

# EPPO Datasheet: *Agrilus anxius*

Last updated: 2020-07-03

## IDENTITY

**Preferred name:** *Agrilus anxius*

**Authority:** Gory

**Taxonomic position:** Animalia: Arthropoda: Hexapoda: Insecta:  
Coleoptera: Buprestidae

**Other scientific names:** *Agrilus gravis* LeConte, *Agrilus torpidus* LeConte

**Common names:** bronze birch borer

[view more common names online...](#)

**EPPO Categorization:** A1 list

[view more categorizations online...](#)

**EU Categorization:** A1 Quarantine pest (Annex II A)

**EPPO Code:** AGRILAX



[more photos...](#)

## Notes on taxonomy and nomenclature

The original 1841 description of *A. anxius* by H. L. Gory included a second species that was first described by Barter and Brown (1949) as *A. liragus* Barter & Brown, and later as the subspecies *A. granulatus liragus* Barter & Brown by Carlson and Knight (1969). The larval host plants of *A. liragus* (or *A. granulatus liragus*) include several species of *Populus*, whereas *A. anxius* is a specialist on *Betula*. Therefore, care must be taken when reading the literature on *A. anxius* prior to 1950 because it may include data for both *Agrilus* species. Although, if the host plant is given, readers can ascertain which *Agrilus* species is being discussed.

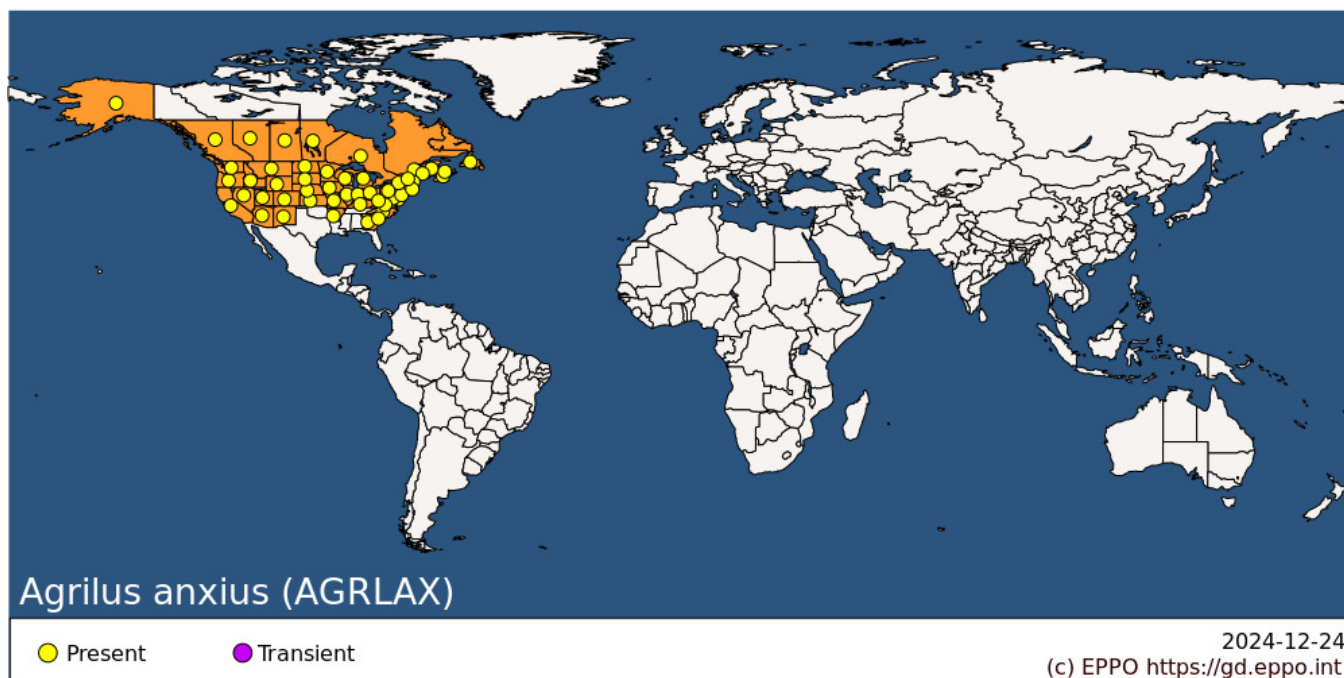
## HOSTS

The larval host plants of *A. anxius* are trees in the genus *Betula* (birch). In North America, primary hosts are *B. alleghaniensis*, *B. lenta*, *B. lutea*, *B. occidentalis*, *B. papyrifera*, and *B. populifolia* (Balch & Prebble, 1940; Ball & Simmons, 1980; Santamour, 1999; Nielsen *et al.*, 2011; Muilenburg & Herms, 2012). When planted in North America, several European and Asian birch species are readily infested and killed by *A. anxius*, including *B. maximowicziana*, *B. pendula*, *B. platyphylla* and *B. pubescens*, (Ball & Simmons, 1980; Miller *et al.*, 1991; Nielsen *et al.*, 2011; Muilenburg & Herms, 2012).

