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Current situation of Citrus Longhorned Beetle [*Anoplophora chinensis* (Forster, 1771)] (Coleoptera: Cerambycidae) in Türkiye and the world

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Abstract: The citrus longhorned beetle *Anoplophora chinensis* (Forster, 1771) (Coleoptera: Cerambycidae), which is considered to be one of the most important pests in the world, is listed in the Plant Quarantine Regulation of Türkiye as a "quarantine pest whose presence in Türkiye is limited and which constitutes an obstacle to import". After this species was first detected in Istanbul in 2014, it was found in Antalya, Bartın, Diyarbakır, Sakarya and Trabzon. *Anoplophora chinensis* which was seen on many tree species, but it prefers generally *Acer* spp., *Platanus orientalis* and *Corylus* spp. in Türkiye. So far, the species has been observed in parks, nurseries and hazelnut production areas. Since it is a polyphagous species and its main host in its native distribution areas is citrus fruits, it is an important threat for ornamental plants and agricultural sectors. It may also pose a threat to broad-leaved species in forest areas in terms of biodiversity. In this study, the current situation of *A. chinensis* in Türkiye and in the world is discussed in detail.
Keywords: Exotic species, Quarantine pest, Wood damage

Türkiye'de ve dünyada Turunçgil Teke Böceği [*Anoplophora chinensis* (Forster, 1771)] (Coleoptera: Cerambycidae)'in güncel durumu

Özet: Dünyada en önemli zararlılar arasında kabul edilen Turunçgil Teke Böceği *Anoplophora chinensis* (Forster, 1771) (Coleoptera: Cerambycidae), ülkemizde Bitki Karantinası Yönetmeliği'ne göre "Türkiye'de Sınırlı Olarak Bulunan ve İthale Mâni Teşkil Eden Karantinaya Tabi Zararlı Organizmalar" arasında yer almaktadır. Türkiye'de 2014 yılında İstanbul'da ilk kez tespit edilmesinin ardından, Antalya, Bartın, Diyarbakır, Sakarya ve Trabzon illerinde bulunmuştur. Birçok ağaç türünde görülen *A. chinensis*, Türkiye'de akçaağaç, çınar ve fındık ağaçlarındaki zararıyla dikkat çekmiştir. Türün şu ana kadar ülkemizde parklar, fidanlıklar ve fındık üretim alanlarında zararı görülmüştür. Polifag bir tür olması ve doğal yayılış alanında esas konukçusunun turunçgiller olması nedeniyle süs bitkileri ve tarım sektörleri için önemli bir tehdittir. Ayrıca orman alanlarındaki geniş yapraklı türler için de biyolojik çeşitlilik açısından tehdit oluşturabilir. Bu çalışmada *A. chinensis*'in Türkiye'deki ve dünyadaki son durumu ayrıntılı bir şekilde ele alınmıştır.
Anahtar kelimeler: Egzotik tür, Karantina zararlısı, Odun zararı

1. Introduction

The species citrus longhorned beetle, *Anoplophora chinensis* (Forster, 1771) (Coleoptera: Cerambycidae), which is among the "Quarantine Pests Limited in Türkiye and Impeding Imports," is considered one of the most important quarantine pests worldwide (Sjöman et al., 2014; TOB, 2021; EPPO, 2023). In this study, taxonomy, morphology, distribution, host plants, life cycle, damage, control of *A. chinensis* have been given with notes on its current situation in Türkiye.

1.1. Taxonomic classification

Anoplophora chinensis belongs to, family Cerambycidae (subfamily: Lamiinae, tribe: Lamiini) of the order Coleoptera and is one of the 36 species within the genus *Anoplophora* (Lingafelter and Hoebeke, 2002). The species was initially described as *Melanauster chinensis* Forster and it was reported to be found under this name in China and Japan (Kojima, 1931; Gressitt, 1939; Lieu, 1945). However, some studies suggest that Japan's native species is *A. malasiaca* (Thomson, 1865) and there is a boundary between the distribution areas of *A. chinensis* and *A. malasiaca* in the northern part of Korea (Makihara, 2000; Makihara, 2007; Iwaizumi et al., 2014). Due to taxonomic revisions at both the genus and species levels, the species has several synonyms (CABI, 2023; EPPO, 2023). A revision in 2002 consolidated species within this genus and *A. malasiaca* was considered synonymous of *A. chinensis* (Lingafelter and Hoebeke, 2002; Haack et al., 2010).

1.2. Morphology

Adult: Glossy black in color, with body lengths typically ranging from 17 to 40 mm (Haack et al., 2010). In a study conducted in Istanbul, the length of adults was found to be between 27-34 mm (Hızal et al., 2015). In Trabzon, the

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average length of females and males was found 28.6 and 25.4 mm, respectively (Eroğlu et al., 2017). Antennae consist of 11 black segments, with a grey or pale blue stripe at the base of each segment. The average antenna length is 31.1 mm for females and 44.1 mm for males (Eroğlu et al., 2017) (Figure 1).

In males, the forewings narrow towards the tip, while in females, this narrowing is not observed (Lingafelter and Hoebeke, 2002). There are generally 10-20 irregularly shaped white spots on the forewings, but in some individuals, there may be no white spots, while in others, the count can reach up to 60 (Haack et al., 2010). In a study in Trabzon, it was reported that there were 10-12 white spots on the forewings (Göktürk and Kuturoğlu, 2021). In another study in the same region, the average number of white spots was found to be 11-12 in females and 14-15 in males. Male individuals have a higher number of distinct white spots compared to females (Eroğlu et al., 2017). Numerous tubercles are present on the upper side of the forewings. This feature distinguishes *A. chinensis* from *A. glabripennis* (Motschulsky, 1854). However, body length and the white spots on the forewings are similar to *A. chinensis* (Lingafelter and Hoebeke, 2002; Haack et al., 2010; Akita et al., 2021).

