

EPPO Datasheet: *Agrilus planipennis*

Last updated: 2021-01-15

IDENTITY

Preferred name: *Agrilus planipennis*

Authority: Fairmaire

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

Other scientific names: *Agrilus marcopoli ulmi* Kurosawa, *Agrilus marcopoli* Obenberger

Common names: emerald ash borer

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EPPO Categorization: A2 list

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EU Categorization: Emergency measures (formerly), A1 Quarantine pest (Annex II A)

EPPO Code: AGRLPL



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Notes on taxonomy and nomenclature

Jendek (1994) synonymized three *Agrilus* species under the name *Agrilus planipennis* Fairmaire (1888; type China), including *A. feretrius* Obenberger (1936; type Taiwan), *A. marcopoli* Obenberger (1930; type China), and *A. marcopoli ulmi* Kurosawa (1956; type Japan). Much of the early literature on *A. planipennis* refers to *A. marcopoli* in China and to *A. marcopoli ulmi* in Japan. More recently, Chamorro *et al.* (2015) reclassified the *A. feretrius* specimens from Taiwan as *Agrilus tomentipennis* along with specimens from Laos.

HOSTS

Native hosts of *A. planipennis* include almost exclusively species of ash (*Fraxinus*). The known Asian species include *Fraxinus chinensis*, *F. chinensis* subsp. *rhynchophylla*, *Fraxinus mandshurica* and *Fraxinus platypoda* (= *F. spaethiana*) (Liu *et al.*, 2003; Wei *et al.*, 2004; Zhao *et al.*, 2005; Mori, 2012). In North America, *A. planipennis* has infested all species of native ash so far encountered, including *Fraxinus americana*, *Fraxinus latifolia*, *Fraxinus nigra*, *Fraxinus pennsylvanica*, *Fraxinus profunda*, and *Fraxinus quadrangulata* (Haack *et al.*, 2002; Poland and McCullough, 2006; Herms, 2015), as well as *Chionanthus virginicus* (Peterson & Cipollini, 2017). In European Russia, *A. planipennis* has infested and completed development in *Fraxinus angustifolia* subsp. *oxycarpa*, *Fraxinus excelsior*, and *Fraxinus ornus* (Baranchikov *et al.*, 2014; Orlova-Bienkowskaja *et al.*, 2020). The North American species *Fraxinus velutina* has been attacked in China (Liu *et al.*, 2003). In laboratory studies, *A. planipennis* has successfully completed development in cut trunk sections of *Fraxinus uhdei* (Herms, 2015) and *Olea europaea* (Cipollini *et al.*, 2017). Reports from Japan (Akiyama & Ohmomo, 1997; Sugiura, 2008) that *A. planipennis* can complete development in *Juglans ailanthifolia*, *Juglans mandshurica*, *Pterocarya rhoifolia*, and *Ulmus davidiana* are now considered incorrect larval host records (referring to personal communications in section 7, p. 12 - EPPO, 2013a; Sugiura N, pers. comm.). Although *Fraxinus japonica* and *Fraxinus lanuginosa* have been reported as larval hosts for *A. planipennis* by various authors, no published rearing records have been found.

