Forest Research, 2021) with younger trees declining more rapidly than mature trees (Woodland Trust, 2021). This pathogen can affect susceptible trees in forests (Díaz-Yáñez et al., 2020), landscape or garden settings (Grosdidier et al., 2020; Marčiulynienė et al., 2018), and in plant nurseries (Alonso Chavez et al., 2015; Kirisits et al., 2012).

<u>*Fraxinus* spp. (ash):</u> *Fraxinus* spp. vary in their susceptibility to *H. fraxineus* (Woodland Trust, 2021). This pathogen has been particularly destructive to the United Kingdom's native *Fraxinus excelsior* (European ash) (Forest Research, 2021). Other European species, such as *F. angustifolia* (narrow-leaved ash), show disease symptoms similar to *F. excelsior* (Gross et al., 2014a) whereas *F. ornus* (manna ash) does not develop disease symptoms in the field (Gross et al., 2014a). Asian species of *Fraxinus*, such as *F. chinensis* and *F. mandshurica*, appear to be less susceptible to *H. fraxineus* and may show only mild foliar symptoms (Forest Research, 2021). Relative susceptibility of a range of *Fraxinus* species known to occur in North America are listed in Appendix A. However, information about the susceptibility of some North American species to *H. fraxineus* is not yet available. These species are listed in Appendix B.

In North America, susceptible *Fraxinus* species included green ash (*F. pennsylvanica*), white ash (*F. americana)*, black ash (*F. nigra*), pumpkin ash, (*F. profunda*), blue ash (*F.

quadrangulata), and other native species in this same genus (see full host list in Appendix A) (Nielsen et al., 2017; Pastirčáková et al., 2020).

Non-*Fraxinus* Hosts: *Hymenoscyphus fraxineus* has been detected in recent years on non-*Fraxinus* hosts, including: mock privet (*Phillyrea latifolia*), narrow-leaved mock privet (*P. angustifolia*), and fringe tree (*Chionanthus virginicus*) (Forest Research, 2018). These infected non-ash hosts were growing near native ash trees with symptoms of ash dieback. Symptoms on the non-ash hosts include leaf lesions and dying branches accompanied by discoloration of the wood beneath the lesions, similar to symptoms seen on ash hosts (Forest Research, 2018).

The host list below includes cultivated and wild plants that 1) are infected or infested by the pest under natural conditions, 2) are frequently described as major, primary, or preferred hosts, and 3) have primary evidence for feeding and damage documented in the literature. Plants are highlighted in bold if they are commercially produced and the pest causes economically significant damage.

Most susceptible *Fraxinus* hosts
***Fraxinus excelsior* (European ash, common ash)**[*], ***Fraxinus nigra* (black ash)**[*], ***Fraxinus quadrangulata* (blue ash)**[*] (Nielsen et al., 2017; Pastirčáková et al., 2020).

***Fraxinus* hosts with moderate susceptibility**
Fraxinus albicans (Texas ash) [*], ***Fraxinus latifolia* (Oregon ash)**[*], ***Fraxinus pennsylvanica* (green ash)**[*], ***Fraxinus velutina* (Arizona ash)**[*] (Nielsen et al., 2017; Pastirčáková et al., 2020).

***Fraxinus* hosts with low susceptibility**
***Fraxinus americana* (white ash)** [*], *Fraxinus chinensis* (Chinese ash), ***Fraxinus profunda* (pumpkin ash)**[*] (Nielsen et al., 2017; Pastirčáková et al., 2020).

Non-ash hosts
Chionanthus virginicus (fringe tree)[*], *Phillyrea latifolia* (mock privet)* (Forest Research, 2018; Leichty, 2020; Mira et al., 2017; Nurseries Caroliniana, 2021).

Pathogen Importance

Ash trees have been an important part of North American forests for millennia. Ash has been a source of wood for making tools, furniture, building materials, and sporting equipment. Ash trees also make up a large proportion of trees planted in urban areas, where they enhance recreational areas and provide shade in cities. In natural areas, ash trees play an important role in native ecosystems. For instance, Mina (2020) mentions that in North America, fallen ash leaves provide a food source for frogs, where they feed tadpoles in bodies of water (Stephens et al., 2013). Another study in North America found more than 40 native insect species rely on ash trees, for either food or breeding, and in turn these insects provide a food source for birds and other animals (Gandhi and Herms, 2010).

[*] Present in the United States

Invasive pathogens and pests present increasing threats to the survival of ash trees. Estimates of mortality induced by *H. fraxineus* are limited and available data are variable (Marçais et al., 2016). High mortality rates have been reported in young ash trees, both seedlings and saplings (Enderle et al., 2013; Koltay et al., 2012; Pliura et al., 2011). Mortality rates of about 50% in four years were reported in mature stands (Lõhmus and Runnel, 2014), while Rosenvald et al. (2015) reported annual mortality rates around 2–5 % per year for solitary ash trees that remained after timber harvesting. In another study, Kessler et al. (2012) reported little mortality due to *H. fraxineus* between 2008 and 2010 in Austria.

<u>Potential impacts on international trade in *Fraxinus*</u>:
There has been a substantial volume of kiln-dried ash lumber exported from the United States over the past 30 years (Luppold and Bumgardner, 2021) with 265,000 m^3 exported in 2020 (Luppold and Bumgardner, 2021). U.S. hardwood is exported to Europe, other parts of North America (Mexico and Canada), Japan, Taiwan, Korea, China (including Hong Kong), and Vietnam (Luppold and Bumgardner, 2021).

Hymenoscyphus fraxineus is considered a harmful organism by Canada (Phytosanitary Export Database (PExD), 2022), and therefore could impact trade with Canada should *H. fraxineus* be introduced into the United States. This pathogen is not known to occur in Taiwan, Vietnam, Hong Kong, or in North America, so potential for introduction of the pathogen may especially be a concern for these trading partners.