Egg: When laid, the eggs of *A. chinensis* are dirty white and later turn creamy-brown. The eggs are long and cylindrical, with a length ranging from 5 to 7 mm (Figure 2) (Haack et al., 2010; Maspero, 2015; Eroğlu et al., 2017; Hızal and Arslangündoğdu, 2017).

Larvae: In the early stages, the larvae are white, becoming creamy as they mature (Figure 2). They have dark brown mouthparts and two black mandibles (Haack et al., 2010; Maspero, 2015; Eroğlu et al., 2017; Hızal and Arslangündoğdu, 2017). They are legless (Haack et al., 2010). The abdomen consists of 10 segments. The first segment of the pronotum is wider than the others (Eroğlu et al., 2017). The dorsal side of the pronotum has a brown, flat cuticular layer. This feature helps distinguishing the larvae of *A. chinensis* from *A. glabripennis* (Haack et al., 2010; Maspero, 2015). Mature larvae are 30-50 mm in length (Haack et al., 2010). In a study conducted by Eroğlu et al. (2017) in Trabzon, they found that early-stage larvae reached 5-6 mm and mature larvae reached 50 mm. In their measurements in July, the larvae were 6.0-7.5 mm and by the end of November, they measured 24-37 mm.

Pupa: White in color, with a pale yellow cuticular layer on its surface. Towards the end of the pupal stage, the colour of the pupal case darkens (Maspero, 2015). The length of pupae ranges from 27 to 38 mm (Haack et al., 2010).

1.3. Distribution

The species is native to China, Japan and Korea, it also occurs in Indonesia, Malaysia, Myanmar, Taiwan, the Philippines and Vietnam in the Far East (Yaghi, 1924; Okamoto, 1927; Gressitt, 1951; Adachi, 1988; Waterhouse, 1993; Lingafelter and Hoebeke, 2002; Loomans et al., 2013; Kim et al., 2019; Keena et al., 2021; CABI, 2023; EPPO, 2023). After its first appearance in Italy in 2000, it was subsequently recorded in the Netherlands (2001), France (2003), the United Kingdom (2005), the Netherlands and Croatia (2007), Germany and Lithuania (2008), Denmark (2011), Switzerland (2014) and Türkiye (2014) (Colombo and Limonta, 2001; Hérard et al., 2006; Maspero et al., 2005; van der Gaag et al., 2008; Vukadin and Hrasovec, 2008; van der Gaag et al., 2010; Seebens et al., 2017; CABI, 2023). The species still occurs in France, Croatia, Italy and Türkiye (Hérard et al., 2019; Özdikmen and Şeker, 2021; Branco et al., 2022; EPPO, 2023). In North America, *A. chinensis* was detected in Canada in 1997 and the United States in 1999. However, as a result of eradication and quarantine efforts, no detections of *A. chinensis* have been reported in North America since 2017 (Table 1) (Haack et al., 2010; Hérard and Maspero, 2019; Chambers, 2023).

Figure 1. Female (a), male (b), pronotum and tubercules on elytra (c), antenna and legs (d) of *Anoplophora chinensis.* (Photo: M. AVCI, Ş. OĞUZOĞLU)

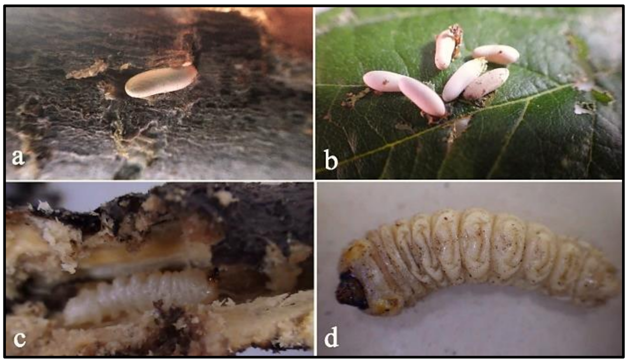

Figure 2. Eggs (a, b), young larvae (c) and mature larva (d) of *Anoplophora chinensis* (Photo: M. AVCI)

Table 1. Worldwide distribution of *Anoplophora chinensis*

Country	First seen year	References (distribution)
Asia		
China	1888	Okamoto, 1927; Gressitt, 1951; Fujiwara-Tsujii et al., 2016; Zhou et al.,2022
Japan	1924*	Yaghi, 1924; Adachi, 1988; Fujiwara-Tsujii et al., 2016; Zhou et al.,2022
Korea	1888	Okamoto, 1927; Fujiwara-Tsujii et al., 2016; Zhou et al.,2022
Indonesia	?	Lingafelter and Hoebeke, 2002; CABI, 2023
Malaysia	?	Hill, 1983; Lingafelter and Hoebeke, 2002; CABI, 2023
Myanmar	1951*	Gressitt, 1951; CABI, 2023
Taiwan	1951*	Gressitt, 1951; CABI, 2023
Philippines	1951	Lingafelter and Hoebeke, 2002; Vitali, 2010; CABI, 2023
Vietnam	1993*	Waterhouse, 1993; CABI, 2023
North America		
Kanada	1997	Haack et al., 2010; Chambers, 2023
ABD	1999	Haack et al., 2010; Chambers, 2023
Europe		
Italy	2000	Colombo and Limonta, 2001; Maspero, 2015; Strangi et al., 2017
Netherlands	2001	Van der Gaag et al., 2008; Loomans et al., 2013; Seebens et al., 2017
France	2003	Hérard et al., 2006
United Kingdom	2005	CABI, 2023
Croatia	2007	Vukadin and Hrasovec, 2008; Vukadin, 2015
Germany	2008	Seebens et al., 2017; CABI, 2023
Lithuania	2008	CABI, 2023
Denmark	2011	Seebens et al., 2017; CABI, 2023
Switzerland	2014	Seebens et al., 2017; CABI, 2023
Türkiye	2014	Hızal et al., 2015; Eroğlu et al., 2017; Topakcı et al., 2017; Yıldız, 2017; TOB, 2021; Özdikmen and Şeker, 2021

*In some countries, the year of the first occurrence of the species could not be found and the date of the first publication was written as the date of the first occurrence.
? It was reported that the species is distributed in some countries, but the year of first occurrence was not found.