**Host list:** *Betula albosinensis*, *Betula alleghaniensis*, *Betula dahurica*, *Betula ermanii*, *Betula lenta*, *Betula maximowicziana*, *Betula nigra*, *Betula occidentalis*, *Betula papyrifera*, *Betula pendula*, *Betula platyphylla* var. *japonica*, *Betula platyphylla* var. *szechuanica*, *Betula platyphylla*, *Betula populifolia*, *Betula pubescens*, *Betula pumila*, *Betula utilis* subsp. *jacquemontii*, *Betula*

## GEOGRAPHICAL DISTRIBUTION

*Agrilus anxius* is native to much of the boreal and north temperate regions of North America where birch occurs (Bright, 1987; Muilenburg & Herms, 2012). Its current range has expanded into the Southern and Western United States as a result of widespread planting of birch species as ornamental trees (Duckles & Svihra, 1995; Muilenburg & Herms, 2012).



**North America:** Canada (Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, Québec, Saskatchewan), United States of America (Alaska, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, District of Columbia, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin, Wyoming)

## BIOLOGY

*A. anxius* usually completes its life cycle in one year but occasionally two years are required, depending on latitude, climatic conditions, and host condition (Balch & Prebble, 1940; Anderson, 1944; Nash *et al.*, 1951). In Ohio and Michigan, adult emergence usually begins at about 278 cumulative degree days (DD), using a base temperature of 10°C and a starting date of January 1 (Muilenburg & Herms, 2012). Adult emergence generally occurs over 10–12 weeks, with peak emergence occurring about 2–4 weeks after first emergence (Barter, 1957; Akers & Nielsen, 1984; Loerch & Cameron, 1984). Adult emergence typically begins in May in Kentucky (Mussey & Potter, 1997), May to June in Ohio and Michigan (Akers & Nielsen, 1984; Muilenburg & Herms, 2012), and late June to early July in New Brunswick, Canada (Balch & Prebble, 1940; Barter, 1957). Individual adults live for 2–5 weeks (Akers & Nielsen, 1990), which is typical of many *Agrilus* species (Chamorro *et al.*, 2015).

*A. anxius* adults consume foliage throughout their lifetime (Barter, 1957; Akers & Nielsen, 1990), which is common among *Agrilus* species (Chamorro *et al.*, 2015). Adults typically feed for about one week to become sexually mature (Rutledge & Keena, 2019). Adults usually consume *Betula* and *Populus* foliage, but can survive and reproduce when fed foliage from other tree species under experimental conditions (Barter, 1957; Akers & Nielsen, 1990). Adults feed mostly along the leaf margin and cause negligible damage to trees (Barter, 1957; Muilenburg & Herms, 2012). No pheromone has yet been identified for *A. anxius* (Silk *et al.*, 2020). Mate location is primarily visual (Rutledge & Keena, 2019), with mating occurring on the trunk, branches, and foliage of birch trees. Adults typically pair for 7–11 minutes (Barter, 1957; Rutledge & Keena, 2012).

Females lay eggs singly or in clusters of up to 16 eggs, averaging 7 (Barter, 1957). Eggs are laid in bark crevices, cracks, and under loose layers of outer bark (Barter, 1957; Loerch & Cameron, 1984). Under laboratory conditions (approximately 25°C, 65% RH, and 16:8 L:D h photoperiod), females lived an average of 30 days and laid 55 eggs each (Rutledge & Keena, 2012). Eggs hatch in about 2 weeks (Barter, 1957).

Newly hatched larvae tunnel directly through the outer bark into the underlying inner bark (phloem) tissue. There are

4 larval instars (Loerch & Cameron, 1983a). Larvae construct galleries in the cambial region at the phloem-xylem interface, with total average gallery length varying between 41-85 cm based on host condition and birch species (Anderson, 1944). Larvae tunnel in the outer sapwood for short distances to molt (Barter, 1957). Larvae use their terminal processes (urogomphi) to pack frass tightly within their galleries (Carlson & Knight, 1969). Larval galleries disrupt downward transport in phloem tissue and upward transport in the outer ring of xylem (sapwood), which at high densities and usually over multiple years can girdle and kill trees (Barter, 1957). All larval instars can overwinter (Barter, 1957). However, only pre-pupal larvae (4th instars that have completed feeding and constructed pupal cells by autumn) that overwinter and experience freezing temperatures will pupate the following spring (Barter, 1957). Upon completion of larval development, 4th instars construct pupal cells in the outer sapwood, generally during late summer or autumn (Barter, 1957; Loerch & Cameron, 1984). Larvae that do not become final instars by autumn will overwinter in the cambial region, complete larval development the following summer, and then overwinter a second time before pupating.