The Canadian Food Inspection Agency (CFIA) prohibits movement of *Fraxinus* spp. for propagation and ornamental use from the United States, due to the removal of USDA-APHIS domestic quarantine regulations for emerald ash borer (*Agrilus planipennis*) (Livingston International, 2021). Ash logs and wood products must be imported with a permit or phytosanitary certificate and in some situations will only be imported between Oct 1 and March 31 (Livingston International, 2021). If *H. fraxineus* is introduced into the United States, further trade restrictions are likely.

Imported *Fraxinus* spp. (ash) plants for planting (except seeds) are Not Authorized Pending Pest Risk Analysis (NAPPRA) from all countries except for emerald ash borer free areas in Canada (USDA, 2017). Canadian authorities have policies in place that prohibit importation of *Fraxinus* spp. into Canada from areas of the world where *H. fraxineus* occurs (CFIA, 2019).

<u>Potential consequences of an introduction of *H. fraxineus* to North America</u>:
An introduction of *H. fraxineus* to the Western hemisphere may affect both biodiversity and the timber industry. North America is one of the two main centers of diversity of genus *Fraxinus* with 22 out of the 48 recognized *Fraxinus* species (Wallander, 2012). *Fraxinus* species are among the most widely distributed trees in forests of eastern North America, and their loss could significantly impact biodiversity supported by them (Gandhi and Herms, 2010). The following North American ash species are commercially important sources of timber: *F. americana* (white ash); *F. latifolia* (Oregon ash); *F. nigra*

(black ash); *F. pennsylvanica* (green ash); *F. profunda* (pumpkin ash); and *F. quadrangulata* (blue ash) (Stewart and Krajicek, 1973).

Known Vectors (or associated insects)

This species is not a known vector, is not known to be vectored, and does not have any associated organisms. However, insects are known to have a role in dispersal of conidia of other *Chalara* species, and *C. fraxinus* is the asexual stage of this fungus (Chalkley, 2021; Kile, 1993).

Known Distribution

This pathogen species is native to:
Asia: China (Drenkhan et al., 2017), Japan (Schoebel et al., 2014), North Korea (Gross and Han, 2015), South Korea (Han et al., 2014), Russian Far-East (Drenkhan et al., 2017).

This pathogen species has been introduced and is most likely established in the following countries:
Oceania: Marshall Islands (Forestry Commission, 2018).
Europe: Austria (Kirisits, 2015), Belarus (Storozhenko et al., n.d.), Belgium (Chandelier et al., 2011), Bosnia and Herzegovina (Stanivukovic et al., 2014), Croatia (Diminic et al., 2017), Czech Republic (Stastný et al., 2009), Denmark (Kosawang et al., 2019), Estonia (Drenkhan et al., 2015), Finland (Rytkönen et al., 2011), France (Husson et al., 2011), Germany (Erfmeier et al., 2019), Guernsey Island (EPPO, 2012), Hungary (Kirisits et al., 2009; Szabó, 2008), Ireland (McCracken et al., 2017), Italy (Giongo et al., 2017), Latvia (Cleary et al., 2012), Lithuania (Schoebel et al., 2014), Luxembourg (Baral and Bemmann, 2014), Montenegro (Milenkovic et al., 2017), the Netherlands (EPPO, 2010; Plant Protection Service, 2010), Norway (Timmermann et al., 2011), Poland (Kowalski, 2006), Romania (Chira et al., 2017), Russia (Drenkhan et al., 2017), Serbia (Keca et al., 2017), Slovakia (Kadasi-Horakova et al., 2017), Slovenia (Ogris et al., 2009), Sweden (Marčiulynienė et al., 2018), Switzerland (Queloz et al., 2011), Ukraine (Davydenko et al., 2013), and United Kingdom (Orton et al., 2018).

Status of infestation in the United States (December 2022)
There is no evidence that *H. fraxineus* is present in the United States.

Pathway

Although *H. fraxineus* disperses aerially, it can also be moved in soil, water, infested leaf litter, plants for planting, or infested wood (CABI, 2021; EPPO, 2013). Long distance movement of the fungus occurs by the transport of infected plant material, notably from nurseries (Kirisits et al., 2012). A big danger for dispersal to new locations is through infected petioles. Gross et al. (2012b) found up to eight different genotypes on a single infected ash petiole; therefore, a small fragment of a petiole might be sufficient to start a new epidemic elsewhere. The invasion of *H. fraxineus* in Europe has been traced back to the introduction of only two specimens of the pathogen (Gross et al., 2014b; McMullan et al., 2018), demonstrating the potential destructiveness of small scale introductions of invasive pathogens.

Seed from infected ash trees (*F. excelsior*) was once considered a potential pathway for introduction of *H. fraxineus* to new locations. Although DNA of *H. fraxineus* has been detected in ash seed (Cleary et al., 2013), transmission from infected seed to germinating seedlings does not appear to happen (Marčiulynienė et al., 2018; van der Linde et al., 2021). Therefore, the seed pathway for introduction seems relatively low risk.

Use the PPQ Commodity Import and Export databases or manuals listed below to determine 1) if host plants or material are allowed to enter the United States from countries where the organism is present and 2) what phytosanitary measures (e.g., inspections, phytosanitary certificates, post entry quarantines, mandatory treatments) are in use. These manuals are updated regularly.

Agricultural Commodity Import Requirements(ACIR) database: ACIR provides a single source to search for and retrieve entry requirements for imported commodities. https://acir.aphis.usda.gov/s/

Plants for Planting Manual: This manual is a resource for regulating imported plants or plant parts for propagation, including buds, bulbs, corms, cuttings, layers, pollen, scions, seeds, tissue, tubers, and like structures.
https://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/plants_for_planting.pdf

Treatment Manual: This manual provides information about treatments applied to imported and domestic commodities to limit the movement of agricultural pests into or within the United States.
https://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf

Potential Distribution within the United States

Fraxinus excelsior, the primary reported host in Europe, is considered present and exotic in North America (Kartesz, 2015). This species has a limited distribution in the United States, found only in a few counties in Connecticut, Kentucky, Massachusetts, New York, and Ohio (Kartesz, 2015; USDA, 2021b). Other susceptible Fraxinus species are distributed throughout the United States, but the eastern half of the country has the greatest potential risk for establishment of this pathogen (Kartesz, 2015; USDA, 2021b). Even with an abundance of susceptible hosts, the pathogen requires environmental conditions conducive to infection and disease development. Based on its known distribution, *H. fraxineus* may establish in Plant Hardiness Zones 2–9 (Takeuchi et al., 2018). These zones encompass most of the continental United States, with the exception of southern and western coastal areas (Takeuchi et al., 2018). Survival of *H. fraxineus* at temperatures above 95°F in infected ash stems is limited, which could reduce its impact in areas where temperatures are extremely hot (Grosdidier et al., 2018).