The species was added to the quarantine list in the EPPO region in 1994 and to the alert list in the NAPPO region in 2001. It is classified as a quarantine pest in Mexico (America), Morocco and Tunisia (Africa), Norway and Moldova (Europe). It is listed on the A1 list in Kazakhstan (2017) and Russia (2014) (Asia), Ukraine (2019), the United Kingdom (2020) and Switzerland (2019) (Europe). It is classified as a quarantine pest on the A2 list in EPPO and European Union countries (as of 2019) (Table 2).

According to a study using CLIMEX, it has been suggested that, except for the northern parts of the United Kingdom and Sweden, the climate in Europe is suitable for the spread of this species (Robinet et al., 2012). Another study using CLIMEX and Maxent indicates that by the years 2050 and 2070, climate conditions will be suitable for the species to spread in Asia, Europe, America and Oceania continents (Zhou et al., 2022). It can be said that the species has the potential to spread almost worldwide, except for the African continent.

1.4. Host plants

The primary host of the species is citrus (*Citrus* spp.). It is among the major pests of citrus in its native range. Additionally, it has been found on other hosts outside of citrus, including *Casuarina* spp., *Juglans regia, Populus* spp., *Salix* spp., *Ulmus* spp. and other forest and fruit trees. In China, it has been observed on over 100 plant species belonging to 29 genera in 19 families (Lim et al., 2014; Sjöman et al., 2014; Huang et al., 2019).

Table 2. Quarantine list of *Anoplophora chinensis* (EPPO, 2023)

Country	List	Addition year
EPPO	A2 list	1994
NAPPO	Alert list	2001
Tunisia	Quarantine pest	2012
Russia	A1 list	2014
EAEU	A1 list	2016
Türkiye	A2 list	2016
Kazakhstan	A1 list	2017
Moldova	Quarantine pest	2017
Mexico	Quarantine pest	2018
Morocco	Quarantine pest	2018
Norway	Quarantine pest	2018
EU	A2 Quarantine pest (Annex II B)	2019
Switzerland	A1 list	2019
Ukraine	A1 list	2019
United Kingdom	A1 list	2020
EU	Emergency measures (formerly)	2022

Outside its native range, the species has been found on a broader range of hosts, with approximately 180 hosts belonging to 87 genera identified (Lim et al., 2014; Sjöman et al., 2014; Huang et al., 2019; Branco et al., 2022; EPPO, 2023). It has also been found on needle-leaved trees such as *Pinus* and *Cryptomeria* species (Lingafelter and Hoebeke, 2002). In addition to citrus species, it is mostly found on a variety of broad-leaved trees, including *Acer* spp. (maple), *Aesculus hippocastaneum* (horse chestnut), *Alnus* sp. (alder), *Betula* sp. (birch), *Carpinus* sp. (hornbeam), *Cornus* sp. (dogwood), *Corylus avellana* (hazel), *Cotoneaster* sp. (cotoneaster), *Crataegus* sp. (hawthorn), *Fagus* sp. (beech), *Lagerstroemia* sp. (crape myrtle), *Liquidambar* sp. (sweetgum), *Malus* sp. (apple), *Platanus* spp. (plane tree), *Populus* sp. (poplar), *Prunus* sp. (cherry), *Pyrus* sp. (pear), *Quercus* sp. (oak), *Rhododendron* sp. (rhododendron), *Rosa* sp. (rose), *Salix* sp. (willow), *Sorbus* sp. (rowan), *Ulmus* sp.

(elm) (Sjöman et al., 2014; Huang et al., 2019). In Europe, it has been most frequently encountered on maple, birch, and hazelnut species (Maspero, 2015). Moreover, since this pest is spread through the transportation of live plant materials, it is found in many plant species used in landscaping, forestry, and agriculture. Due to the wide variety of hosts, it has the potential to infest all broad-leaved tree species. It differs in this respect from *A. glabripennis*, which is mostly transported to new areas through wooden packaging materials (Haack et al., 2010). Both pest species have been mostly found on various hardwood trees such as maple, citrus, willow, etc. (Fukaya, 2003). In Türkiye, *A. chinensis* has been found on *Acer palmatum*, *A. saccharum*, *A. negundo*, *A. platanoides*, *Aesculus hippocastaneum*, *Carpinus betulus*, *Corylus* spp., *Fraxinus* spp., *Melia azedarach*, *Platanus orientalis*, *Populus nigra*, *Rosa* spp., *Rubus* spp., *Salix caprea*, *S. babylonica* (Hızal et al., 2015; Eroğlu et al., 2017; Hızal and Arslangündoğdu, 2017; Topakcı et al., 2017; Usta et al., 2017; Yıldız, 2017; Özdikmen and Şeker, 2021; Turan and Erdoğan, 2022).

1.5. Life cycle

The number of generation and longevity of *A. chinensis* are influenced by climate factors, especially temperature, as well as feeding conditions and the timing of egg laying. It typically completes its life cycle in one year, but if the larval stage lacks sufficient nutrition, it may take two years (Haack et al., 2010; Maspero, 2015). In Northern Italy, it has been reported that the species can complete its development in two years due to delayed hatching associated with temperature (Maspero, 2015). In the United Kingdom and the Netherlands, it is reported that the species can take a minimum of 2 years and mostly 3-4 years to complete its development (Eyre et al., 2010). In Japan, the species has been found to have 1-2 generations and the timing of egg laying influences the number of generation and longevity (Adachi, 1994). There is variation in longevity and number of generations among individuals within the species. In Japan, it has been reported that 57% of larvae complete their development at 20 °C (Adachi, 1994). Egg laying and hatching are reported to be directly proportional to temperature (Adachi, 1988). Therefore, biological periods are intertwined in the development of the species (Figure 3).