Larvae construct individual pupal cells that are about half their body length and pass the winter inside in a U- or J-shaped position (Carlson & Knight, 1969). Pupation occurs in May-June in Michigan (Carlson & Knight, 1969) and (Pennsylvania (Loerch & Cameron, 1984).

Adults chew D-shaped exit holes as they emerge that are 3–5 mm wide (Muilenburg & Herms, 2012). Adult emergence usually occurs from May to the end of July (Barter, 1957; Akers & Nielsen, 1984). Newly emerged adults have nearly a 1:1 sex ratio (Barter, 1957).

*A. anxius* colonizes most *Betula* species and cultivars, although host resistance varies with *B. nigra* appearing to be nearly immune to colonization (Nielsen *et al.*, 2011). *A. anxius* is typically a secondary invader of North American birch species (e.g. *B. allegheniensis*, *B. lutea*, *B. papyrifera*, *B. populifolia*) that have been stressed by drought, late spring frosts, old age, insect defoliation, soil compaction, and stem or root injury (Balch & Prebble, 1944; Anderson, 1944; Barter, 1957; Muilenburg & Herms, 2012; Haack & Petrice, 2019). European and Asian birch species that have been studied are much more susceptible than North American species to *A. anxius* (Miller *et al.*, 1991; Nielsen *et al.*, 2011). For example, in a 20-year common garden study in Ohio, USA, with a high number of replicates, bronze birch borer infestation caused complete mortality of Eurasian species (*B. maximowicziana*, *B. pendula*, *B. platyphylla* var. *szechuanica*, *B. pubescens*), but the majority of individuals (>75%) of North American species (*B. nigra*, *B. papyrifera*, *B. populifolia*) were still alive at the end of the study (Nielsen *et al.*, 2011). European and Asian birch species are highly susceptible to *A. anxius* colonization even when not stressed (Muilenburg & Herms, 2012). *A. anxius* infests birch trees of all sizes, with larvae being found in branches as small as 1 cm in diameter (Muilenburg & Herms, 2012).

In North America, *A. anxius* populations generally exist at endemic levels (Balch & Prebble, 1940). However, periodic outbreaks have been reported during the past century, usually being associated with widespread drought and defoliation (Balch & Prebble, 1940; Nash *et al.*, 1951; Houston, 1987; Muilenburg & Herms, 2012; Haack & Petrice, 2019).

## DETECTION AND IDENTIFICATION

### Signs and symptoms

Trees that have been infested or currently are infested with *A. anxius* will have one or more of the following signs or symptoms: D-shaped holes on the bark surface created by emerging adults, meandering or zig-zag larval galleries filled with frass at the phloem–xylem interface, or serpentine swellings or ridges visible through the outer bark where wound periderm (callus tissue) has grown over larval galleries (Anderson, 1944; Barter, 1957). Trees infested with *A. anxius* exhibit branch dieback, especially after multiple years of infestation, usually beginning with the upper crown branches (Ball & Simmons, 1980). Branch dieback is usually preceded by yellowing and thinning of the foliage.

### Trapping

When developing survey protocols for *A. anxius* it is important to recall that *A. anxius* infests North American birch

species when they are stressed, whereas it will infest both stressed and healthy Eurasian birch. Therefore, girdling individual North American birch trees usually increases the tree's attractiveness to *A. anxius* adults (Rutledge, 2020; Silk *et al.*, 2020). The specific host compounds, or combination of compounds, that *A. anxius* adults use to locate stressed trees is still unknown (Silk *et al.*, 2020). *A. anxius* adults have been collected on both green and purple traps (Petrice *et al.*, 2013; Rutledge, 2020; Silk *et al.*, 2020). In addition, ground-nesting solitary wasps in the genus *Cerceris*, which specialize in capturing buprestid adults, can be used as biosurveillance tools for many buprestids, including *A. anxius* (Kurczewski & Miller, 1984; Swink *et al.*, 2013).

## **Morphology**

### ***Eggs***

The eggs of *A. anxius* are creamy white when first laid, becoming more yellow as they mature (Barter, 1957). Eggs appear oval in shape, but flattened, and are 1.3 to 1.5 mm long and 0.8 to 1.0 mm wide (Barter, 1957; Carlson & Knight, 1969). Females coat the eggs after deposition with a whitish substance that likely helps cement the eggs to the bark and prevent desiccation (Barter, 1957).

