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City longhorn beetle (*Aeolesthes sarta*): A review of the species, its distribution, ecology, damage, prevention and control

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Abstract: The city longhorn beetle (*Aeolesthes sarta*) (CLB) (Coleoptera – Cerambycidae) is a polyphagous invasive pest of both healthy and suppressed broadleaved trees in central Asia. CLB causes a great degree of damage in the countries of its origin. To understand this pest in a better way, a detailed review study has been conducted to gather all the valuable information related to the CLB. This review study covers the main aspects of the CLB, its morphology, ecology, distribution, damage, and control measures. The life span of the CLB is two years. It is mainly distributed in the central Asian countries and preferably damages broadleaved tree species, especially *Juglans regia*, *Populus alba*, *P. euphratica*, *Acer* spp, *Salix alba*, *S. babylonica*, *Malus pumila*, *M. sylvestris*, *Platanus orientalis* and *Ulmus* spp. Effective control and management practices include cutting, removing + burning of infested trees, cultivating high resilient tree species, use of biocontrol agents (i.e. fungus), and use of aluminium phosphide as a pesticide to significantly help control the CLB population. A CLB invasion in a new favourable habitat could impose a serious threat to broadleaf forests and plantations. Therefore, the keen monitoring and surveying of woodland management techniques are recommended. The strict monitoring and inspection of traded wood material at airports and seaports are highly recommended. There is a need to conduct multiple research studies to profoundly understand the CLB phenology, ecology, transportation mode, and damage severity to bridge the gap.

Keywords: *Trirachys sartus*; city longhorned beetle (CLB); Quetta borer; sarta longhorn beetle (SLB); Coleoptera – Cerambycidae; biology; recommendations

The order Coleoptera may be interpreted to have groups of insects potentially more harmful to trees than any other corresponding series of insects found in other large orders of the class Insecta (Stebbing 1914). Due to the pair of long, distinctive antennae that crown the head, the longicorn or long-horned beetle is arguably the Coleoptera member that is well suited for tunnel development in trees (Stebbing 1914). The genus *Aeolesthes* comprises 31 species (Bhawane, Mamlayya 2013); out of these, the city longhorn beetle (CLB) *Aeolesthes sarta* or *Trirachys sartus* is one of the most significant species (GBIF 2021; CABI 2022; EPPO 2022). Trees are a vital source of sequestering carbon dioxide from the atmosphere (Farooqi et al. 2020; Hayat et al. 2020; Khan et al. 2021) and a pest like the CLB that is polyphagous in nature with an inclusive range of host plants (Kadyrov 2007; Kamran et al. 2017) chiefly attacks tree trunks and causes a serious threat to the trees. The CLB

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is regarded as a major pest of broadleaf tree species in several countries (Kadyrov 2007). A warm climate and a preferred host tree species in a particular region provide a favourable habitat for invasive pests to colonise (Hayat et al. 2021). Poplars and willows, as well as plane trees, acacias, and ashes, have been devastated in numerous central Asian towns, including Dushanbe (Kadyrov 2007). In Pakistan, the CLB is commonly known as the Quetta borer (Kamran et al. 2017). *Aeolesthes sarta* has become a pest across both natural and artificial forest stands (Bhawane, Mamlayya 2013). In Indian woodlands, *Aeolesthes sarta* and *A. holosericea* are considered major pests of hardwood tree species, where the CLB has been recorded to feed on 15 different types of tree species (Bhawane, Mamlayya 2013). It is assumed that the CLB evolved in Pakistan and the western portion of India, with substantial dispersal in Afghanistan, Iran, and other central Asian countries (Farashiani et al. 2000; Orlinski 2006). In particular, the species is most troublesome in areas with hot and dry environments (CABI 2006). This longhorn beetle is a major pest problem of most broadleaved tree species in central Asia. They can be found in train stations, streets or parks, tiny gardens, and fruit orchards (Vorontsov 1995) as well as along roads or parks in densely populated places (Hoskovec et al. 2021). *Aeolesthes sarta* has a distinct ability to attack and breed on the main stem and major branches (Farrashiani et al. 2001). It can lead to the reduction of poplar tree forests, which are a significant source of wood in the industry, and infestations are also noticeable in highland woods (Arshad, Hafiz 1983). Just like many other broadleaved tree species, i.e. popular, willow, elm, platanus etc., apple orchards and shelter belts have also been found to be substantially infected (Kamran et al. 2017). The CLB was found to prefer apple orchards (one of the pests' primary hosts) for oviposition (Kamran et al. 2017). A severe infestation (large population) can cause the decline of the canopy and the afflicted trees to dry out within 2 to 3 years (Krivosheina, Tokgaev 1985). Larval boring can cause structural damage to the host trees and interrupt the flow of water and nutrients, resulting in the loss of several branches and, eventually, the entire tree (Morewood et al. 2004; Poland et al. 2006; Khan et al. 2013; Mazaheri et al. 2015). The CLB exhibits no signs of infection on coniferous trees; however, development in the pine is probably possible (Vorontsov 1995). The CLB (*Aeolesthes sarta*) is on the A2 list and is the major pest of broadleaved trees in their native and exotic ranges (EPPO 2021a). So far, the CLB has not established itself in Europe (Vanhanen et al. 2008).

