European and Mediterranean Plant Protection Organization
Organisation Européenne et Méditerranéenne pour la Protection des Plantes

EPPO Data sheets on pests recommended for regulation
Fiches informatives sur les organismes recommandés pour réglementation

Agrilus anxius

Identity

Name: *Agrilus anxius* Gory, 1841
Synonyms: none.
Taxonomic position: Insecta: Coleoptera: Buprestidae.
Common names: bronze birch borer (English); agrile du bouleau (French).
EPPO code: AGRLAX.
Phytosanitary categorization: EPPO A1 list no. 362.

Hosts

Agrilus anxius is a specialist wood-borer of *Betula* species. In North America, primary hosts are *B. papyrifera*, *B. populifolia*. *B. lenta*, *B. lutea, B. occidentalis,* and *B. alleghaniensis* (Balch & Prebble, 1940; Ball & Simmons, 1980; Nielsen *et al.*, 2011). European and Asian birch species rigorously examined thus far in North America are highly susceptible to *A. anxius* colonization, including *B. pendula, B. pubescens*, *B. maximowicziana*, and *B. szechuanica* (Ball & Simmons, 1980; Miller *et al.*, 1991; Nielsen *et al.*, 2011).

Geographical distribution

EPPO region: absent.
EU: absent.
Asia: absent.
North America: Canada (Alberta, British Columbia, Labrador, Manitoba, New Brunswick, Newfoundland, Northwest Territories, Nova Scotia, Ontario, Quebec, Saskatchewan, Yukon); United States (Alaska, Arkansas, California, Colorado, Connecticut, Delaware, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New York, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, South Dakota, Tennessee, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin, Wyoming).

Agrilus anxius is endemic throughout the boreal and northern temperate regions of North America. Its current range expands into the Southern and Western United States as a result of widespread planting of birch species as amenity trees beyond their native range (Bright, 1987; Johnson *et al.*, 2001).

Biology

Agrilus anxius exhibits an annual or biennial life cycle depending on latitude, climatic conditions, and host condition (Slingerland, 1906; Balch & Prebble, 1940; Anderson, 1944; Nash *et al.*, 1951). In Ohio and Michigan, adult emergence has been shown to begin at about 550 cumulative degree days, using a base temperature of 50°F and a starting date of January 1 (Herms, 2004), i.e. about 305 DD using a base 10°C. Adult emergence occurs over a period of 10–12 weeks, with peak emergence occurring approximately 2–4 weeks after first emergence (Akers & Nielsen, 1984). Adults (Fig. 1) are active between May and August, depending on climate (Barter, 1957; Akers & Nielsen, 1984; Loerch & Cameron, 1984; Mussey & Potter, 1997), and live for 2–5 weeks (Akers & Nielsen, 1990).

Adult feeding is obligate for survival and reproductive maturation (Barter, 1957; Akers & Nielsen, 1990). Adults can feed successfully on leaves of several species (e.g. *Salix, Betula, Populus*), but foliar damage is negligible (Akers & Nielsen, 1990). Females lay eggs singly or in clusters, consisting of up to 14 eggs, in bark crevices, cracks, and under loose layers of outer bark (Barter, 1957; Loerch & Cameron, 1984). Females have the potential to produce about 75 eggs in a lifetime (Barter, 1957). Egg eclosion occurs after approximately 2 weeks (Barter, 1957).

Neonates bore through the outer bark into phloem tissue and complete 4 instars (Fig. 2A) (Loerch & Cameron, 1983a). Larval feeding results in formation of frass-filled galleries in the phloem and phloem-xylem interface. Galleries vary in length based on host condition and species (Fig. 2B). Larvae produce shorter galleries (approximately 25 cm) in unfavourable hosts (resistant trees) compared to their long, sinuous galleries (approximately 127 cm) in favourable hosts (more susceptible trees) (Anderson, 1944; Barter, 1957). Galleries disrupt phloem transport, which at high densities can girdle and kill trees (Barter, 1957). All instars

Fig. 1 *Agrilus anxius* adult and D-shaped exit hole (photo credit: DG Nielsen).