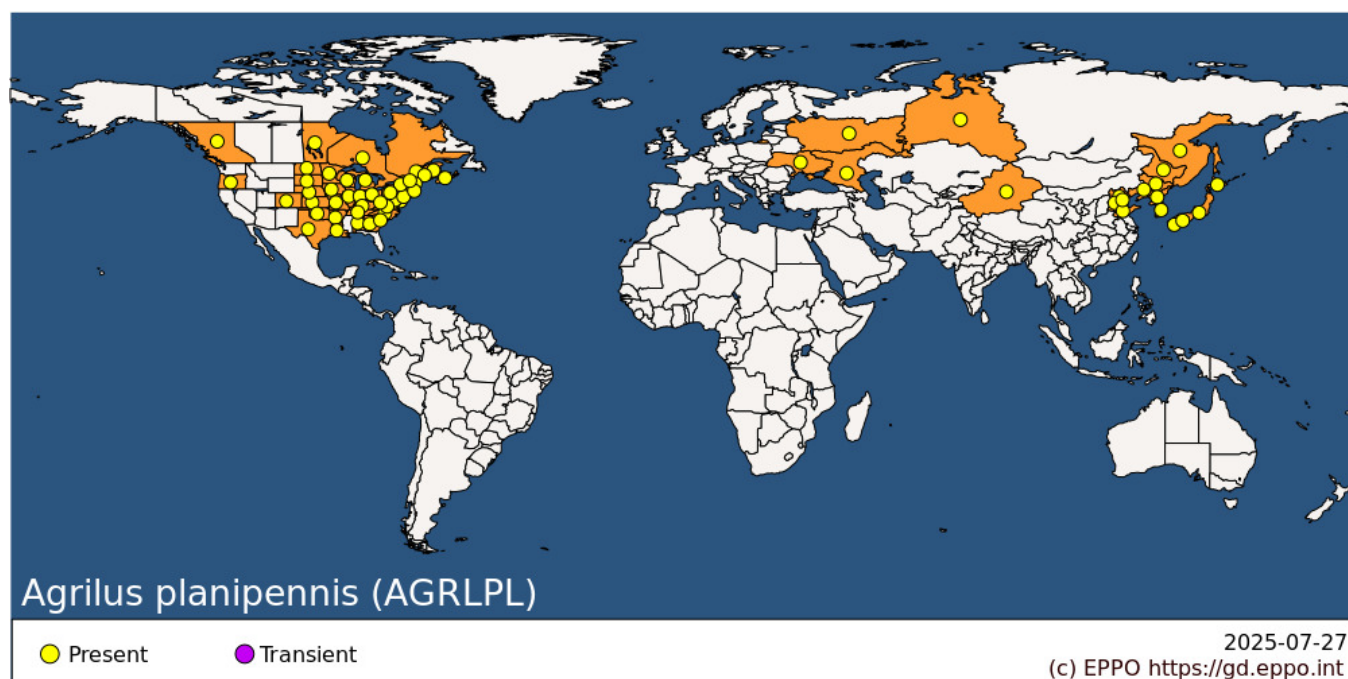
Host list: *Chionanthus virginicus*, *Fraxinus americana*, *Fraxinus angustifolia* subsp. *oxycarpa*, *Fraxinus chinensis* subsp. *rhynchophylla*, *Fraxinus chinensis*, *Fraxinus excelsior*, *Fraxinus latifolia*, *Fraxinus mandshurica*, *Fraxinus nigra*, *Fraxinus ornus*, *Fraxinus pennsylvanica*, *Fraxinus platypoda*, *Fraxinus quadrangulata*, *Fraxinus velutina*

GEOGRAPHICAL DISTRIBUTION

A. planipennis is native to several Asian countries (China, Japan, North Korea, South Korea, and the Russian Far East). Early reports of *A. planipennis* occurring in Mongolia (Yu, 1992; Jendek, 1994) have been questioned in

recent publications (Orlova-Bienkowskaja & Volkovitsh, 2018, EFSA *et al.*, 2020). In addition, Schaefer (2005) reported that ash (*Fraxinus*) trees are absent in Mongolia and that no *A. planipennis* specimens were present in Mongolia's National University insect collection in Ulaanbaatar. Similarly, reports of *A. planipennis* being native to Taiwan (Jendek, 1994) and Laos (Jendek & Grebennikov, 2011), are now uncertain given that these specimens were recently reassigned to the species *Agrilus tomentipennis* Jendek & Chamorro (Jendek & Chamorro, 2012; Chamorro *et al.*, 2015), which is highly similar in appearance to *A. planipennis*. Clearly, more research is needed to define the true native range of *A. planipennis* in South-Eastern Asia.