The CLB is a significant invasive pest of broadleaved trees in central Asia. Information about the ecology, damage, control methods, phytosanitary measures, etc., is scattered. Therefore, the presented review is focused on gathering and summarising the available information about the CLB ecology, distribution, host preferences, and control and management strategies, while also recommending some reasonable control and phytosanitary measures, identifying the knowledge gap and providing an outlook toward further research on the CLB (*Aeolesthes sarta*).

MORPHOLOGY AND LIFE CYCLE OF THE CLB

The adult CLBs have an extended dark grey-brown body whose elytra are covered with petite silvery hairs (Khan et al. 2013; CABI 2022) (Table 1, Figure 1). The body length of male and female adult beetles varies from 4.2 to 4.5 cm (Khan et al. 2013). The male has antennae 2.5 times as long as the body; however, the female antennae are shorter than the body (Ahmad et al., 1977; Khan et al., 2013, CABI, 2022). The apex of the elytra is obliquely abrupt, with an unprotected outer angle and a lobed or slender spinal vertebral angle (Ahmad et al. 1977). The life cycle of the CLB usually takes two years to complete (Ahmad et al. 1977; Orlinskii et al. 1991; Vorontsov 1995; Farashiani et al. 2000; EPPO 2005). The eggs, white in colour, are usually laid in a long cluster shape varying 3.1–4.9 mm in length, which typically occurs 1–5 days after the female emerges from the pupal chamber (Ahmad et al. 1977) and lasts 1–3 weeks. Females lay eggs in wounds, cracks, and slit-like niches in the bark of trunks and large branches for approximately two months (Ahmad et al. 1977; EPPO 2006). At only 15 °C, viable eggs are produced. Though below 11 °C or above 35 °C, oviposition does not occur (Ahmad et al. 1977). The laid eggs start to hatch within 9–11 days (Farashiani et al. 2000) and the 1st instar larva hatch and start to feed on the phylum (Mazaheri et al. 2011). The maximum egg hatching occurs at 22–24 °C (Ahmad et al. 1977). The larva stage is comprised of three instars (Ahmad et al. 1977;

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Table 1. Morphological characteristics of *Aeolesthes sarta*