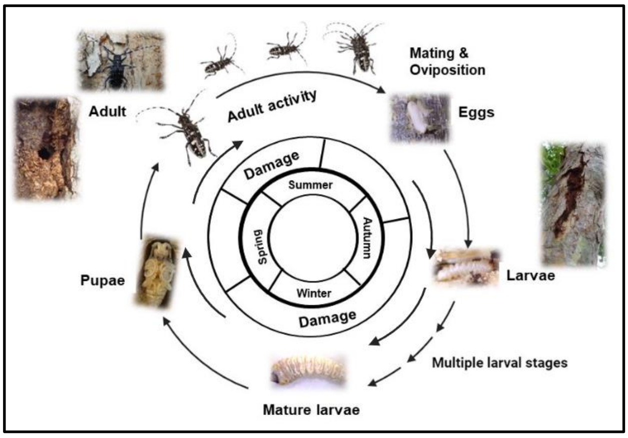

Figure 3. Life cycle and damage signs of *Anoplophora chinensis* (Ş. OĞUZOĞLU)

As with other insect species, temperature plays a significant role in the adult and egg stages of this species. The longevity and fertility of adults are influenced by temperature and the host plant (Keena et al., 2021). Adults can be observed from April to December depending on temperature. However, they are most intensively detected during the period between May and July. Approximately 10-15 days before mating, they feed on shoots, branches and leaves for maturation (Maspero, 2015; Eroğlu et al., 2017). In a laboratory study conducted under different temperature conditions, the maximum longevity of females was found to be at 42 and 33°C and for males, it was at 42 and 39°C in China and Italy, respectively (Keena et al., 2021). In a field study on *Citrus* sp., it was reported that adults survived for approximately 77 days and engaged in feeding for about 9 days (Adachi, 1988). Another study found variations in longevity on different hosts (117.0±31 days in the *Citrus unshiu*, 82.0±19 days in the *Vaccinium cyanococcus* and 32.0±9.2 days in the *Salix schwerinii*) duration at 24°C (Fujiwara-Tsujii et al., 2016).

Yanagihara (1937) determined that a female laid 70-80 eggs on *Casuarina equisetifolia*, while Adachi (1988) found that a female on *Citrus* sp. laid 91-321 (average 194) eggs (van der Gaag et al., 2010). In another study, fecundity was found to vary among *Acer*, *Citrus* and *Platanus* host tree species, with females laying between 60-140 eggs (Iwaizumi et al., 2014). Under laboratory conditions, the optimal temperature range for females to lay eggs was found to be between 15-30°C (Keena et al., 2021).

Females typically lay eggs in the root collar, exposed roots and the lower part of the stem near the root. They create a crack in the bark and deposit only one egg in it. When the shell of this crack dries, it cracks, taking on a T-shape (Haack et al., 2010; Maspero, 2015). The eggs hatch approximately 1-2 weeks after being laid in the summer months. Calculations based on a thermal constant value of 6.7 °C indicate that 184 degree-days are required for 50% of *A. chinensis* eggs to hatch (Huang et al., 2003).

Larvae primarily feed by creating oval-shaped galleries in the cambium layer and later in the living wood and heartwood. They discard feeding frass near the location where the eggs were laid (Maspero, 2015). Larval development is completed after 11 instars. The majority of individuals spend the winter in the larval stage (Keena and Richards, 2022). Mature larvae pupate at the end of spring or the beginning of summer at the end of the feeding galleries. Adults emerge from holes they open in a circular shape, ranging from 6 to 20 mm (average 10-15 mm) (Figure 4) (Haack et al., 2010; Maspero, 2015).

While females of *A. glabripennis* deposit their eggs beneath the bark by chewing funnel-shaped holes in the bark, *A. chinensis* only chews cracks and lays its eggs in the bark. There are also differences in the preferred oviposition sites on the tree between the species: *A. glabripennis* favours the upper trunk and main branches (Haack, 2006), whereas *A. chinensis* prefers the lower trunk, root collar, or exposed roots (Hérard et al., 2006; Sjöman et al., 2014). Additionally, the emergence periods of adults are similar for both species (Akita et al., 2021; Sunamura et al., 2022).

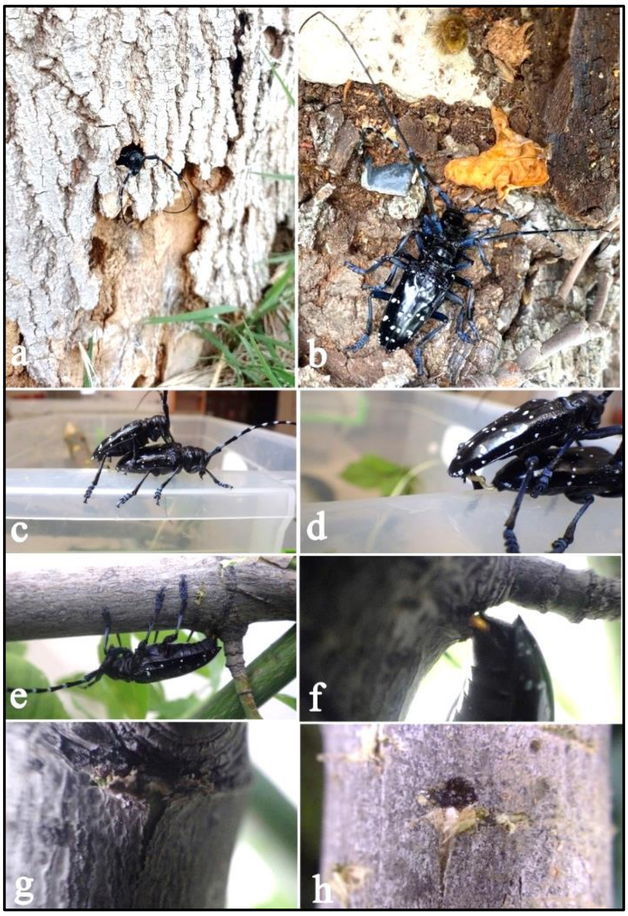

Figure 4. Exited from bark (a), mating (b, c, d), egg laying (e, f) and T-shaped oviposition (g, h) of *Anoplophora chinensis* (Photo: M. AVCI, Ş. OĞUZOĞLU)