In recent decades, *A. planipennis* has spread to new parts of China as well as to North America and Europe. In China, *A. planipennis* was recently reported in the western province of Xinjiang, where it is considered non-native (Orlova-Bienkowskaja & Volkovitsh, 2018). In North America, *A. planipennis* was first reported in 2002 near Detroit, Michigan, US and in neighboring Windsor, Ontario, CA (Haack *et al.*, 2002). As of December 2020, *A. planipennis* was found in 35 US states and the District of Columbia and in five Canadian provinces (EABinfo, 2020). In Europe, *A. planipennis* adults were first collected in European Russia near Moscow in 2003 but not positively identified until 2005 (Baranchikov *et al.*, 2008; Haack *et al.*, 2015). As of 2020, *A. planipennis* has spread to several regions of European Russia and into Western Ukraine (Orlova-Bienkowskaja *et al.*, 2020; Volkovitsh & Suslov, 2020). The exact pathways by which *A. planipennis* first reached North America and European Russia are unknown. However, wood packaging is considered the likely original source in North America, and either nursery stock or wood packaging in Russia (Haack *et al.*, 2015).



EPPO Region: Russian Federation (the) (Central Russia, Far East, Southern Russia, Western Siberia), Ukraine
Asia: China (Beijing, Hebei, Heilongjiang, Jilin, Liaoning, Shandong, Tianjin, Xinjiang), Japan (Hokkaido, Honshu, Kyushu, Shikoku), Korea, Democratic People's Republic of, Korea, Republic of
North America: Canada (British Columbia, Manitoba, New Brunswick, Nova Scotia, Ontario, Québec), United States of America (Alabama, Arkansas, Colorado, Connecticut, Delaware, District of Columbia, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Vermont, Virginia, West Virginia, Wisconsin)

BIOLOGY

Agrilus is the largest genus of animals worldwide, with over 3200 recognized species (Kelnarova *et al.*, 2019). *Agrilus* are native to Africa, Asia, Australia, Europe and the Americas, but not New Zealand (Chamorro *et al.*, 2015). *Agrilus* larvae typically feed and develop in the cambial region of woody plants (vines, shrubs, and trees) as well as

internally in the lower stems and roots of some herbaceous perennials (Chamorro *et al.*, 2015). Adults often have striking metallic colours and members of the family Buprestidae are often referred to as jewel beetles. Several *Agrilus* species are of economic importance in forestry, arboriculture, and agriculture. No native European or North American species of *Agrilus* are known to infest and kill ash trees, although some infest branches which are dying or recently dead, e.g., *A. convexicollis* Redtenbacher in Europe (Orlova-Bienkowskaja & Volkovitsh, 2015) and *A. subcinctus* Gory in North America (Petrice *et al.*, 2009).