Survey and Key Diagnostics

Approved Methods for Pest Surveillance:

For the current approved methods and guidance for survey and identification, see Approved Methods for Pest Surveillance (AMPS) pest page on the CAPS Resource and Collaboration website, at https://caps.ceris.purdue.edu/approved-methods.

Appendix A. Hosts of *Hymenoscyphus fraxineus* known to occur in North America, relative susceptibility to the pathogen, commercial production, and economic damage.

Host	Common Name	Susceptibility	Commercially produced?	Economic damage? (10% or more)	References
		Highly susceptible *Fraxinus* hosts			
Fraxinus excelsior (not native, but present in some U.S. states) (Kartesz, 2015)	European, common ash	High (although cultivars vary in their susceptibility (Douglas et al., 2017; Pastirčáková et al., 2020; Skovsgaard et al., 2017))	Yes (Skovgaard et al., 2017; Douglas et al., 2017).	Yes, direct mortality rates in Europe ranged from 80% of young trees to 20% of older trees (Stocks et al., 2017)	Gross et al., 2014a; Kowalski, 2006; Nielsen et al., 2017; Pastirčáková et al., 2020
Fraxinus nigra	black ash	High	Mixed results. Yes, produced commercially for lumber (Stewart and Krajicek, 1973). No, it is not commercially important, although it is useful for traditional basket making, and has an ecological role as food for various	Yes, this species was severely affected by infection with *H. fraxineus*, crown damage ranged from 75-85% (Nielsen et al., 2017)	Drenkhan and Hanso, 2010; Gross et al., 2014a; Nielsen et al., 2017

			animals (United States Forest Service, 2021)		
Fraxinus quadrangulata	blue ash	Moderate to High	Yes, the wood is hard and durable, used for furniture, tools, etc. (COSEWIC, 20)	Yes, *F. quadrangulata* was severely affected, showing crown damage up to 75% (Nielsen et al., 2017)	Nielsen et al., 2017; Pastirčáková et al., 2020
Moderately susceptible *Fraxinus* hosts					
Fraxinus albicans	Texas ash	Moderate	No strong evidence	No damage rating in percentages (Nielsen et al., 2017)	Nielsen et al., 2017
Fraxinus latifolia	Oregon ash	Moderate	Yes (Oregon Wood Innovation Center, 2021)	Yes, crown damage was rated at 30% (Nielsen et al., 2017)	Nielsen et al., 2017; Pastirčáková et al., 2020
Fraxinus pennsylvanica (Synonym: *F. cinerea, F. pennsylvanica* v. *lanceolata, F. pennsylvanica* v. *subintegerrima)*	green ash	Low to Moderate	Yes, it is produced commercially in the southern U.S., for tools, baseball bats, etc., also used as a popular ornamental tree, and important ecologically (Stewart and Krajicek, 1973; United States Department of	Yes, trees showed defoliation ranging from 10-50% (Nielsen et al., 2017)	Gross et al., 2014a; Nielsen et al., 2017; Pastirčáková et al., 2020

			Agriculture, 2021).		
Fraxinus velutina	Arizona ash	Moderate	Yes, this tree has landscape value in some parts of the United States (Horticulture Unlimited, 2021)	Yes/No In one source, 20-30% defoliation was reported on this plant (Pastirčáková et al., 2020). In another source, this was the healthiest North American species studied, with crown damage ratings less than 10% (Nielsen et al., 2017)	Nielsen et al., 2017; Pastirčáková et al., 2020
Least susceptible *Fraxinus* hosts					
Fraxinus americana	white ash	Low	Quality, high value wood for tools, sports equipment due to the strength and resilience of the wood (Griffith, 1991)	Yes, 10% crown damage on 6 of 10 trees and one tree killed outright (Nielsen et al., 2017)	Drenkhan and Hanso, 2010; Gross et al., 2014a; Nielsen et al., 2017; Pastirčáková et al., 2020
Fraxinus chinensis (Synonym: *Fraxinus chinensis* subsp. *chinensis*) (not native, but present in some U.S. states (USDA, 2021b))	Chinese ash	Low	It is used for medicinal purposes, as an ornamental plant, and the wood is used or cabinet making (Fern, 2021).	No, plants showed necrotic, sunken lesions of variable size, no damage rating, and few apothecia (Nielsen et al., 2017)	Han et al., 2014; Nielsen et al., 2017; Pastirčáková et al., 2020

Fraxinus profunda	pumpkin ash	Low	Yes (Stewart and Krajicek, 1973)	Yes, crown damage score up to 30% (Nielsen et al., 2017)	Nielsen et al., 2017; Pastirčáková et al., 2020
Non-ash hosts					
Chionanthus virginicus	fringe tree	Infected when nearby infected native ash trees	Yes, small scale, it is a native tree (Leichty, 2020)	No damage ratings, only one report (Forestry Commission, 2018)	Forest Research, 2018
Phillyrea latifolia	mock privet	Infected when nearby infected native ash trees	Yes, this plant has value as a landscape tree (Nurseries Caroliniana, 2021)	No ratings of disease severity available (Forest Research, 2018)	Forest Research, 2018

Appendix B. Compilation of twenty-seven *Fraxinus* species documented to occur in North America, either present and native/naturalized species, or as present and exotic/introduced species.