1.6. Damage

During the adult stage, the species feeds on shoots, while in the larval stage, it feeds on the roots and stems of trees (Haack et al., 2010; Eroğlu et al., 2017). The species can cause damage to both large and small-diameter trees. It tends to avoid very small-diameter stems for oviposition. However, studies have identified larvae in stems with a diameter of 1-3 cm. Although larval density is low in young trees or those with a small diameter, it can still lead to the death of the tree (Lieu, 1945; Haack et al., 2010; van der Gaag et al., 2010).

Anoplophora chinensis, a primary pest, may attack both healthy and stressed trees (Haack et al., 2010). As it spends the winter in the larval stage, the damage during this period is more significant. During the larval stage, it feeds inside the wood, creating elliptical, broad cavities and causes damage to the tree's vascular bundles, leading to its death. The length of the cavities created by larvae can reach up to 12 cm (Eroğlu et al., 2017). Additionally, larval feeding reduces the quality of the wood. When larval density is high in a tree, the severity of the damage increases, making the host trees more prone to breakage and tipping. Furthermore, *A. chinensis* larvae can feed from the lower part of the trunk to the root area (Branco et al., 2022). The sawdust and frass produced by larval feeding inside the wood are expelled through holes in the bark and cracked areas (Maspero, 2015). In a study with 52 larvae completing their development in tall saplings and young trees, it was found that the larvae consumed an average of 26.98% of the wood volume in the trunk and main root (Eroğlu et al., 2017). The same study also indicated that *A. chinensis* causes damage in the underground parts of the roots, reaching up to 15.5 cm below ground. After completing the pupal stage inside the wood, the emerging adults feed on fresh shoots and branches. Due to the short duration of the adult stage, the severity of damage in these parts of the tree is relatively low (Figure 5).

Due to the diversity of host plants, which is among the factors that affect the severity of damage (Haack et al., 2010; Jucker and Lupi, 2011; Sjöman et al., 2014; Branco et al., 2022), controlling its spread can be challenging, as host diversity increases the rate of spread and decreases the chances of success in control efforts (Zhou et al., 2022). In China, it mainly prefers *Citrus* species but has caused significant economic losses in other fruit tree species as well (Adachi, 1989; Haack et al., 2010). In the areas it infests, it is mostly detected in *Acer* species (van der Gaag et al., 2010). Additionally, in Europe (France, Croatia, Italy, Germany, Denmark, Switzerland and Netherlands), it has caused losses in deciduous species such as *Aesculus hippocastanum*, *Corylus* spp., *Lagerstroemia indica*, *Populus* spp., *Salix* spp. and *Ulmus* spp. besides *Acer* species (van der Gaag et al., 2010; Marchioro et al., 2022).

The rate of species spread also effects the severity of damage. While most adults tend to stay close to the tree from which they emerged, it has been observed that they can disperse up to 1-3 km (Haack et al., 2010). According to predictive scenarios, the time elapsed for the species to be detected after entering a tree is estimated to be 4.9 years in agricultural and urban green areas and 8.4 years in forested areas (Baker et al., 2019).

1.7. Control

1.7.1. Eradication studies

The most used management strategies for *A. chinensis* include eradication efforts and preventing its spread by halting live plant imports from countries where the species is present or by controlling imported plants (Brabbs et al., 2015). As with other wood-boring insects, detecting *A. chinensis* without exit holes can be challenging, necessitating the removal of potentially infested trees from the area (Haack et al., 2010; Straw et al., 2015; Xu and Teale, 2021). However, despite successful eradication efforts preventing the insect's spread and damage, these studies are often evaluated inefficient in terms of time, cost and labour. Additionally, implementing eradication efforts on a large scale can be socially and ecologically problematic. Eradication may be preferable in small parks or limited areas with a confined distribution and recent discoveries. Eradicating *A. chinensis* is more challenging compared to *A. glabripennis* because *A. chinensis* can cause damage up to the roots, making removal of these parts difficult (Eroğlu et al., 2017). Although eradication efforts reduce its harm and rate of spread, vigilance in implementing internal and external quarantine measures during live plant transport is crucial in conjunction with control measures (Branco et al., 2022).