Life Stages		Characteristics	Value	Reference
Egg		shape	elliptical	Ahmad et al. (1977)
		size	3–4 mm	EPPO (2005); CABI (2022)
		colour	white	–
		No. of egg laid/female	156 (average)	Ahmad et al. (1977)
Larva		size	5.4 mm (Y) 5.6 cm (M)	USDA (1968); Ahmad et al. (1977)
		colour	creamy yellow (Y); pale yellowish with golden hairs (M)	EPPO (2005); Khan et al. (2013)
		No. of instars	3	Khan et al. (2013)
		duration	16–18 months	Ahmad et al. (1977); Khan et al. (2013)
Pupa		size	3.6 cm	Ahmad et al. (1977); EPPO (2005)
		duration of pupa in pupal chamber	7–8 months (September–April)	Khan et al. (2013)
Adult	male	size	22–42.2 mm	Ahmad et al. (1977); Khan et al. (2013)
		life span	7–15 days	Ahmad et al. (1977)
	female	size	29.2–43 mm	Ahmad et al. (1977); Khan et al. (2013)
		life span	19–25 days	Ahmad et al. (1977)

Y – young; M – mature

Khan et al. 2013); the 1st instar larva is creamy white in colour, 5.5 mm long and 2 mm wide, and has duration of approximately four months; the 2nd instar larva is creamy white in colour, 3.1–6 cm long and 1–1.2 cm wide, and has a duration of approximately eight months; and the 3rd instar larva is pale yellow in colour, 9–11 cm long and 1–1.5 cm wide, and has a duration of approximately four months (Ahmadet al. 1977). Mature larvae feeding on sapwood (Khan, Kundoo 2018) penetrate the wood, creating a long (approximately 25 cm) tunnel that rises parallel to the vertical axis of the trunk or branches, then turns to produce a 15 cm long downward gallery near the course of the first season of growth. The overwintering larvae are protected at the bottom of the gallery by a double stopper made of wood fibres formed when the larvae dig through the wood. In the spring, the larvae continue eating, and, in late summer, they create a pupal chamber (Mazaheri et al., 2011). The length of the pupal chamber is 6–7 cm and its diameter ranges from 1.8 cm to 2 cm (Khan et al. 2013). After preparing the pupal chamber, the 3rd instar larva transforms into a whitish-yellow pupa 30–45 mm in size (Ahmad et al. 1977; EPPO 2005; Khan et al. 2013) around August (Khan et al. 2013). The latterly developed adult beetles spend the second winter in these chambers and leave them the following spring. The adults habitually feed, but superficially, on tree bark (Ahmad et al. 1977; Farashiani et al. 2000), or maturation feeding has not been observed (EPPO 2006). The CLB adults generally leave their pupation cells in April or early May (Ahmad et al. 1977; Khan et al. 2013) when the outside average temperature is 20 °C (Mazaheri et al. 2011).

During the daytime, they hide underneath the bark in the larval galleries and other shelters. They are nocturnal, the males appear first followed by the females, and move around till morning on the surface of the particular tree on which they grow. The adult beetles seldom fly, and they tend to stay on the surface of the host on which they develop. Mating occurs between 8 hours and two days after emergence. The males have the ability to mate several times (Ahmad et al. 1977). Adult males live 7–15 days, and females live 19–25 days (Ahmad et al. 1977). The adult beetles eat bark, and they have an odd tendency to chomp more than