***Fraxinus* species in the United States**	**Sources**
Fraxinus albicans	Kartesz, 2015; USDA, 2021b
Fraxinus americana	Atha and Boom, 2017; Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus anomala (includes varieties var. *anomala*, var. *lowellii*)	Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus berlandieriana	Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus biltmoreana	Atha and Boom, 2017; Wallander, 2012
Fraxinus caroliniana	Kartesz, 2015; USDA, 2021b
Fraxinus chinensis (exotic)	Hinsinger et al., 2013b; USDA, 2021b
Fraxinus coriacea	Wallander, 2012
Fraxinus cubensis	Wallander, 2012
Fraxinus cuspidata	Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus dipetala	Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus excelsior (exotic)	Atha and Boom, 2017; Kartesz, 2015; USDA, 2021b
Fraxinus gooddingii (rare)	Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus greggii	Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus griffithii (Hawaiian Islands)	Kartesz, 2015
Fraxinus latifolia	Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus nigra	Atha and Boom, 2017; Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus ornus	USDA, 2021b
Fraxinus papillosa	Kartesz, 2015; USDA, 2021b
Fraxinus parryi (rare)	Kartesz, 2015
Fraxinus pauciflora	Wallander, 2012
Fraxinus pennsylvanica	Atha and Boom, 2017; Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus profunda	Atha and Boom, 2017; Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus quadrangulata	Atha and Boom, 2017; Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus smallii	Wallander, 2012

Fraxinus uhdei (exotic)	Kartesz, 2015; USDA, 2021b; Wallander, 2012
Fraxinus velutina	Kartesz, 2015; USDA, 2021b; Wallander, 2012

References

Alonso Chavez, V., S. Parnell, and F. van den Bosch. 2015. Designing strategies for epidemic control in a tree nursery: the case of ash dieback in the UK. Forests 6:11.

Atha, D., and B. Boom. 2017. Field Guide to the Ash Trees of Northeastern United States. Center for Conservation Strategy, The New York Botanical Garden, Bronx, NY.

Bakys, R., R. Vasaitis, P. Barklund, K. Ihrmark, and J. Stenlid. 2009. Investigations concerning the role of *Chalara fraxinea* in declining *Fraxinus excelsior*. Plant Pathology 58:8.

Bakys, R., A. Vasiliauskas, K. Ihrmark, J. Stenlid, A. Menkis, and R. Vasaitis. 2011. Root rot, associated fungi and their impact on health condition of declining *Fraxinus excelsior* stands in Lithuania. Scandinavian Journal of Forest Research 26:7.

Baral, H.-O., and M. Bemmann. 2014. *Hymenoscyphus fraxineus* vs. *Hymenoscyphus albidus*– A comparative light microscopic study on the causal agent of European ash dieback and related foliicolous, stroma-forming species. Mycology 5(4):228-290.

CABI. 2021. *Hymenoscyphus fraxineus* (ash dieback). CAB International.

CFIA. 2019. Emerald ash borer - *Agrilus planipennis in* C. F. I. A. (CFIA), ed.

Chalkley, D. 2021. Invasive Fungi. Ash dieback-*Chalara fraxinea*. Systematic Mycology and Microbiology Laboratory, ARS, USDA.

Chandelier, A., N. Delhaye, and M. Helson. 2011. First report of the ash dieback pathogen Hymenoscyphus pseudoalbidus (anamorph Chalara fraxinea) on Fraxinus excelsior in Belgium. Plant Disease 95(2):220.

Chira, D., F. Chira, I. Taut, O. Popovici, I. Blada, and N. Donita. 2017. Evolution of ash dieback in Romania. Pages 185-194 R. Vasaitis & R. Enderle (Eds.), Dieback of European Ash (*Fraxinus* spp.)- Consequences and Guidelines for Sustainable Management.

Cleary, M., N. Arhipova, T. Gaitnieks, J. Stenlid, and R. Vasaitis. 2013. Natural infection of *Fraxinus excelsior* seeds by *Chalara fraxinea*. Forest Pathology 43(1):83-85.

Cleary, M. R., N. Arhipova, T. Gaitnieks, J. Stenlid, and R. Vasaitis. 2012. Natural infection of *Fraxinus excelsior* seeds by *Chalara fraxinea*. Forest Pathology 43(1):83-85.

Coker, T. L. R., J. Rozsypálek, A. Edwards, T. P. Harwood, L. Butfoy, and R. J. A. Buggs. 2019. Estimating mortality rates of European ash (Fraxinus excelsior) under the ash dieback (Hymenoscyphus fraxineus) epidemic. PLANTS, PEOPLE, PLANET 1(1):48-58.

COSEWIC. 20. Blue ash (Fraxinus quadrangulata): COSEWIC assessment and status report 2014. *in*. Government of Canada, 14.

Davydenko, K., R. Vasaitis, J. Stenlid, and A. Menkis. 2013. Fungi in foliage and shoots of *Fraxinus excelsior* in eastern Ukraine: a first report on *Hymenoscyphus pseudoalbidus*. Forest Pathology:1-6.

Díaz-Yáñez, O., B. Mola-Yudego, V. Timmermann, M. M. Tollefsrud, A. M. Hietala, and J. Oliva. 2020. The invasive forest pathogen *Hymenoscyphus fraxineus* boosts