Several studies and reviews have been published on the life-history of *A. planipennis* in China, Europe, and North America. Below is a summary based largely on Yu (1992), Haack *et al.* (2002), Cappaert *et al.* (2005), Wei *et al.* (2007), Wang *et al.* (2010), Chamorro *et al.* (2015), Herms & McCullough (2014), Haack *et al.* (2015), Poland *et al.* (2015), Orlova-Bienkowskaja & Biełkowski (2016), Valenta *et al.* (2017) and EFSA *et al.* (2020). *A. planipennis* typically has one generation per year although some individuals may require two years when developing in vigorous hosts, when developing from eggs laid in late summer, or where summer temperatures are cool. Depending on latitude and local temperatures, adult emergence usually begins in May or June, peaks in late May to early July, and adult activity can persist into September. After emergence, adults feed on host foliage for 1-2 weeks to become sexually mature. Adults are most active on sunny days. Adult males orient visually towards females when seeking mates. Adult females produce at least one short-range pheromone and two contact pheromones. Mating occurs on foliage and the bark surface of host trees. Adults feed throughout their lifespan and will mate multiple times. Eggs are laid singly or in small groups on the bark surface, usually in bark cracks and crevices. Adults usually live 3-9 weeks and females lay an average of 40 to 90 eggs in their lifetime. Eggs hatch in 1-2 weeks. Newly hatched larvae tunnel through the outer bark to the cambial region where they tunnel and feed in the inner bark (phloem) and outermost sapwood, creating meandering frass-packed galleries. There are four larval instars. Fourth-instar larvae construct pupal cells in the outer bark if the bark is sufficiently thick or in the outer sapwood. Most individuals overwinter as fourth-instar larvae, in a doubled-over position and referred to as J-shaped larvae or prepupae. Crosthwaite *et al.* (2011) reported a supercooling point of about -30 °C for *A. planipennis* prepupae. However, Orlova-Bienkowskaja & Biełkowski (2020) noted that *A. planipennis* populations have survived in areas experiencing -30 °C but so far not in areas experiencing -34 °C or below. If larvae do not become fourth instars by autumn, they overwinter in the cambial region and complete larval development the next summer, and then overwinter a second time before becoming adults. Pupation usually begins in April or May and takes about 3-4 weeks. Newly formed adults take about 1 week to harden their exoskeleton before chewing their way out of the tree through D-shaped exit holes that are about 3–4 mm wide.

DETECTION AND IDENTIFICATION

Signs and symptoms

Signs are physical damage to the plant usually made by the insect pest, whereas symptoms are a tree's response to the infestation. In the case of *A. planipennis*, the two most commonly observed signs include frass-filled larval galleries in the cambial region and adult exit holes on the bark surface (DeGroot *et al.*, 2006; EFSA *et al.*, 2020). Another sign, although less often seen, are notches along the leaf margins where adults have fed. Some vertebrates produce signs that can be used to locate infested trees such as woodpeckers that produce holes in the bark when feeding on *A. planipennis* or squirrels that feed on larvae and leave behind strips of ragged bark (DeGroot *et al.*, 2006). Typical symptoms include yellowing and thinning of foliage, crown dieback and eventual tree mortality. On some ash trees, epicormic shoots develop along the lower trunk of heavily infested trees, and at times the bark produces vertical splits or cracks, 5-15 cm long, usually over larval galleries where the sapwood has produced callus tissue in response to larval feeding. As no European species of *Agrilus* are known to infest the trunks of ash, the occurrence of galleries and exit holes typical of *Agrilus* in ash tree trunks and larger branches should automatically be suspect.

Trapping

Development of traps and lures for *A. planipennis* has been the focus of many studies (Herms & McCullough, 2014; Poland *et al.* 2015; EFSA *et al.*, 2020). Various shades of green and purple are highly attractive to *A. planipennis* adults. Both funnel traps and sticky prism traps have been used in regional surveys. Traps can be placed in the canopy, beneath the canopy, or near ground level. Traps baited with certain green leaf volatiles [e.g., (3Z)-hexenol]

or pheromones [e.g., (3Z)-lactone] capture more *A. planipennis* adults than unbaited traps (Silk *et al.*, 2020). Girdled ash trees are more attractive to *A. planipennis* than non-girdled trees and therefore can be used as a detection tool. For example, individual ash trees could be girdled in late spring or early summer to attract ovipositing *A. planipennis* and then debarked in autumn or winter to look for *A. planipennis* larvae and their galleries (Herms & McCullough, 2014). Survey methods and strategies for eradication of *A. planipennis* populations discovered in Europe have been published (EPPO, 2013b; EFSA *et al.*, 2020; Evans *et al.*, 2020).

Morphology

Several papers provide detailed photos of *A. planipennis* adults, including Chamorro *et al.* (2015) and Volkovitsh *et al.* (2020). Photos of all *A. planipennis* immature stages are presented in Chamorro *et al.* (2012), Haack *et al.* (2015), and EFSA *et al.* (2020), among others. Additional photos of *A. planipennis* larvae can be found in Petrice *et al.* (2009) and Volkovitsh *et al.* (2020).