### ***Larva***

Larvae are creamy white with a brown head and urogomphi. The body is dorsoventrally flattened. The head is small and protracted into the enlarged prothorax. There are 10 abdominal segments, with the last terminating in two sclerotized tooth-like structures that are often called urogomphi, anal forceps, or terminal processes (Carlson & Knight, 1969; Loerch & Cameron, 1983a; Chamorro *et al.*, 2015). Such terminal processes are characteristic of all known *Agrilus* larvae (Chamorro *et al.*, 2015). *A. anxius* is recognized as having four larval instars (Loerch & Cameron, 1983a), although Barter (1957) reported five instars. Mature last-instar larvae measure 30-40 mm long (Barter, 1957; Carlson & Knight, 1969).

### ***Pupa***

Pupation takes place inside the cells that were constructed in the outer sapwood by the mature larvae prior to overwintering. The larva first contracts its body to about half its former length and then molts to the pupal stage (Barter, 1957). Pupae are creamy white at first, but as pupation progress the eyes darken first, then the mouthparts, and lastly the elytra, until the entire pupa becomes bronze to black (Barter, 1957; Carlson & Knight, 1969). These colour changes are very similar to those seen for *A. planipennis* as described in Haack *et al.* (2015).

### ***Adult***

Adults are narrow, subcylindrical with coppery-bronze metallic colouration. They are usually 6-11 mm long (Barter, 1957), but can vary between 5–13 mm (Paiero *et al.*, 2012). Males have a ventral groove on the first and second abdominal segments that is absent in females (Barter, 1957). Differences in aedeagus morphology are the most reliable characters to separate adult male *A. anxius* from the morphologically similar *A. liragus* (= *A. granulatus liragus*) (Barter & Brown, 1949; Carlson & Knight, 1969). Additionally, *A. anxius* has 22 chromosomes whereas *A. liragus* has 20 (Barter, 1957).

## **PATHWAYS FOR MOVEMENT**

There is no information about natural dispersion of *A. anxius* adults by flight. However, under laboratory conditions, the emerald ash borer (*Agrilus planipennis*), which is similar in size to *A. anxius*, can fly on average 1.3 km per day, with some individuals exceeding 7 km per day (Taylor *et al.*, 2010). Most *Agrilus* species, like many other bark- and wood-infesting insects, can be transported in live host plants or wood products such as logs, firewood, solid wood packaging, lumber, bark, and wood chips (Meurisse *et al.*, 2019). For example, during 1985-2000 there were 38 distinct interceptions of *Agrilus* species made at US ports of entry that originated from 11 countries, and of these 28 were from dunnage, 4 from crates, 5 from plants or plant parts, and 1 specimen was found loose in the ship hold (Haack *et al.*, 2002; Haack, 2006). Importation of wood chips from North America to Europe is a potential pathway for movement *Agrilus* species and other pests, especially when the chips are relatively large in size, untreated and stored outdoors in close proximity to susceptible host trees (McCullough *et al.*, 2007; Kopinga *et al.*, 2010; Flø *et al.*, 2014).

## PEST SIGNIFICANCE

### Economic impact

In North America, *A. anxius* is considered the most serious pest of birch trees in both forest and amenity plantings (Barter, 1957; Ball & Simmons, 1980). In urban landscapes, *A. anxius* has caused widespread mortality of ornamental and street trees. In the northern hardwood and boreal forests of North America, periodic outbreaks of *A. anxius* have also led to widespread mortality of birch, causing negative impacts on forest tree composition and wildlife (Balch & Prebble, 1944; Nash *et al.*, 1951; Millers *et al.*, 1989; Haack & Petrice, 2019).

*Betula* species occur throughout most of Europe but are most common in the temperate and boreal forests of Northern Europe (Beck *et al.*, 2016). Moreover, birch are the most important commercial broadleaved species in Northern Europe, being used for pulpwood, fuel wood, lumber, plywood, and as amenity trees (Hynynen *et al.*, 2010; Beck *et al.*, 2016).

### Control

Control and detection of this type of wood-boring insect is difficult. There are several insecticides (e.g. azadiractin, bifenthrin, dicofen, dimethoate, dinotefuran, emamectin benzoate, imidacloprid, permethrin) that have been shown to control *Agrilus* species to varying degrees (Appleby *et al.*, 1973; Petrice & Haack, 2006; McKenzie *et al.*, 2010; Smitley *et al.*, 2010; McCullough *et al.*, 2011; Herms *et al.*, 2019). They may be used in nurseries and on ornamental birch trees. Depending on the label, they can be applied as soil drenches, soil injections, trunk injections, lower trunk sprays, or cover sprays on the trunk, branches and foliage (Herms *et al.*, 2019). The systemic insecticide emamectin benzoate, which is applied as a trunk injection, has demonstrated 2-year control against both *A. planipennis* larvae and leaf-feeding adults (McCullough *et al.*, 2011; Herms *et al.*, 2019).