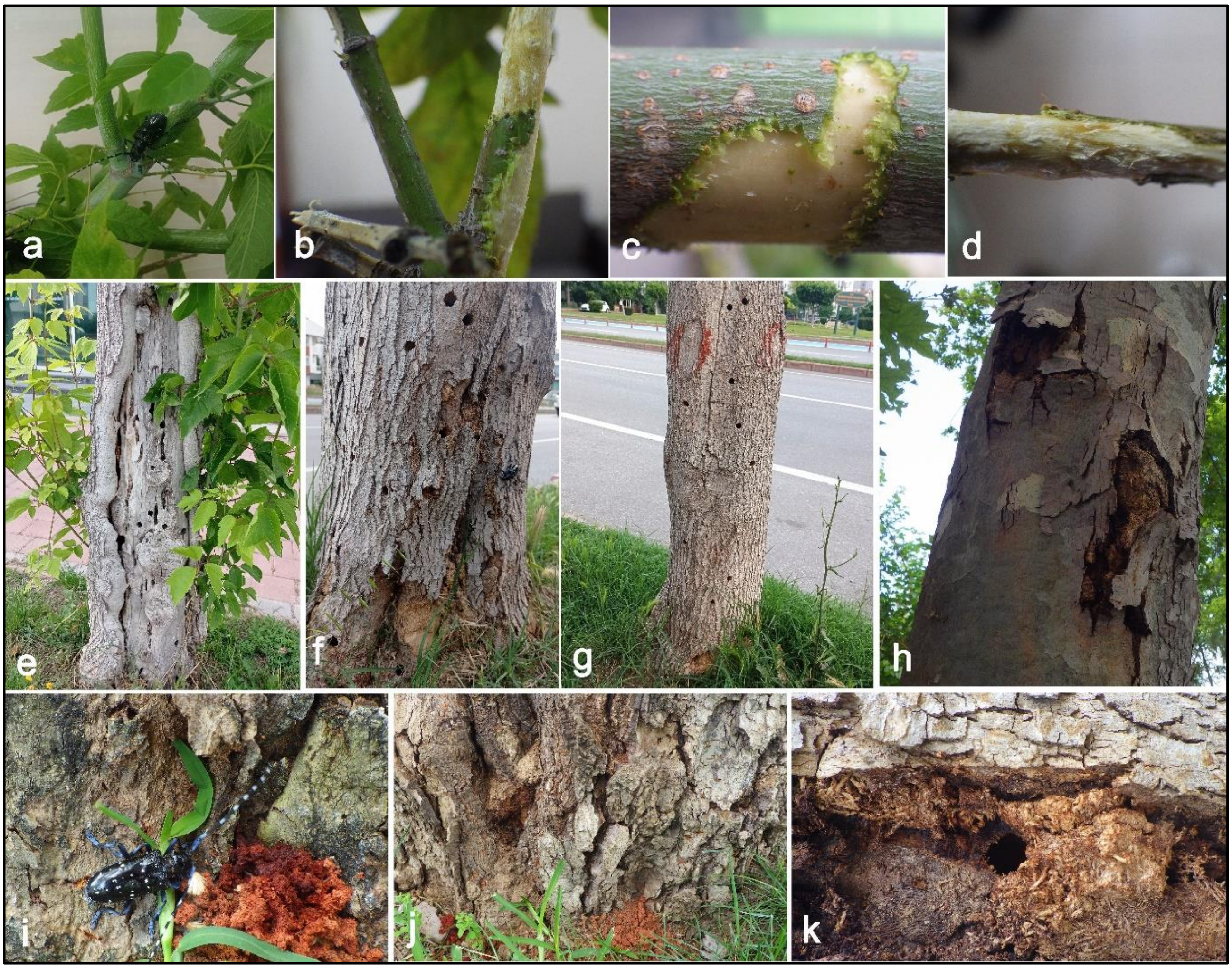

Figure 5. Damage of *Anoplophora chinensis*: Maturation feeding damage (a, b, c and d), exit holes (e, f and g), crack in the bark and frass of an inner larval galleries (h), exit frass (i and j), exit hole and frass (k) (Photo: Ş. OĞUZOĞLU)

In Italy, where it was first detected in Europe, eradication efforts have been implemented to prevent its spread within the country and entry into other countries. Over 18 000 plants have been destroyed in eradication efforts, with approximately 12 million Euros spent in Italy (Jucker and Lupi, 2011). In Europe, eradication efforts have been carried out in an area of approximately 600 km^2 from 2008 to 2020 (Branco et al., 2022). Between 2001 and 2008, 3 million dollars were spent on monitoring and control efforts for *A. chinensis* in Europe (Haack et al., 2010). In Italy (Lombardy region), budget for eradication and control studies in 2008-2013 is approximately 19 million dollars (Hérard and Maspero, 2019). In the United States and Canada, over 398 million dollars have been spent on eradication efforts for thousands of trees at risk of infestation (Warren et al., 2009). Eradication efforts in Europe and North America have achieved success rates of over 45% and subsequent detections of the species have not been reported in outbreak areas in North America since 2007 (Hérard and Maspero, 2019; Hoppe et al., 2019; Marchioro et al., 2022).

1.7.2. Pheromone studies

Due to the lack of a specific pheromone blends for *A. chinensis*, pheromone blends for *A. glabripennis* are used in pheromone trapping (Fukaya et al., 1999; Yasui et al., 2003; Haack et al., 2010; van der Gaag et al., 2010; Maspero, 2015; Marchioro et al., 2022). However, studies have been conducted on determining the sex pheromones of *A. chinensis* (Wang, 1998; Hansen et al., 2015). It has been found that the component 4-(n-heptyloxy) butanal, which is present in the attractive pheromone structure produced by male individuals of *A. glabripennis*, is also present in the pheromone structure of male *A. chinensis*. It has been suggested that this component should be used in control efforts against *A. chinensis* (Hansen et al., 2015). In a study conducted in Italy, *A. glabripennis*-pheromone lures specific were tested for their efficacy against in *A. chinensis* using three different trap models (multi-funnel, 3-baited and multi-baited trap), three different pheromone lure types (Glabriwit, Chemtica and Snergy) and two different trap placement configurations. The results indicated that the pheromone types had similar trapping performance and that Glabriwit and Snergy pheromones were more effective when used with the Econex trap type (Marchioro et al., 2022).

1.7.3. Enemies and biological control

Eradication studies aside, various methods such as chemical injection, pheromone traps and others are used (Xu and Teale, 2021). However, it is known that effective biological control is known to be both environmentally friendly and cost-effective in the long term (Fernandez-Conradi et al., 2021). There are studies on parasitoid and predator species that target the species (Table 3) (Delvare et al., 2004; Brabbs et al., 2015; Wang et al., 2021; Wang et al., 2022). An egg parasitoid (*Aprostocetus fukutai*) and a larval parasitoid (*Scleroderma sichuanensis*) of the species have been identified in China and Japan. *Aprostocetus fukutai* Miwa & Sonan, 1935 (Hymenoptera: Eulophidae) has been reported to be effective in citrus orchards in Southern China, with an efficacy rate of up to 80% on *A. chinensis* (Hérard et al., 2017; Wang et al., 2022). *Scleroderma sichuanensis* Xiao (Hymenoptera: Bethylidae) has been reported to parasitize *A. chinensis* larvae at a rate between 5-44% (Du et al., 2006). In Italy, the egg parasitoid *A. anoplophorae* Delvare (Hymenoptera: Eulophidae) was found to parasitize 72% of the eggs (Delvare et al., 2004). Additionally, in Italy, two larval parasitoids [*Spathius erythrocephalus* Wesmael (Hymenoptera: Braconidae) and *Trigonoderus princeps* Westwood (Hymenoptera: Pteromalidae)] have been identified (Hérard et al., 2005; Maspero et al., 2005).