Egg

Eggs are creamy yellow when first laid, turning reddish brown before hatching (DeGroot *et al.*, 2006; Chamorro *et al.*, 2012). Eggs are oval in cross section and somewhat flattened, measuring about 1.0–1.2 mm long; 0.6 mm wide, and 0.3 mm high. A glue-like substance on the bottom of the egg helps fasten it to the bark surface (Chamorro *et al.*, 2012).

Larva

Mature fourth-instar larvae of *A. planipennis* are 26–36 mm long and creamy white (Yu, 1992; Chamorro *et al.*, 2012). The body is elongate, and dorsoventrally flattened. The head is small, brown, and retracted into the prothorax, exposing only the mouthparts. The prothorax is enlarged, and the meso and metathorax are slightly narrower. Spiracles are found on the mesothorax and abdominal segments 1–8. The abdomen is 10-segmented terminates in a pair of brownish, sclerotized tooth-like structures that are often called urogomphi, anal forceps, or terminal processes (Petrice *et al.*, 2009; Chamorro *et al.*, 2012). Such terminal processes are characteristic of all known *Agrilus* larvae (Chamorro *et al.*, 2015). The prothoracic plate is pigmented with a bifurcated pronotal groove and abdominal segments 2–7 are trapezoidal or bell-shaped in appearance (Petrice *et al.*, 2009; Chamorro *et al.*, 2012).

Pupa

Pupation occurs in the cells that were constructed in the outer sapwood or outer bark by the mature larvae prior to overwintering. The larva contracts its body and then molts to the pupal stage. Pupae are 10–18 mm long, 4–6 mm wide, and creamy white at first. As pupation progresses the eyes darken first, then the mouthparts, and lastly the elytra, until the entire pupa darkens (Haack *et al.*, 2015). The antennae stretch back to the base of the elytra and the last few segments of the abdomen bend slightly ventrad (Yu, 1992).

Adult

Adults of *A. planipennis* are 8.5–15.0 mm long and 3.0–3.5 mm wide (Yu, 1992; DeGroot *et al.*, 2006; Chamorro *et al.*, 2015). The body is narrow, elongate, cuneiform, and a beautiful metallic blue-green colour. The elytra are glabrous. The head is flat and the vertex is shield-shaped. The compound eyes are kidney-shaped and somewhat bronze-coloured. The prothorax is transversely rectangular and slightly wider than the head, but the same width as the anterior margin of the elytra. The anterior margin of the elytra is raised, forming a transverse ridge.

More information on the detection and identification of *A. planipennis* can be found in the EPPO Standard PM 7/154 (EPPO, 2023).

PATHWAYS FOR MOVEMENT

Under laboratory conditions, *A. planipennis* adults can fly on average 1.3 km per day, with some individuals exceeding 7 km per day (Taylor *et al.*, 2010). However, long-distance movement that involves 10s or 100s of kilometers likely results from human assistance. Although there have been no reports of *A. planipennis* being intercepted in wood packaging material, several *Agrilus* individuals that were identified only to the genus level have

been intercepted. For example, between 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 recovered from dunnage, 4 from crating, 5 from live plants or plant parts, and 1 specimen was found loose in the ship (Haack *et al.*, 2002; Haack, 2006). In North America, *A. planipennis* has been moved in ash nursery stock, ash logs, ash firewood, and also been found hitch-hiking on the outside and inside of vehicles (Buck and Marshall, 2008; Haack *et al.*, 2015). In addition, Short *et al.* (2020) suggested that *A. planipennis* adults could hitch-hike on trains. Petrice & Haack (2006) reported that a small percentage of *A. planipennis* can emerge from firewood for two seasons after the wood was cut from infested trees.