Trees infested with buprestids can be cut down and then chipped or heat-treated to kill larvae and pupae within the host material (McCullough *et al.*, 2007). However, there are uncertainties about the maximum allowable size of wood chips to guarantee complete mortality of any larvae or pupae present (McCullough *et al.*, 2007; Kopinga *et al.*, 2010; Økland *et al.*, 2012). Additionally, the efficacy of heat-treatment in killing *Agrilus* larvae and pupae depends on the chamber temperature, the internal wood temperature, and duration of heat (Myers *et al.*, 2009; Goebel *et al.*, 2010; EPPO, 2020).

Several parasitoids of *A. anxius* have been documented in North America, including egg parasitoids in the families Aphelinidae and Encyrtidae, and larval parasitoids in the families Braconidae, Chalcididae, Eulophidae, Eurytomidae, and Ichneumonidae (Nash *et al.*, 1951; Barter, 1957; Loerch & Cameron, 1983b; Taylor *et al.*, 2012; Triapitsyn *et al.*, 2015). Although some natural enemies have caused more than 50% mortality to *A. anxius* eggs or larvae (Nash *et al.*, 1951; Barter, 1957; Loerch & Cameron, 1983b), there have been no studies on the role that these parasitoids play in the population dynamics of *A. anxius* in North America. With respect to entomopathogens, Kyei-Poku *et al.* (2011) reported a microsporidian infecting *A. anxius* in Ontario that varied greatly in incidence among populations.

## Phytosanitary risk

The wide geographic distribution of *A. anxius* in North America, from Alaska and Canada to parts of the Southern United States, indicates that *A. anxius* can tolerate a wide range of climatic conditions, and could probably establish throughout much of the EPPO region. Birch species exist throughout much of Europe and Asia, with some *Betula* species, such as *B. pendula* and *B. pubescens*, being very common in Northern Europe (Beck *et al.*, 2016). For example, in Nordic and Baltic countries, birch species comprise from 11–16% and 17–28%, respectively, of the total volume of growing stock (Hynynen *et al.*, 2010). Considering the high susceptibility of European *Betula* species to *A. anxius*, the introduction and establishment of this beetle would be likely to result in widespread mortality of *Betula* trees in forests, nurseries, and cities throughout Eurasia, with a similar effect to that of the introduction of the Asian buprestid *A. planipennis* on ash (*Fraxinus*) trees in North America (Poland & McCullough, 2006). As evidence of the growing concern that *A. anxius* could be introduced to Europe there are several recent efforts in Europe to develop contingency plans and survey methods for *A. anxius* prior to its possible arrival (EFSA *et al.*, 2020; Evans *et al.*, 2020; Petter *et al.*, 2020).

## PHYTOSANITARY MEASURES

Suggested phytosanitary measures are specified in the PRA performed by EPPO (EPPO, 2011); they are as follows. Plants for planting (except seeds) of *Betula* should originate from countries found free from the pest or be of small diameter (<2 cm for plants with stem, <1 cm for scions). Alternatively, they may be grown under insect-proof conditions. Wood chips should originate from countries found free from the pest or undergo heat treatment or fumigation. *Betula* wood with or without bark and furniture and other objects made of untreated birch wood should originate from countries found free from the pest, or undergo heat treatment or irradiation. Alternatively, outer sapwood should have been removed or wood commodities should be stored in the country of export for an appropriate period (1 year for wood chips, 2 years for wood). Importing during winter and processing some wood commodities (including woodchips) before the next flight period may be authorized under an import permit.

As a general approach, it has also been recommended that when importing plants for planting (except seeds) and wood commodities of *Betula* from countries where *A. anxius* occurs, precautions should have been taken to avoid any infestations while the consignments are transported through possibly infested areas (EPPO, 2017).

## REFERENCES

- Akers RC & Nielsen DG (1984) Predicting *Agrilus anxius* Gory (Coleoptera: Buprestidae) adult emergence by heat unit accumulation. *Journal of Economic Entomology* **77**, 1459–1463.
- Akers RC & Nielsen DG (1990) Reproductive-biology of the bronze birch borer (Coleoptera: Buprestidae) on selected trees. *Journal of Entomological Science* **25**, 196–203.
- Anderson RF (1944) The relation between host condition and attacks by the bronzed birch borer. *Journal of Economic Entomology* **37**, 588–596.
- Appleby JE, Randell R & Rachesky S (1973) Chemical control of bronze birch borer. *Journal of Economic Entomology* **66**, 258–259.
- Balch RE & Prebble JS (1940) The bronze birch borer and its relation to the dying of birch in New Brunswick forests. *Forestry Chronicle* **16**, 179–201.
- Ball J & Simmons G (1980) The relationship between bronze birch borer and birch dieback. *Journal of Arboriculture* **6**, 309–314.
- Barter GW (1957) Studies of the bronze birch borer, *Agrilus anxius* Gory, in New Brunswick. *Canadian Entomologist* **89**, 12–36.
- Barter GW & Brown WJ (1949) On the identity of *Agrilus anxius* Gory and some allied species (Coleoptera:



Buprestidae). *Canadian Entomologist* **81**, 245–249.