can overwinter (Barter, 1957). However, pre-pupal larvae (4th instars that have completed feeding and constructed pupal cells) must overwinter or experience freezing temperatures for pupation to occur (Barter, 1957). Upon completion of larval development, 4th instars construct pupal cells interior to the cambial layer, generally during late summer or early autumn (Barter, 1957; Loerch & Cameron, 1984). If similar to *A. planipennis*, a congener to *A. anxius* (Petrice & Haack, 2007), 4th instars of *A. anxius* could persist in this non-feeding stage for extended periods of time. Pupation occurs in April–May (Loerch & Cameron, 1984). Adults emerge from the stems between May and July leaving D-shaped holes that are 3–5 mm wide (Fig. 1) (Akers & Nielsen, 1984).

Agrilus anxius colonizes most *Betula* species and cultivars, although host resistance varies. An intensive study suggests that *B. nigra* is immune to colonization (Nielsen *et al.*, 2011). Bronze birch borer is considered a secondary invader of stressed trees (Houston, 1987), and colonization of other North American species (e.g. *B. papyrifera, B. populifolia, B. lutea, B. allegheniensis*) has been associated with drought, old age, insect defoliation, soil compaction, and stem or root injury (Balch & Prebble, 1944; Anderson, 1944; Barter, 1957; Jones *et al.*, 1993). European and Asian species that have been studied are much more susceptible than North American species (Miller *et al.*, 1991; Nielsen *et al.*, 2011). 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. pendula*, *B. pubescens, B. maximowicziana, B. szechuanica*), but the majority of individuals (>75%) of North American species (*B. papyrifera, B. populifolia, B. nigra*) were still alive at the end of the study (Nielsen *et al.*, 2011). Drought stress is not necessary for colonization of *B. pendula* by *A. anxius*, as both irrigated and non-irrigated *B. pendula* trees were highly susceptible to *A. anxius* colonization in a controlled experiment (BK Hale and DA Herms, unpublished). Birch trees as small as 2.5 cm are colonized by *A. anxius* (DA Herms and DG Nielsen, pers. obs.).

In North America, *A. anxius* populations generally exist at endemic levels (Balch & Prebble, 1940). However, periodic outbreaks have been reported during the 20th century and have been associated with predisposing stress (Balch & Prebble, 1940; Nash *et al.*, 1951; Houston, 1987; Jones *et al.*, 1993). For example, following a severe drought, mortality of over 105 million birch trees was associated with an outbreak of *A. anxius* in the Great Lakes region of North America (Jones *et al.*, 1993; Minnesota DNR, 1993, 1994).

Fig. 2 (A) *Agrilus anxius* larva. (B) Serpentine larval gallery. (C) Externally visible bark ridges resulting from wound periderm growth over larval galleries.

Detection and identification

Symptoms

Trees infested with *A. anxius* contain at least one of the following: D-shaped holes created by emerging adults (Fig. 1), larval galleries filled with frass at the phloem–xylem interface (Fig. 2B), or serpentine swellings or ridges visible through the bark where wound periderm (callus) has grown over galleries (Fig. 2C) (Anderson, 1944; Barter, 1957). Trees infested with *A. anxius* may exhibit branch dieback, proceeding distally to proximally in the crown (Ball & Simmons, 1980). Branch dieback is sometimes preceded by yellow or thinning foliage.

Morphology

Eggs
The eggs of *A. anxius* are white to creamy, becoming more yellow as they mature (Barter, 1957). Eggs are oval in shape and approximately 1.5 mm long by 0.75 mm wide (Hutchings, 1923; Barter, 1957).

Larva
Larvae are white to creamy in colour and dorso-ventrally flat (Fig. 2A). The head is small and protracted into the wide prothorax. There are eight abdominal segments followed by two caudal segments (Barter, 1957). The final caudal segment terminates in two sclerotized tooth-like styles (urogomphi), which are characteristic of *Agrilus* (Slingerland, 1906). Mature larvae are 8–20 mm long and have four instars (Loerch & Cameron, 1983a).

Pupa
Pupation takes place in shallow cells excavated in the xylem interior to the cambium. Pupae are creamy-white upon molting and become increasingly darker as pupation progresses, ultimately achieving a bronze to black colour (Barter, 1957).