PEST SIGNIFICANCE

Economic impact

A. planipennis has infested and killed ash trees in Asia where the pest is native as well as in Europe and North America where it has been introduced. *A. planipennis* readily kills stressed ash trees, but in addition it can kill healthy ash trees especially if the trees are non-coevolved ash species such as those native to Europe and North America. *A. planipennis* can infest and kill large mature ash trees as well as trees and branches as small as 1 cm in diameter (EPPO, 2013b). Hundreds of millions of ash trees have been killed in North America, resulting in billions of dollars spent on tree protection, removal, and replacement (Herms & McCullough, 2014). *A. planipennis* is considered the most costly non-native forest insect to have invaded the United States (Aukema *et al.*, 2011). In European Russia, *A. planipennis* has so far killed mostly plantations of the North American ash species *F. pennsylvanica* (Orlova-Bienkowskaja *et al.*, 2020), but as the pest spreads in Europe major economic impacts are expected given that several ash species are common throughout Europe and many are already known to be susceptible to *A. planipennis* (Baranchikov *et al.*, 2014; EFSA *et al.*, 2020).

The only non-ash larval host of *A. planipennis* so far documented in North America has been the white fringetree *Chionanthus virginicus* (Peterson & Cipollini, 2017). *Chionanthus* and *Fraxinus* are both genera in the Oleaceae family. *A. planipennis* has infested *C. virginicus* at multiple sites in at least four US states; however, compared to ash trees, mortality rates of *C. virginicus* are much lower (Peterson & Cipollini 2017).

Several ecological impacts have been documented in North America following the introduction of *A. planipennis*. For example, Klooster *et al.* (2016) documented over 99% ash tree mortality in several forest stands in Michigan, an ending of ash seed production, increased openings in the forest canopy, an accumulation of coarse woody debris resulting from the dying ash trees, an increase in alien invasive plants, and changes to arthropod and bird communities. In addition, Wagner & Todd (2016) documented 98 arthropods in the United States that are ash specialists as larvae or adults, including 32 species of Lepidoptera, 25 Hemiptera, 24 Coleoptera, 9 Diptera, 5 Acari, and 3 Hymenoptera. In European Russia, populations of various ash-associated xylophagous beetles and their natural enemies are increasing as the geographic range of *A. planipennis* expands (Orlova-Bienkowskaja, 2015; Orlova-Bienkowskaja & Volkovitsh, 2015).

Control

Several insecticides have been tested in North America to protect ash trees from *A. planipennis* (Herms *et al.*, 2019). Depending on the product label, these insecticides can be applied as soil drenches, soil injections, trunk injections, or cover sprays on the trunk, branches and foliage. The systemic insecticide emamectin benzoate gives 2 to 3 years of control against both *A. planipennis* larvae and leaf-feeding adults (McCullough *et al.*, 2011; 2019; Herms *et al.*, 2019). Due to the expense of treatment, insecticides are typically used on high-value landscape ash trees.

Trees infested with *A. planipennis* can be cut down and chipped to kill larvae and pupae within the host material (McCullough *et al.*, 2007). To ensure high pest mortality when chipping, the openings in the chipper screen should be 2.5 cm in size or smaller.

The current heat treatment standard in ISPM 15 for wood packaging materials requires that a minimum core temperature of 56°C be maintained for 30 continuous minutes. Haack and Petrice (unpublished data) recorded 100% *A. planipennis* mortality in small ash logs subjected to a core temperature of 56 °C for 30 minutes while holding the

heating chamber temperature constant at 60°, 65°, 70° or 75°C. In other studies, summarized by Haack *et al.* (2014), a few *A. planipennis* have survived various heat treatment schedules but in none of these tests did the researchers follow ISPM-15 guidelines exactly.