Beck P, Caudullo G, de Rigo D, & Tinner W (2016) *Betula pendula*, *Betula pubescens* and other birches in Europe: distribution, habitat, usage and threats. In: San-Miguel-Ayanz, J, de Rigo D, Caudullo G, Houston Durrant T, Mauri A (Eds.), European Atlas of Forest Tree Species. Publications Office of the European Union, Luxembourg, pp. e010226+

Bright DE (1987) The metallic wood-boring beetles of Canada and Alaska: Coleoptera: Buprestidae. *Insects and Arachnids of Canada Handbook Series* **15**, 255–256.

Carlson RW & Knight FB (1969) Biology, taxonomy, and evolution of four sympatric *Agrilus* beetles. *Contributions of the American Entomological Institute* **4**(3), 1–105.

Chamorro ML, Jendek E, Haack RA, Petrice TR, Woodley NE, Konstantinov AS, Volkovitsh MG, Yang XK, Grebennikov VV, & Lingafelter SW (2015) Illustrated guide to the emerald ash borer *Agrilus planipennis* Fairmaire and related species (Coleoptera, Buprestidae). Pensoft, Sofia, Bulgaria. 197 pp.

Duckles B & Svihra P (1995). Bronze birch borer discovered in California. University of California, Cooperative Extension, Hortscript No. 16.

EFSA (2020) Schrader G, Kinkar M & Vos S. Pest survey card on *Agrilus anxius*. EFSA Supporting Publication 2020:EN-1777. 23 pp.

EPPO (2011) Report of a Pest Risk Analysis for *Agrilus anxius*. Document 11-16988. Paris. Available at <https://gd.eppo.int/taxon/AGRLAX/documents>

EPPO (2017) EPPO Standard PM 8/6(1) *Betula*. Commodity-specific phytosanitary measures. *EPPO Bulletin* **47**, 461–469.

EPPO (2020) *Agrilus bilineatus*. EPPO datasheets on pests recommended for regulation. *EPPO Bulletin* **50**, 158–165.

Evans HF, Williams D, Hoch G, Loomans A & Marzano M (2020) Developing a European toolbox to manage potential invasion by emerald ash borer (*Agrilus planipennis*) and bronze birch borer (*Agrilus anxius*), important pests of ash and birch. *Forestry* **93**, 187–196.

Flø D, Krokene P & Økland B (2014) Importing deciduous wood chips from North America to northern Europe: The risk of introducing bark- and wood-boring insects. *Scandinavian Journal of Forest Research* **29**, 77–89.

Goebel PC, Bumgardner MS, Herms DA & Sabula A (2010) Failure to phytosanitize firewood infested with emerald ash borer (*Agrilus planipennis*) in a small dry kiln using ISPM-15 standards. *Journal of Economic Entomology* **103**, 597–602.

Haack RA (2006) Exotic bark- and wood-boring coleoptera in the United States: recent establishments and interceptions. *Canadian Journal of Forest Research* **36**, 269–288.

Haack RA & Petrice TR (2019) Historical population increases and related inciting factors of *Agrilus anxius*, *Agrilus bilineatus*, and *Agrilus granulatus liragus* (Coleoptera: Buprestidae) in the Lake States (Michigan, Minnesota, and Wisconsin). *The Great Lakes Entomologist*, **52**, 21–33.

Haack RA, Jendek E, Liu H, Marchant KR, Petrice TR, Poland TM & Ye, H. (2002) The emerald ash borer: a new exotic pest in North America. *Newsletter of the Michigan Entomological Society* **47**, 1–5.

Haack RA, Baranchikov Y, Bauer LS & Poland TM (2015) Emerald ash borer biology and invasion history, pp. 1–13. In R Van Driesche, J Duan, K Abell, L Bauer & J Gould (eds.), *Biology and control of emerald ash borer*. FHTET–2014–09. USDA Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV.

Herms DA, McCullough DG, Clifford CS, Smitley DR, Miller FD, Cranshaw W (2019) Insecticide options for protecting ash trees from emerald ash borer. North Central IPM Center Bulletin. 3rd Edition. 16 pp. Online at: [http://www.emeraldashborer.info/documents/Multistate\\_EAB\\_Insecticide\\_Fact\\_Sheet.pdf](http://www.emeraldashborer.info/documents/Multistate_EAB_Insecticide_Fact_Sheet.pdf)

[accessed on 19 June 2020].