mortality and triggers niche replacement of European ash (*Fraxinus excelsior*). Nature: Scientific Reports 10:10.
Diminic, D., D. Kajba, M. Milotic, I. Andric, and J. Kranjec. 2017. Susceptibility of *Fraxinus angustifolia* clones to *Hymenoscyphus fraxineus* in lowland Croatia. Baltic Forestry 23(1):233-243.
Douglas, G. C., J. M. Namara, K. O'Connell, L. Dunne, and J. Grant. 2017. Vegetative propagation of dieback-tolerant *Fraxinus excelsior* on commercial scale. Guidelines for Sustainable Management, Swedish University of Agricultural Sciences:11.
Downie, J. A. 2017. Ash dieback epidemic in Europe: How can molecular technologies help? PLoS pathogens 13(7):6.
Drenkhan, R., K. Adamson, and M. Hanso. 2015. *Fraxinus sogdiana*, a central Asian ash species, is susceptible to *Hymenoscyphus fraxineus*. Plant Protection Science 51(3):150-152.
Drenkhan, R., and M. Hanso. 2010. New host species for *Chalara fraxinea*. New disease reports 22(16):2044-0588.2010.
Drenkhan, R., H. Solheim, A. Bogacheva, T. Riit, K. Adamson, and T. Drenkhan. 2017. Hymenoscyphus fraxineus is a leaf pathogen of local Fraxinus species in the Russian Far East. Plant Pathology 66:490-500.
Enderle, R., F. Peters, A. Nakou, and B. Metzler. 2013. Temporal development of ash dieback symptoms and spatial distribution of collar rots in a provenance trial of *Fraxinus excelsior*. European journal of forest research 132(5):865-876.
EPPO. 2010. First report of *Chalara fraxinea* in the Netherlands (2010/151). European and Mediterranean Plant Protection Organization (EPPO), Paris. 4 pp.
EPPO. 2012. First report of *Chalara fraxinea* in Guernsey (2012/237). European and Mediterranean Plant Protection Organization (EPPO), Paris. 5 pp.
EPPO. 2013. *Hymenoscyphus pseudoalbidus*. European and Mediterranean Plant Protection Organization (EPPO).
Erfmeier, A., K. L. Haldan, L. M. Beckmann, M. Behrens, J. Rotert, and J. Schrautzer. 2019. Ash dieback and its impact in near-natural forest remnants- a plant community-based inventory. Frontiers in Plant Science 10:1-12.
Farr, D. F., and A. Y. Rossman. 2021. *Hymenoscyphus fraxineus* data in Fungal Databases ARS, USDA Last accessed November 12, 2021, https://nt.ars-grin.gov/fungaldatabases/.
Fern, K. 2021. Temperate Plants Database. Last accessed November 15, 2021, temperate.theferns.info.
Fones, H. N., C. Mardon, and S. J. Gurr. 2016. A role for the asexual spores in infection of *Fraxinus excelsior* by the ash-dieback fungus *Hymenoscyphus fraxineus*. Scientific Reports 6(1):1-10.
Forest Research. 2018. Chalara ash dieback on different ash species and non-ash hosts. Pages 5 *in*, online.
Forest Research. 2021. Ash dieback (*Hymenoscyphus fraxineus*), 23. https://www.forestresearch.gov.uk/tools-and-resources/fthr/pest-and-disease-resources/ash-dieback-hymenoscyphus-fraxineus/.
Forestry Commission. 2018. Ash dieback found on three new species of tree. *in*, England.

Gandhi, K. J., and D. A. Herms. 2010. Direct and indirect effects of alien insect herbivores on ecological processes and interactions in forests of eastern North America. Biological Invasions 12(2):389-405.
Giongo, S., C. M. O. Longa, E. D. Maso, L. Montecchio, and G. Maresi. 2017. Evaluating the impact of *Hymenoscyphus fraxineus* in Trentino (Alps, Northern Italy): first investigations. iForest 10:871-878.
Griffith, R. S. 1991. *Fraxinus americana*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer), https://www.fs.usda.gov/database/feis/plants/tree/fraame/all.html
Grosdidier, M., R. Ioos, and B. Marçais. 2018. Do higher summer temperatures restrict the dissemination of *Hymenoscyphus fraxineus* in France? Forest Pathology 48(4):8.
Grosdidier, M., T. Scordia, R. Ioos, and B. Marçais. 2020. Landscape epidemiology of ash dieback. Journal of Ecology 108(5):1789-1799.
Gross, A., C. R. Grünig, V. Queloz, and O. Holdenrieder. 2012a. A molecular toolkit for population genetic investigations of the ash dieback pathogen *Hymenoscyphus pseudoalbidus*. Forest Pathology 42:13.
Gross, A., and J. G. Han. 2015. *Hymenoscyphus fraxineus* and two new *Hymenoscyphus* species identified in Korea. Mycological Progress 14(4):1-13.
Gross, A., O. Holdenrieder, M. Pautasso, V. Queloz, and T. N. Sieber. 2014a. *Hymenoscyphus pseudoalbidus*, the causal agent of European ash dieback. Molecular Plant Pathology 15(1):5-21.
Gross, A., T. Hosoya, and V. Queloz. 2014b. Population structure of the invasive forest pathogen *Hymenoscyphus pseudoalbidus*. Molecular Ecology 23(12):2943-2960.
Gross, A., P. L. Zaffarano, A. Duo, and C. Grünig. 2012b. Reproductive mode and life cycle of the ash dieback pathogen *Hymenoscyphus pseudoalbidus*. Fungal genetics and biology 49(12):977-986.
Han, J. G., B. Shrestha, T. Hosoya, K. H. Lee, G. H. Sung, and H. D. Shin. 2014. First report of the ash dieback pathogen *Hymenoscyphus fraxineus* in Korea. Mycobiology 42(4):391-396.
Hauptman, T., B. Piškur, M. De Groot, N. Ogris, M. Ferlan, and D. Jurc. 2013. Temperature effect on *Chalara fraxinea:* heat treatment of saplings as a possible disease control method. Forest Pathology 43(5):360-370.
Hinsinger, D. D., J. Basak, M. Gaudeul, C. Cruaud, P. Bertolino, and e. al. 2013a. The phylogeny and biogeographic history of ashes (*Fraxinus,* Oleaceae) highlight the roles of migration and vicariance in the diversification of temperate trees PLoS ONE. 8(11):14.
Hinsinger, D. D., J. Basak, M. Gaudeul, C. Cruaud, P. Bertolino, N. Frascaria-Lacoste, and J. Bousquet. 2013b. The phylogeny and biogeographic history of ashes (*Fraxinus*, Oleaceae) highlight the roles of migration and vicariance in the diversification of temperate trees PLoS One 8(11):14.
Horticulture Unlimited. 2021. *Fraxinus velutina*. Last accessed November 22, 2021, https://horticultureunlimited.com/tree/fraxinus-velutina/.
Huff, M., J. Seaman, D. Wu, T. Zhebentyayeva, L. J. Kelly, N. Faridi, C. D. Nelson, E. Cooper, T. Best, K. Steiner, J. Koch, J. Romero Severson, J. E. Carlson, R.