Adult
Adults are narrow, subcylindrical with coppery-bronze metallic colouration. They are 7–12 mm long and females are slightly larger than males (Barter, 1957). Males have ventral grooves on the first and second abdominal segments (Barter, 1957). Adult male *A. anxius* can be differentiated from the morphologically similar *A. liragus* (bronze poplar borer) by genitalia morphology. The lateral lobes of *A. anxius* male genitalia are less narrow apically and more bluntly pointed (Barter & Brown, 1949). Additionally, *A. anxius* has 22 chromosomes whereas *A. liragus* has 20 (Smith, 1949).

Pathways for movement

There is no information about *A. anxius* adult dispersion by flight or wind. However, when tethered to a flight mill, *A. planipennis*, a similarly sized congener to *A. anxius*, flies on average 1.3 km per day and can exceed 7 km per day (Taylor *et al.*, 2010). *Agrilus* spp. can also be transported by movement of infested plants or wood products, including dunnage, crates, pallets, wood chips, lumber and firewood (Haack, 2006). In particular, non-sanitized wood-packing material constructed from recently cut trees can frequently harbour wood-boring insects (Haack, 2006). The non-feeding pre-pupal and pupal stages of *Agrilus* can survive for up to 2 years in cut firewood (Petrice & Haack, 2007). A potential pathway for movement of *A. anxius* into Europe is the importation of woodchips from North America for biofuel. Large volumes of deciduous wood chips, which include material from *Betula* spp., are imported and stored outdoors in close proximity to susceptible birch species (Kopinga *et al.*, 2010).

Pest significance

Economic impact

In North America, *A. anxius* is 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 community composition and wildlife (Balch & Prebble, 1944; Nash *et al.*, 1951; Millers *et al.*, 1989; Jones *et al.*, 1993).

Betula spp. exist throughout most of Europe but are most dominant in temperate and boreal forests of Northern Europe (Hultén & Fries, 1986). In Northern Europe, birch are the most important commercial broadleaved species (Hynynen *et al.*, 2010), and depending on species, are used for pulpwood, fuel wood, lumber, plywood, and as amenity trees.

Control

Control and detection of this type of wood-boring insect is difficult. There are several insecticides (e.g. azadiractin, bifenthrin, dicrotophos, dimethoate, dinotefuran, emamectin benzoate, imidacloprid, permethrin) that have been shown to control *Agrilus* spp. to varying degrees (Appleby *et al.*, 1973; Petrice & Haack, 2006; Herms *et al.*, 2009; McKenzie *et al.*, 2010; Smitley *et al.*, 2010). They may be used in nurseries or 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.*, 2009).

Trees infested with buprestids can be removed and then chipped/ground or heat-treated to kill larvae and pupae (McCullough *et al.*, 2007). However, there are uncertainties about the maximum size of wood chips that will guarantee absence of larvae and pupae (McCullough *et al.*, 2007; Kopinga *et al.*, 2010). Additionally, the efficacy of heat-treatment in killing larvae and pupae of wood-boring insects depends on the amount of bark retained on logs (Haack & Petrice, 2009), the type of heat used (e.g. dry heat vs. steam heat) (Nzokou *et al.*, 2008; Myers *et al.*, 2009), and the intensity and duration of heat (Myers *et al.*, 2009; Goebel *et al.*, 2010).

A rich suite of natural enemies to *A. anxius* exists in North America (Nash *et al.*, 1951; Barter, 1957; Loerch & Cameron, 1983b). Although natural enemies have caused substantial mortality to North American populations of *A. anxius* in some cases (>50% of egg or larval mortality: Nash *et al.*, 1951; Barter, 1957; Loerch & Cameron, 1983b), there are no studies of their effects on population dynamics and their ability to regulate populations of *A. anxius* in North America.

Phytosanitary risk

The wide geographical distribution of *A. anxius* in North America, from Northern Canada to the Southern United States, indicates that *A. anxius* can tolerate a wide range of climatic conditions, and could be physiologically pre-adapted to establish throughout much of the EPPO region. Birch species exist throughout most of Europe and Asia. Some species, such as *B. pendula* and *B. pubescens*, dominate stands in Northern Europe. 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* spp. to *A. anxius* (Nielsen *et al.*, 2011), the introduction and establishment of this beetle may be expected to result in outbreaks and widespread mortality of *Betula* in forests, nurseries, and cities throughout Eurasia. If it were to be introduced and establish, *A. anxius* could threaten to extirpate European *Betula* spp. on a continental scale, just as the establishment and spread of *A. planipennis* in North America threatens the survival of *Fraxinus* spp in North America (Poland & McCullough, 2006).