Hynynen J, Niemistö P, Viherä-aarnio A, Brunner A, Hein S & Velling P (2010) Silviculture of birch (*Betula pendula* Roth and *Betula pubescens* Ehrh.) in northern Europe. *Forestry* **83**, 103–119.

Kopinga J, Moraal LG, Verwer CC & Clerckx APPM (2010). Phytosanitary risks of wood chips. Alterra Report 2059, pp. 88. Alterra, Wageningen (NL)

Kurczewski FE & Miller RC (1984) Observations on the nesting of three species of *Cerceris* (Hymenoptera: Sphecidae). *Florida Entomologist* **67**, 146–155.

Kyei-Poku G, Gauthier D, Schwarz R & Frankenhuyzen KV (2011) Morphology, molecular characteristics and prevalence of a *Cystosporogenes* species (Microsporidia) isolated from *Agrilus anxius* (Coleoptera: Buprestidae) *Journal of Invertebrate Pathology* **107**, 1–10.

Loerch CR & Cameron EA (1983a) Determination of larval instars of the bronze birch borer, *Agrilus anxius* (Coleoptera: Buprestidae). *Annals of the Entomological Society of America* **76**, 948–952.

Loerch CR & Cameron EA (1983b) Natural enemies of immature stages of the bronze birch borer, *Agrilus anxius*, (Coleoptera: Buprestidae) in Pennsylvania. *Environmental Entomology* **12**, 1798–1801.

Loerch CR & Cameron EA (1984) Within-tree distributions and seasonality of immature stages of the bronze birch borer, *Agrilus anxius* (Coleoptera: Buprestidae). *Canadian Entomologist* **116**, 147–152.

McCullough DG, Poland TM, Cappaert D, Clark EL, Fraser I, Mastro V, Smith S & Pell C (2007) Effects of chipping, grinding, and heat on survival of emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae), in chips. *Journal of Economic Entomology* **100**, 1304–1315.

McCullough DG, Poland TM, Anulewicz AC, Lewis P & Cappaert D (2011) Evaluation of *Agrilus planipennis* control provided by emamectin benzoate and two neonicotinoid insecticides, one and two seasons after treatment. *Journal of Economic Entomology* **104**, 1599–1612.

McKenzie N, Helson B, Thompson D, Otis G, McFarlane J, Buscarini T & Meating J (2010) Azadirachtin: an effective systemic insecticide for control of *Agrilus planipennis* (Coleoptera: Buprestidae). *Journal of Economic Entomology* **103**, 708–717.

Meurisse N, Rassati D, Hurley BP, Brockerhoff EG & Haack RA (2019) Common pathways by which non-native forest insects move internationally and domestically. *Journal of Pest Science* **92**, 13–27.

Miller RO, Bloese PD, Hanover JW & Haack RA (1991) Paper birch and European white birch vary in growth and resistance to bronze birch borer. *Journal of the American Society for Horticultural Science* **116**, 580–584.

Millers I, Shriner DS & Rizzo D (1989) History of hardwood decline in the eastern United States. General Technical Report NE-126. USDA Forest Service, Northeastern Forest Experiment Station, Broomall, PA (US).

Muilenburg VL & Herms DA (2012) A review of bronze birch borer (*Agrilus anxius*, Coleoptera: Buprestidae) life history, ecology, and management. *Environmental Entomology* **41**, 1372–1385.

Mussey GJ & Potter DA (1997) Phenological correlations between flowering plants and activity of urban landscape pests in Kentucky. *Journal of Economic Entomology* **90**, 1615–1627.

Myers SW, Fraser I & Mastro VC (2009) Evaluation of heat treatment schedules for emerald ash borer (Coleoptera: Buprestidae). *Journal of Economic Entomology* **102**, 2048–2055.

Nash RW, Duda EJ & Gray NH (1951) Studies on Extensive Dying, Regeneration, and Management of Birch. *Maine Forest Service Bulletin* **15**, 82 pp. Maine Forest Service, Augusta, ME (US).