Buggs, and M. Staton. 2022. A high-quality reference genome for *Fraxinus pennsylvanica* for ash species restoration and research. Molecular Ecology Resources 22(4):1284-1302.

Husson, C., O. Cael, J.-P. Grandjean, L.-M. Nageleisen, and B. Marçais. 2012. Occurrence of Hymenoscyphus pseudoalbidus on infected ash logs. Plant Pathology 61(5):889-895.

Husson, C., B. Scala, O. Caël, P. Frey, N. Feau, R. Ioos, and B. Marçais. 2011. *Chalara fraxinea* is an invasive pathogen in France. European Journal of Plant Pathology 130(3):311-324.

Kadasi-Horakova, M., K. Adamcikova, K. Pastircakova, V. Longauerova, and M. Malova. 2017. Natural infection of *Fraxinus angustifolia* by *Hymenoscyphus fraxineus* in Slovakia. Baltic Forestry 23(1):52-55.

Kartesz. 2015. BONAP's North American Plant Atlas, http://www.bonap.org

Keca, N., T. Kirisits, and A. Menkis. 2017. First report of the invasive ash dieback pathogen Hymenoscyphus fraxineus on Fraxinus excelsior and F. angustifolia in Serbia. Baltic Forestry 23(1):56-59.

Kessler, M., T. L. Cech, M. Brandstetter, and T. Kirisits. 2012. Dieback of ash (*Fraxinus excelsior* and *Fraxinus angustifolia*) in Eastern Austria: Disease development on monitoring plots from 2007 to 2010. Journal of Agricultural Extension and Rural Development 4(9):5.

Kile, G. A. 1993. Plant diseases caused by species of *Ceratocystis* sensu stricto and *Chalara*. Pages 10 *in* M. J. Wingfield, K. A. Seifert, and J. F. Webber, (eds.). Ceratocystis and Ophiostoma: Taxonomy, Ecology, and Pathogenicity. The American Phytopathological Society, St. Paul, Minnesota, USA.

Kirisits, T. 2015. Ascocarp formation of Hymenoscyphus fraxineus on several-year-old pseudosclerotial leaf rachises of Fraxinus excelsior. Forest Pathology 45:4.

Kirisits, T., P. Kritsch, K. Krauml, M. Matlakova, and E. Halmschlager. 2012. Ash dieback associated with *Hymenoscyphus pseudoalbidus* in forest nurseries in Austria. Journal of Agricultural Extension and Rural Development 4(9):230-235.

Kirisits, T., M. Matlakova, S. Mottinger-Kroupa, T. L. Cech, and E. Halmschlager. 2009. The current situation of ash dieback caused by *Chalara fraxinea* in Austria. Pages 97-119 *in* Proceedings of the conference of IUFRO working party. Citeseer.

Kjær, E. D., L. V. McKinney, L. R. Nielsen, L. N. Hansen, and J. K. Hansen. 2012. Adaptive potential of ash (Fraxinus excelsior) populations against the novel emerging pathogen Hymenoscyphus pseudoalbidus. Evolutionary applications 5(3):219-228.

Koltay, A., I. Szabó, and G. Janik. 2012. *Chalara fraxinea* incidence in Hungarian ash (*Fraxinus excelsior*) forests. Journal of Agricultural Extension and Rural Development 4(9):3.

Kosawang, C., H. Sorensen, E. Dahl Kjaer, L. V. McKinney, and D. B. Collinge. 2019. Defining the twig fungal communities of *Fraxinus* species and *Fraxinus excelsior* genotypes with differences in susceptibility to ash dieback. Fungal Ecology 42:1-8.

Kowalski, T. 2006. *Chalara fraxinea* sp. nov. associated with dieback of ash (*Fraxinus excelsior*) in Poland. Forest Pathology 36(4):264-270.

Kowalski, T., and C. Bartnik. 2010. Morphologial variation in colonies of *Chalara fraxinea* isolated from ash (*Fraxinus excelsior* L.) stems with symptoms of dieback and effects of temperature on colony growth and structure. Acta Agrobotanica 63(1):7.

Kowalski, T., and P. Bilański. 2019. *Hymenoscyphus pusillus*, a new species on leaves of *Fraxinus pennsylvanica* in Poland. Forest Pathology:e12481.

Langer, G. 2017. Collar rots in forests of Northwest Germany affected by ash dieback. Baltic Forestry 23(1):15.

Leichty, M. 2020. Chionanthus virginicus. Nursery Management:7.

Livingston International. 2021. Import Requirement Changes for Ash species/*Fraxinus* spp. from the U.S., https://www.livingstonintl.com/import-requirements-changes-for-ash-species-fraxinus-spp-from-the-u-s/.

Lõhmus, A., and K. Runnel. 2014. Ash dieback can rapidly eradicate isolated epiphyte populations in production forests: A case study. Biological Conservation 169:4.

Luppold, W., and M. Bumgardner. 2021. Regional analysis of U.S. lumber exports for important hardwood species from 1990 to 2020. Forest Products Journal 71(3):8.

Madsen, C. L., C. Kosawang, I. M. Thomsen, L. N. Hansen, L. R. Nielsen, and E. D. Kjær. 2021. Combined progress in symptoms caused by *Hymenoscyphus fraxineus* and *Armillaria* species, and corresponding mortality in young and old ash trees. Forest Ecology and Management 491:119177.

Marçais, B., C. Husson, L. Godart, and O. Cael. 2016. Influence of site and stand factors on *Hymenoscyphus fraxineus*-induced basal lesions. Plant Pathology 65(9):1452-1461.