Several parasitoids of *A. planipennis* have been reported in the literature from Asia, Europe, and North America (Taylor *et al.*, 2012; Orlova-Bienkowskaja & Belokobylskij, 2014; Bauer *et al.*, 2015; Duan *et al.*, 2019). The egg parasitoids include species of *Oobius* (Encyrtidae) and *Ooencyrtus* (Encyrtidae). The larval parasitoids include species of *Atanycolus* (Braconidae), *Balcha* (Eupelmidae), *Cubocephalus* (Ichneumonidae), *Dolichomitus* (Ichneumonidae), *Eupelmus* (Eupelmidae), *Orthizema* (Ichneumonidae), *Phasgonophora* (Chalcididae), *Spathius* (Braconidae), *Sclerodermus* (Bethyidae), and *Tetrastichus* (Eulophidae). In North America, three biocontrol agents from China and one from the Russian Far East have been released to help control *A. planipennis* (Bauer *et al.*, 2015; Duan *et al.*, 2019). The parasitoids from China include the encyrtid egg parasitoid *Oobius agrili* and two larval parasitoids, the braconid *Spathius agrili* and the eulophid *Tetrastichus planipennisi* and from Russia, the braconid *Spathius galinae* was introduced. Of the three Chinese parasitoids, *O. agrili* and *T. planipennisi* appear to be well established and spreading naturally in North America, whereas it is too early to assess the Russian parasitoid, which was first released in 2016 (Duan *et al.*, 2019a, 2019b). As for predators of *A. planipennis*, woodpeckers (Picidae) are the most important group (Jennings *et al.*, 2016). Some of the insect predators associated with *A. planipennis* include species of Cleridae, Passandridae, and Trogossitidae (Liu *et al.*, 2003).

Phytosanitary risk

Fraxinus spp. are widespread components of mixed deciduous forests in Europe as far as the Caucasus, throughout (*F. excelsior*), in the south (*F. angustifolia*) and in the centre and southeast (*F. ornus*) (EFSA *et al.*, 2020). They are commonly grown for amenity purposes and are known to be susceptible to *A. planipennis*. The North American species *F. pennsylvanica* is planted for timber and shelter in Central and South-Eastern Europe and is highly susceptible to *A. planipennis*. The introduction of *A. planipennis* into North America and European Russia shows that there are pathways to disseminate this pest outside its area of origin, especially in wood packaging material. Ash mortality has been reported in both North America and European Russia. Control and detection of this type of wood-boring insect is difficult. In view of its area of origin and the areas where it has been introduced, it is highly probable that *A. planipennis* could become established in most of Europe where *Fraxinus* spp. are common.

PHYTOSANITARY MEASURES

The Asian buprestid *A. planipennis* was first detected in North America (USA and Canada) in 2002 and then in the European part of Russia (Moscow region) in 2005. *A. planipennis* was added to EPPO A1 List of pests recommended for regulation in 2004 based on a PRA performed by the EPPO Panel on Quarantine Pests for Forestry in 2003. Later, in 2009, *A. planipennis* was transferred to the A2 List given its establishment in European Russia (EPPO, 2013a). EPPO member countries are thus recommended to regulate *A. planipennis* as a quarantine pest. Suggested phytosanitary measures are specified in the PRA performed by EPPO (EPPO, 2013a) and they are as follows. Plants for planting (except seeds) of *Fraxinus* (and currently a few other tree genera that were listed as potential hosts in Japan) should originate from countries found free from the pest. Alternatively, they may be grown under insect-proof conditions. Wood chips, wood waste, firewood, bark, and cut branches should originate from countries found free from the pest. If bark is present on firewood, lumber, logs or furniture made from untreated wood then the bark should be removed as well as the outer 2.5 cm of sapwood. Wood packaging should be treated to ISPM-15 standards. As a general approach, it has also been recommended that when importing plants for planting (except seeds) and wood commodities of *Fraxinus* from countries where *A. planipennis* occurs, precautions should have been taken to avoid any infestations while the consignments are transported through possibly infested areas (EPPO, 2020).

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