Nielsen DG, Muilenburg VL & Herms DA (2011) Comparative resistance of Asian, European, and North American



- birch (*Betula*) spp. to bronze birch borer (Coleoptera: Buprestidae). *Environmental Entomology* **40**, 648–653.
- Økland B, Haack RA & Wilhelmsen G (2012) Detection probability of forest pests in current inspection protocols – a case study of the bronze birch borer. *Scandinavian Journal of Forest Research* **27**, 285–297.
- Paiero SM, Jackson MD, Jewiss-Gaines A, Kimoto T, Gill BD & Marshall SA (2012) Field guide to the jewel beetles of northeastern North America. Canadian Food Inspection Agency, Ottawa, Ontario, Canada. 411 pp.
- Petrice TR & Haack RA (2006) Efficacy of three insecticides applied to bark to control *Agrilus planipennis* (Coleoptera: Buprestidae). *Great Lakes Entomologist* **39**, 27–33.
- Petrice TR, Haack RA & Poland TM (2013) Attraction of *Agrilus planipennis* (Coleoptera: Buprestidae) and other buprestids to sticky traps of various colors and shapes. *The Great Lakes Entomologist* **46**, 13–30.
- Petter F, Orlinski A, Suffert M, Roy AS & Ward M (2020) EPPO perspective on *Agrilus planipennis* (emerald ash borer) and *Agrilus anxius* (bronze birch borer). *Forestry* **93**, 220–224
- Poland TM & McCullough DG (2006) Emerald ash borer: invasion of the urban forest and the threat to North America's ash resource. *Journal of Forestry* **104**, 118–124.
- Rutledge CE (2020) Preliminary studies on using emerald ash borer (Coleoptera: Buprestidae) monitoring tools for bronze birch borer (Coleoptera: Buprestidae) detection and management. *Forestry* **93**, 297–304.
- Rutledge CE & Keena MA (2012) Mating frequency and fecundity in *Agrilus anxius* (Coleoptera: Buprestidae). *Annals of the Entomological Society of America* **105**, 852–858.
- Rutledge CE & Keena MA (2019) Mating behavior and reproductive biology of emerald ash borer (Coleoptera: Buprestidae) and two of its native congeners, the twolined chestnut borer and the bronze birch borer. *Journal of Economic Entomology* **112**, 2620–2631.
- Santamour FS (1999) Progress in the development of borer-resistant white-barked birches. *Journal of Arboriculture* **25(3)**, 151-162.
- Silk PJ, Ryall K, Grant GG, Roscoe LE, Mayo P, Williams M, LeClair G, Kimoto T, Williams D & Rutledge C (2020) Tree girdling and host tree volatiles provides a useful trap for bronze birch borer *Agrilus anxius* Gory (Coleoptera: Buprestidae). *Forestry* **93**, 265–272.
- Smitley DR, Docola JJ & Cox DL (2010) Multiple-year protection of ash trees from emerald ash borer with a single trunk injection of emamectin benzoate, and single-year protection with an imidacloprid basal drench. *Arboriculture & Urban Forestry* **36**, 206–211.
- Swink WG, Paiero SM & Nalepa CA (2013) Buprestidae collected as prey by the solitary, ground nesting philanthine wasp *Cerceris fumipennis* (Hymenoptera: Crabronidae) in North Carolina. *Annals of the Entomological Society of America* **106**, 111-116.
- Taylor PB, Duan JJ, Fuester RW, Hoddle R & van Driesche R. (2012) Parasitoid guilds of *Agrilus* woodborers (Coleoptera: Buprestidae): their diversity and potential for use in biological control. *Psyche* doi:10.1155/2012/813929
- Taylor RAJ, Bauer LS, Poland TM & Windell KN (2010) Flight performance of *Agrilus planipennis* (Coleoptera: Buprestidae) on a flight mill and in free flight. *Journal of Insect Behavior* **23**, 128–148.
- Triapitsyn SV, Petrice TR, Gates MW, Bauer LS (2015) Two new species of *Oobius* Trjapitzin (Hymenoptera, Encyrtidae) egg parasitoids of *Agrilus* spp. (Coleoptera, Buprestidae) from the USA, including a key and taxonomic notes on other congeneric Nearctic taxa. *ZooKeys* **498**, 29–50.

## ACKNOWLEDGEMENTS

This datasheet was originally prepared in 2011 by VL Muilenburg and DA Herms, Ohio Agricultural Research and Development Center, The Ohio State University, Wooster, OH, USA.

The current datasheet was extensively revised and updated where needed in 2020 by Robert A. Haack, USDA Forest Service, Northern Research Station, Lansing, MI, USA (emeritus). His valuable contribution is gratefully acknowledged.

### **How to cite this datasheet?**

EPPO (2024) *Agrilus anxius*. EPPO datasheets on pests recommended for regulation. Available online. <https://gd.eppo.int>

### **Datasheet history**

This datasheet was first published in the EPPO Bulletin in 2011 and revised in 2020. It is now maintained in an electronic format in the EPPO Global Database. The sections on 'Identity', 'Hosts', and 'Geographical distribution' are automatically updated from the database. For other sections, the date of last revision is indicated on the right.

EPPO (2011) *Agrilus anxius*. Datasheets on pests recommended for regulation. *EPPO Bulletin* **41**(3), 409-413. <https://doi.org/10.1111/j.1365-2338.2011.02510.x>



Co-funded by the  
European Union