Marčiulynienė, D., K. Davydenko, J. Stenlid, D. Shabunin, and M. Cleary. 2018. *Fraxinus excelsior* seed is not a probable introduction pathway for *Hymenoscyphus fraxineus*. Forest Pathology 48(1):e12392.

McCracken, A. R., G. C. Douglas, C. Ryan, M. DeStefanis, and L. R. Cooke. 2017. Ash dieback on the island of Ireland. Pages 125-139 *in* R. Vasaitis and R. Enderle, (eds.). Dieback of European Ash (Fraxinus spp.): Consequences and Guidelines for Sustainable Management.

McMullan, M., M. Rafiqi, G. Kaithakottil, B. J. Clavijo, L. Bilham, E. Orton, L. Percival-Alwyn, B. J. Ward, A. Edwards, D. G. O. Saunders, G. Garcia Accinelli, J. Wright, W. Verweij, G. Koutsovoulos, K. Yoshida, T. Hosoya, L. Williamson, P. Jennings, R. Ioos, C. Husson, A. M. Hietala, A. Vivian-Smith, H. Solheim, D. MaClean, C. Fosker, N. Hall, J. K. M. Brown, D. Swarbreck, M. Blaxter, J. A. Downie, and M. D. Clark. 2018. The ash dieback invasion of Europe was founded by two genetically divergent individuals. Nature Ecology & Evolution 2:10.

Milenkovic, I., T. Jung, Z. Stanivukovic, and D. Karadzic. 2017. First report of *Hymenoscyphus fraxineus* on *Fraxinus excelsior* in Montenegro. Forest Pathology:1-4.

Mina, M. 2020. Are ash trees doomed? Forest Monitor, https://www.forest-monitor.com/en/are-ash-trees-doomed/.

Mira, S., A. Arnal, and F. Pérez-García. 2017. Seed germination of *Phillyrea angustifolia* L., a species of difficult propagation. Forest Systems 26(1):10.

Nielsen, L. R., L. V. McKinney, A. M. Hietala, and E. D. Kjær. 2017. The susceptibility of Asian, European and North American *Fraxinus* species to the ash dieback

pathogen *Hymenoscyphus fraxineus* reflects their phylogenetic history. European journal of forest research 136:14.
Nurseries Caroliniana. 2021. *Phillyrea latifolia*. Last accessed November 22, 2021, https://nurcar.com/products/phillyrea-latifolia#:~:text=Phillyrea.,rarely%20seen%20in%20the%20landscape.
Ogris, N., T. Hauptman, and D. Jurc. 2009. *Chalara fraxinea* causing common ash dieback newly reported in Slovenia. New disease reports 19.
Oregon Wood Innovation Center. 2021. Oregon ash (*Fraxinus latifolia*). College of Forestry, Oregon State University, Corvallis, OR. Last accessed November 15, 2021, https://owic.oregonstate.edu/oregon-ash-fraxinus-latifolia.
Orton, E. S., C. M. Brasier, L. J. Bilham, A. Bansal, J. F. Webber, and J. K. M. Brown. 2018. Population structure of the ash dieback pathogen, *Hymenoscyphus fraxineus*, in relation to its mode of arrival in the UK. Plant Pathology 67:255-264.
Pastirčáková, K., K. Adamčíková, M. Barta, J. Pažitný, P. Hoťka, I. Sarvašová, and M. Kádasi Horáková. 2020. Host range of *Hymenoscyphus fraxineus* in Slovak arboreta. Forests 11(5):596.
Phytosanitary Export Database (PExD). 2022. Phytosanitary Certificate Issuance and Tracking System (PCIT). Last accessed December 4, 2022.
Plant Protection Service. 2010. Pest Report - The Netherlands: First finding of *Chalara fraxinea* on *Fraxinus* sp. in The Netherlands. Ministry of Agriculture, Nature and Food Quality, Plant Protection Service of the Netherlands, Division of Plant Health Advice & International Affairs.
Pliura, A., V. Lygis, V. Suchockas, and E. Bartkevicius. 2011. Performance of twenty four European *Fraxinus excelsior* populations in three Lithuanian progeny trials with a special emphasis on resistance to *Chalara fraxinea*. Baltic Forestry 17(1):18.
Queloz, V., C. R. Grünig, R. Berndt, T. Kowalski, T. N. Sieber, and O. Holdenrieder. 2011. Cryptic speciation in *Hymenoscyphus albidus*. Forest Pathology 41(2):133-142.
Rosenvald, R., R. Drenkhan, T. Riit, and A. Lõhmus. 2015. Towards silvicultural mitigation of the European ash (*Fraxinus excelsior*) dieback: the importance of acclimated trees in retention forestry. Canadian Journal of Forest Research 45:9.
Rytkönen, A., A. Lilja, R. Drenkhan, T. Gaitnieks, and J. Hantula. 2011. First record of *Chalara fraxinea* in Finland and genetic variation among isolates sampled from Åland, mainland Finland, Estonia and Latvia. Forest Pathology 41(3):169-174.
Sansford, C. 2015. Revised assessment of the risk of spread of H*ymenoscyphus fraxineus* on untreated wood of ash (*Fraxinus* spp., particularly *Fraxinus excelsior*) for DAFM and DARDNI. *in*. Department of Agriculture, Food and the Marine (DAFM) and Department of Agriculture and Rural Development Northern Ireland (DARDNI).
Schoebel, C. N., S. Zoller, and D. Rigling. 2014. Detection and genetic characterisation of a novel mycovirus in Hymenoscyphus fraxineus, the causal agent of ash dieback. Infection, Genetics and Evolution 28:78-86.
Schumacher, J. 2011. The general situation regarding ash dieback in Germany and investigations concerning the invasion and distribution strategies of Chalara fraxinea in woody tissue 1. EPPO Bulletin 41(1):7-10.

Sinclair, W., H. Griffiths, and R. Davis. 1996. Ash yellows and lilac witches'-broom: phytoplasmal diseases of concern in forestry and horticulture.

Sinclair, W. A., and H. M. Griffiths. 2000. Variation in aggressiveness of ash yellows phytoplasmas. Plant Disease 84:6.