Entomopathogenic nematodes, specifically *Steinernema feltiae* Filipjev (Rhabditida: Steinernematidae) and *S. carpocapsae* species, have been inoculated into larvae, pupae and adults of *A. chinensis*, resulting in 94-100% mortality in larvae (Jinshui et al., 1997). Application methods involving nematode control have been reported as effective (Brabbs et al., 2015). In a laboratory study using different virulence of *Metarhizium anisopliae* (Metschnikoff) Sorokin (Hypocreales), mortality ranging from 40-96.7% was observed in *A. chinensis* larvae (Cai et al., 2012). In a study conducted in China, two different applications were carried out using *Beauveria brongniartii* Petch (Hypocreales: Cordycipitaceae) on the entire tree and half of the tree, resulting in 84-100% mortality in the whole-tree application and 55-73% mortality in the half-tree application (Tsutsumi et al., 1990; Brabbs et al., 2015).

The parasitic beetle *Dastarcus helophoroides* (Fairmaire) (Coleoptera: Bothrideridae) has been used in control studies of *A. chinensis* in citrus orchards in China, focusing on its adults and eggs and has been reported to be successful (Zhang and Wang, 2019). This species is effective against late-stage larvae and young adults, parasitizing both *A. chinensis* and *A. glabripennis*. However, the host selectivity of *D. helophoroides* has been identified and its effectiveness on *Acer* trees is found to be low (Brabbs et al., 2015).

In China, the ant species *Oecophylla smaragdina* (Fabricius) (Hymenoptera: Formicidae) has been reported to feed on *A. chinensis* larvae and has been successful in control efforts. However, due to being a tropical species, its suitability for use in Europe is considered inappropriate (Brabbs et al., 2015; Zhang and Wang, 2019). Some woodpecker species have been found to feed on *A. glabripennis*, reducing the pest population by 31-79%. Accordingly, it has been suggested that a pair of woodpeckers would be effective in controlling *A. glabripennis* in an area of approximately 100 hectares (Li et al., 2000; Zhu, 2002). The invasive nature of *A. chinensis* makes it challenging to find a suitable and effective biological agent in nature. Additionally, the broad host preference of the pest complicates the ability of natural enemies to locate the target, making biological control more difficult (Haack et al., 2010; Xu and Teale, 2021).

1.7.4. Scent detection dogs

In Austria, trained dogs with odour and sound sensitivity have been used since 2010 for the detection of *A. glabripennis* as part of a management project. Dogs have also been employed for the detection of *A. chinensis* in Croatia, Germany, Italy, Netherlands and Switzerland. In the Netherlands, dogs examined 15,000 maple seedlings imported from China within three days, detecting five plants infested with *A. chinensis* (Hoyer-Tomiczek and Sauseng, 2013).

1.7.5. Mechanical control

In Rome, Italy, following the detection of *A. chinensis* in 2008, mechanical control measures were implemented in areas where eradication efforts were not feasible to preserve and sustain the city's tourism value. As part of the mechanical control, the trunks and root areas of trees were covered with mesh screens and wire fences to prevent adult beetles from spreading to other trees (Roselli et al., 2013). This practice can be applied in areas where eradication efforts are not feasible or in small-scale areas. In the Lombardy region of Italy, 1 229 infested trees were identified and 215 of these trees were treated by cutting them at ground level to ensure the loss of vitality in the stumps. Additionally, to prevent the spread of adults, the trunks of the remaining uncut trees were covered with iron nets up to one meter above the ground, creating a physical barrier (Caremi and Ciampitti, 2006).

2. The Current Status of *Anoplophora chinensis* in Türkiye

In Türkiye, it was first detected in Şile-İstanbul Kumbaba Nursery on 12 June 2014 (Hızal et al., 2015). After the first detection, a pest risk analysis was conducted, the species was moved from Annex-1-A "Quarantine pests unknown to exist in Türkiye and preventing import" to Annex-1-B "Quarantine pests with limited presence in Türkiye and preventing import" in the Plant Quarantine Regulation. Measures to prevent the spread of the species were outlined in the "Regulation on the Control of Sudden Oak Death and Pine Needle Cast Disease, Citrus Longhorn Beetle and Chestnut Gall Wasp", published in the Official Gazette on 17 June 2014 (Bozkurt, 2018). The increase in its spread was observed in the Şile district of İstanbul (Altunışık, 2015) and it was also found in Zeytinburnu, Ataşehir, Beykoz, Sultanbeyli, Bahçeşehir, Beşiktaş, Eyüp Sultan, Fatih, Gaziosmanpaşa and Sultangazi districts (Hızal and Arslangündoğdu, 2017; İBB, 2023). In addition to İstanbul, the species was observed in a private nursery in Bartın in 2014 (Yıldız, 2017). In Trabzon, it was detected in 2016 at the Atasu nursery of Trabzon Municipality (Eroğlu et al., 2017). In 2018, it was detected in hazelnut orchards in the Esiroğlu, Öğütlü, Bahçekaya, Günay and Alaçam districts of Maçka (Bozkurt, 2018; Göktürk and Kuturoğlu, 2021; İlarslan, 2022). In Antalya, the presence of the species was confirmed in the Mediterranean University campus garden and phylogenetic analyses indicated that the population originated from China (Topakcı et al., 2017). In addition, it was recorded in Sakarya in 2020 (TOB, 2021) and its presence was documented in Diyarbakır in 2021 (Özdikmen and Şeker, 2021).