Phytosanitary measures

Agrilus anxius was added in 2011 to the EPPO A1 List of pests recommended for regulation, and EPPO member countries are thus recommended to regulate it as a quarantine pest. Suggested phytosanitary measures are specified in the PRA performed by EPPO in 2010; they are as follows.

Plants for planting of *Betula* should originate from countries found free from the pest or be a small diameter (<2 cm). Alternatively they may be grown under insect-proof conditions.

Betula wood commodities should originate from countries found free from the pest or undergo heat treatment, chemical treatment, irradiation, chipping, or grinding. Alternatively they may be stored in the country of export for an appropriate period (1 year for wood chips, 2 years for wood).

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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.

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

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 (2009) Bark- and wood-borer colonization of logs and lumber after heat treatment to ISPM 15 specifications: the role of residual bark. *Journal of Economic Entomology* **102**, 1075–1084.

Herms DA (2004) Using degree-days and plant phenology to predict pest activity. In: *IPM (Integrated Pest Management) of Midwest Landscapes* (eds Krischik V & Davidson J), pp. 49–59. Minnesota Agricultural Experiment Station Publication SB-07645, 316 pp. St. Paul, MN Minnesota (US).

Herms DA, McCullough DG, Smitley DR, Sadof CS, Williamson RC & Nixon PL (2009) Insecticide options for protecting ash trees from emerald ash borer. *North Central IPM Center Bulletin*, 12 pp.

Houston DR (1987) Forest tree declines of past and present: current understanding. *Canadian Journal of Plant Pathology* **9**, 349–360.

Hultén E & Fries M (1986) *Atlas of North European Vascular Plants: North of the Tropic of Cancer. I. Introduction, Taxonomic Index to the Maps*, 996 pp. Koeltz Scientific Books, Königstein (DE).

Hutchings CB (1923) Some biologic observations on the bronze birch borer *Agrilus anxius*, Gory. In: *15th Annual Report of the Quebec Society for the Protection of Plants from Insects and Fungous Diseases*, pp. 89–92. The Entomological Society of Ontario, Quebec (CA).

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 (Oxford)* **83**, 103–119.

Johnson MP, Hartman JR, McNiel RE & Fountain WM (2001) Evaluation of dogwood and birch species and cultivars for resistance to key insect pests and diseases. *Journal of Environmental Horticulture* **19**, 73–78.

Jones EA, Reed DD, Mroz GD, Liechty HO & Cattelino PJ (1993) Climate stress as a precursor to forest decline: paper birch in northern Michigan, 1985-1990. *Canadian Journal of Forest Research* **23**, 229–233.

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

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: Buperstidae) 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.

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

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).

Minnesota DNR (Department of Natural Resources). (1993) Birch survey. In: *Minnesota Forest Health Report 1992*, pp. 67–77. Minnesota Department of Natural Resources, St. Paul, MN (US).

Minnesota DNR (Department of Natural Resources) (1994) Birch survey. In: . *Minnesota Forest Health Report 1994* , pp. 9–14. Minnesota Department of Natural Resources, St. Paul, MN (US).

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.

Nzokou P, Tourteilot S & Kamdem DP (2008) Kiln and microwave heat treatment of logs infested by the emerald ash borer (*Agrilus planipennis* Fairmaire) (Coleoptera: Buprestidae). *Forest Products Journal* **58**, 68–72.

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 (2007) Can emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae), emerge from logs two summers after infested trees are cut? *Great Lakes Entomologist* **40**, 92–95.

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.

Slingerland MV (1906) The bronze birch borer. *Cornell Agricultural Experimental Station Bulletin* **234**, 63–78.

Smith SG (1949) Evolutionary changes in the sex chromosomes of Coleoptera. I. Wood borers of the genus *Agrilus*. *Evolution* **3**, 344–357.

Smitley DR, Doccola 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.

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.