Skovsgaard, J. P., I. M. Thomsen, I. M. Skovsgaard, and T. Martinussen. 2010. Associations among symptoms of dieback in even-aged stands of ash (*Fraxinus excelsior* L.). Forest Pathology 40:12.

Skovsgaard, J. P., G. J. Wilhelm, I. M. Thomsen, B. Metzler, T. Kirisits, L. Havrdová, R. Enderle, D. Dobrowolska, M. Cleary, and J. Clark. 2017. Silvicultural strategies for *Fraxinus excelsior* in response to dieback caused by *Hymenoscyphus fraxineus*. Forestry 90.

Sollars, E. S., A. L. Harper, L. J. Kelly, C. M. Sambles, R. H. Ramirez-Gonzalez, D. Swarbreck, G. Kaithakottil, E. D. Cooper, C. Uauy, L. Havlickova, G. Worswick, D. J. Studholme, J. Zohren, D. L. Salmon, B. J. Clavijo, Y. Li, Z. He, A. Fellgett, L. V. McKinney, L. R. Nielsen, G. C. Douglas, E. D. Kjær, J. A. Downie, D. Boshier, S. Lee, J. Clark, M. Grant, I. Bancroft, M. Caccamo, and R. J. Buggs. 2017. Genome sequence and genetic diversity of European ash trees. Nature 541(7636):212-216.

Stanivukovic, Z., D. Karadzic, and I. Milenkovic. 2014. The first record of the parasitic fungus *Hymenoscyphus fraxineus* (T. Kowalski) Baral, Queloz, Hosoya on common ash in Bosnia and Herzegovina. UDK 3:19-34.

Stastný, P., D. Palovcíková, and L. Jankovský. 2009. Ash Dieback in the Czech Republic. SDU Faculty of Forestry Journal A(Special):124-128.

Stephens, J. P., K. A. Berven, and S. D. Tiegs. 2013. Anthropogenic changes to leaf litter input affect the fitness of a larval amphibian. Freshwater Biology 58:17.

Stewart, H. A., and J. E. Krajicek. 1973. Ash... an American wood. *in* U. S. D. o. A. Forest Service, ed.

Stocks, J. J., R. J. A. Buggs, and S. J. Lee. 2017. A first assessment of *Fraxinus excelsior* (common ash) susceptibility to *Hymenoscyphus fraxineus* (ash dieback) throughout the British Isles. Nature: Scientific Reports 7:8.

Stocks, J. J., C. L. Metheringham, W. J. Plumb, S. J. Lee, L. J. Kelly, R. A. Nichols, and R. J. A. Buggs. 2019. Genomic basis of European ash tree resistance to ash dieback fungus. Nat Ecol Evol 3(12):1686-1696.

Storozhenko, V. G., Y. N. Baranchikov, L. G. Seraya, V. V. Chebotareva, P. A. Chebotarev, and A. V. Yaruk. Features of *Hymenoscyphus fraxineus* fruiting in forests of Minsk Upland and Central forest-steppe. 1 pp.

Szabó, I. 2008. First report of *Chalara fraxinea* affecting common ash in Hungary. New disease reports 18:30.

Takeuchi, Y., G. Fowler, and A. S. Joseph. 2018. SAFARIS: Global Plant Hardiness Zone Development. North Carolina State University, Center for Integrated Pest Management; United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Science and Technology, Plant Epidemiology and Risk Analysis Laboratory, Raleigh, NC. 6p.

Timmermann, V., I. Børja, A. M. Hietala, T. Kirisits, and H. Solheim. 2011. Ash dieback: pathogen spread and diurnal patterns of ascospore dispersal, with special emphasis on Norway. EPPO Bulletin 41(1):14-20.

United States Department of Agriculture, F. S. 2021. Green Ash: *Fraxinus pennsylvanica* Marsh. Pages 10.
United States Forest Service. 2021. Black ash. *in* F. S. United States Department of Agriculture, ed.
USDA. 2016. Treatment Manual. United States Department of Agriculture (USDA), ed. USDA, online.
USDA. 2021a. Miscellaneous and Processed Products Import Manual. Pages 246 *in* A. P. H. I. S. United States Department of Agriculture (USDA), ed. USDA, online.
USDA, 2021b. The PLANTS Database. United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Greensboro, NC USA. Last accessed http://plants.usda.gov.
USDA. 2022a. Agricultural Commodity Import Requirements(ACIR) database: United States Department of Agriculture, Animal and Plant Health Inspection Srevice, https://acir.aphis.usda.gov/s/
USDA. 2022b. Plants for Planting Manual. United States Department of Agriculture, Animal and Plant Health Inspection Service.
van der Linde, S., A. Perez-Sierra, R. H. Needham, M. Combes, and S. A. McCartan. 2021. Identification, detection and eradication of Hymenoscyphus fraxineus from ash (Fraxinus excelsior) seeds. Forestry: An International Journal of Forest Research.
Wallander, E. 2012. Systematics and floral evolution in *Fraxinus* (Oleaceae). Belgische Dendrologie Belge 2012:39-58.
Woodland Trust. 2021. Ash dieback.7. Last accessed Nov 4, 2021, https://www.woodlandtrust.org.uk/trees-woods-and-wildlife/tree-pests-and-diseases/key-tree-pests-and-diseases/ash-dieback/.
Zheng, H.-D., and W.-Y. Zhuang. 2014. Hymenoscyphus albidoides sp. nov. and H. pseudoalbidus from China. Mycological Progress 13(3):625-638.

USDA-APHIS-PPQ-ST staff developed this datasheet. Cite this document as:

PPQ. 2022. Cooperative Agricultural Pest Survey (CAPS) Pest Datasheet for *Hymenoscyphus fraxineus* (Helotiales): Ash dieback. United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (PPQ), Raleigh, NC.

Versions

April, 2013: Version 1 completed.
April, 2015: Version 2 completed. Complete update of datasheet to include current information.
December, 2022: Version 3 completed. Complete update of datasheet to include current information.

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