The main host in Türkiye is *Acer* spp. and it has been identified in *Acer palmatum*, *A. saccharum*, *A. negundo*, *A. platanoides*, *Aesculus hippocastaneum*, *Carpinus betulus*, *Corylus* spp., *Fraxinus* spp., *Melia azedarach*, *Platanus orientalis*, *Populus nigra*, *Rosa* spp., *Rubus* spp., *Salix caprea*, *Salix babylonica* so far (Hızal et al., 2015; Eroğlu et al., 2017; Hızal and Arslangündoğdu, 2017; Topakcı et al., 2017; Usta et al., 2017; Yıldız, 2017; Özdikmen and Şeker, 2021; Turan and Erdoğan, 2022). Mostly detected in urban green areas, the species has reached agricultural areas in Trabzon and has also been observed in hazelnut production areas as well (Usta et al., 2017; Bozkurt, 2018; Göktürk and Kuturoğlu, 2021; İlarslan, 2022).

Following the first detection of the species in Türkiye, teams from the Provincial Directorate of Agriculture and Forestry and the Directorate of Parks and Gardens of the Metropolitan Municipality in İstanbul carried out eradication works in urban green areas, targeting ornamental plants (mostly maple, willow, poplar, and plane trees). Infested trees were marked, cut down, chipped, and burned. Due to objections against tree cutting, in addition to eradication efforts, a micro-injection application of Imidacloprid SC 350, a larvicide, was carried out. The green parts of the trees were also during the flight period of the adults. The application of the pesticide has been successful and a reduction in the population has been reported (Altunışık, 2015; Bozkurt, 2018; Antalya Municipality Parks and Gardens Directorate, personal communication). *Anoplophora chinensis* was first detected in Antalya, Muratpaşa district, on 30 May 2016 by the Provincial Directorate of Agriculture and Forestry of Antalya. Subsequently, it was also detected in the municipalities of Kepez and Konyaaltı. In these areas, detection surveys were conducted in a 6 847 da areas, resulting in the destruction of 137 plane trees and 92 maple trees. In addition, in 2020, the species was found on plane trees in the Manavgat district and 40 plane trees in the area were eradicated. Insecticides have been sprayed on the canopy of trees in areas where the pest is present. The applied insecticides in the area have been stated to be effective. It has also been reported that examination studies are continuing (AİTOM, 2023). In 2017, Muratpaşa Municipality reported the destruction of 15 trees (Hürriyet, 2023). The Antalya Metropolitan Municipality Parks and Gardens Directorate teams have conducted chemical control studies, and it has been stated that adults died following chemical control (Parks and Gardens Directorate, personal communication). Furthermore, the species was identified at the molecular level after it was detected in the Akdeniz University campus garden (Topakcı et al., 2017). In Bartın, damage caused by *A. chinensis* adults was observed on three maple species (*Acer palmatum*, *A. negundo* and *A. platanoides*) in a private nursery and emergence holes of adults were observed (Yıldız, 2017).

Damage caused by *A. chinensis* in hazelnut fields in Trabzon was first detected in Maçka, Esiroğlu locality, where a risk of infestation was identified in an area of 1 082 da (decars). As a result, the Trabzon Provincial Directorate of Agriculture and Forestry quarantined a 2 km diameter area in this region. Hazelnut growers and technical personnel were informed about the importance of the pest. In 2018, a chemical control study was conducted in by relevant institutions and the Trabzon Metropolitan Municipality in an area of 400 da. The risk area was determined to be 3 565 da in 2020 and chemical control measures were implemented in 760 da. Eradication measures were carried out in 2020-2021 in the districts of Esiroğlu, Öğütlü, Bahçekaya, Günay, Alaçam in an area of 3 266 da. The eradication process began with the felling of infected trees and the controlled burning of the felled trees within the quarantine zone. According to the regulation published by the Ministry of Agriculture and Forestry in the Official Gazette on 2 December 2020 (İlarslan, 2022), the farmers were paid approximately 130 000 Euro (~831 thousand TL) in 2019 and approximately 3 million Euro (~24 million TL) in 2020 as quarantine compensation. In the same area, a pheromone trial was conducted in June 2019 using three pheromone traps and plastic bottle traps, but it was not effective. It has been stated that the pest in Trabzon has an annual flight range of 400 metres, highlighting the speed of spread of the species (Göktürk and Kuturoğlu, 2021).

3. Conclusion

The species *A. chinensis* is an economically and ecologically significant quarantine pest. Although it is listed in the EPPO (2023) and CABI (2023) sources as **"Present, Transient under eradication"** for our country, this species is established in specific regions. In Istanbul, where *A. chinensis* was first detected, there have been significant losses of trees in parks and gardens. Many trees in parks have been cut down due to the damage caused by this species in Antalya. The damage caused by the species in these provinces will have a negative effect on the production of ornamental plant and the development of the landscaping sector. In the Eastern Black Sea region, it was first identified in Trabzon and quickly moved from the nursery area to hazelnut orchards, becoming the most important pest in hazelnut production in the region. It has caused both production losses and the death of hazelnut trees. In addition to hazelnuts, the main host plants of this insect in its native habitat are citrus species. Potential damage to citrus fruits in the Mediterranean region in Türkiye could result in severe economic losses similar to those observed in hazelnuts. It can also affect agricultural sectors other than hazelnut and citrus and the ornamental plant sectors. It may prefer broad-leaved species in forest areas and pose a threat to biodiversity. This pest may also pose a threat to broad-leaved species used as non-wood forest products.

Monitoring and control efforts in the identified regions, as well as monitoring activities for early detection and intervention in undetected areas, are considered crucial to controlling the spread of the insect.

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