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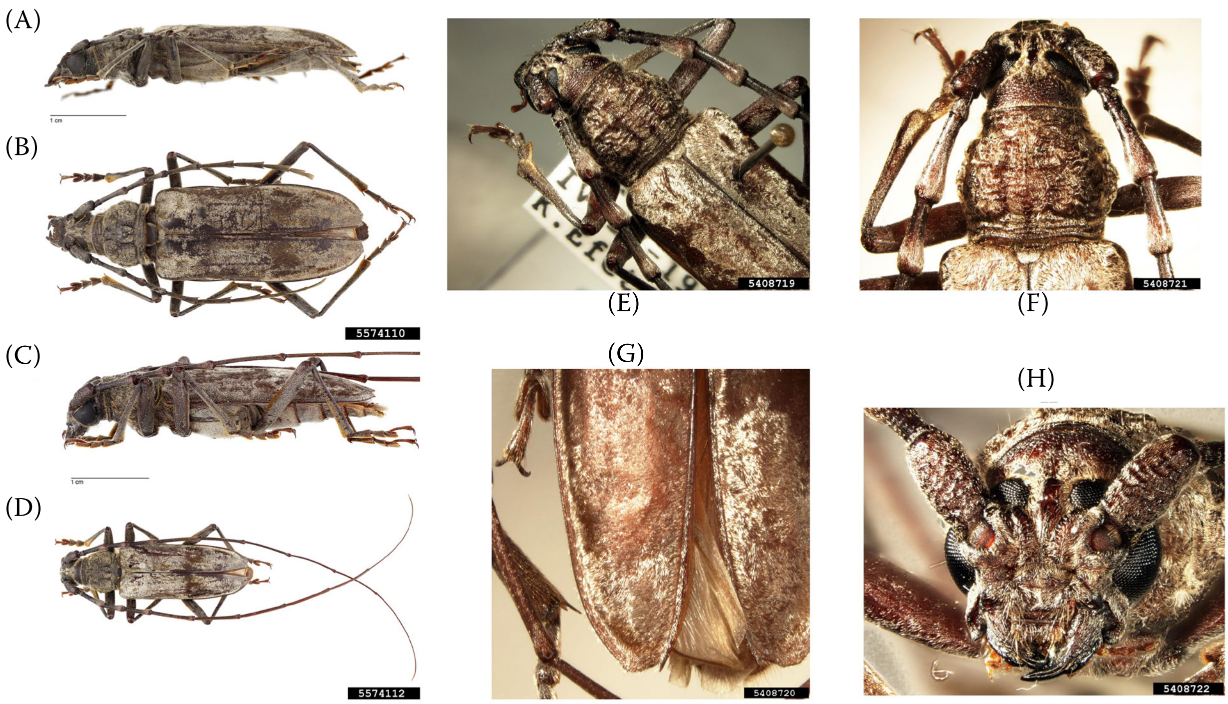

Figure 1. Adults of *Aeolesthes sarta* (A) adult female lateral view, (B) adult female dorsal view, (C) adult male lateral view, (D) adult male dorsal view, (E) adult head and thorax dorsal view, (F) adult antenna segments and thorax pattern, (G) frontal view of adult head illustrating, pair of eyes, mandibles, pair of antennas originating point, (H) dorsal view of back side of elytra of adult beetle illustrating tiny hair growth and gape between it

Source: (A–D) Hanna Royals (Royals 2018a, b); (E–H) Kira Zhaurova (Zhaurova 2010a, b, c, d)

they ingest (Khan, Kundoos 2018). The flight period for the adults is initiated in the second part of April and lasts more or less until mid-July (GBIF 2021). Laboratory experiments have revealed that the mean length of the generation time to complete a cycle is 612.5 days (Mazaheri et al. 2006), while for modelling, the number of degree-days (DDs) essential to complete a generation cycle used is 700 DDs (Vanhanen et al. 2008).

Detection of CLB based on the tree's physical appearance. Detecting the CLB can be performed in three simple ways, (*i*) branch and tree dieback is easily detected by seeing wilting and drying leaves (EPPO 2005; Mazaheri et al. 2011), (*ii*) the presence of sawdust and excretion particles at the base of the tree trunk (EPPO 2005; Mazaheri et al. 2011; Khan, Kundoo 2018), (*iii*) the presence of a 1–2 cm diameter exit hole in the main trunk or large branches (Mazaheri et al. 2011), all these signs combined indicate the presence of CLBs. Besides that, adult beetles can be found sitting on tree trunks and are rather noticeable (EPPO 2005; CABI 2022). Although a few long-horned beetle species, i.e. the Asian long-horned beetle (*Anoplophora glabripennis*) and black and white citrus long-horned beetle (*A. chinensis*), in the region are similar to the CLB and display very similar traits, the one main difference is in the size of the exit holes. The size of the exit holes of the CLB ranges from 10 mm to 20 mm, while the Asian and citrus long-horned beetle exit holes range from 10 mm to 15 mm; also, both produce T-shaped oviposition slits (Haack et al. 2010).

DISTRIBUTION OF THE CLB

Aeolesthes sarta can be found at elevations up to 2 000 m a.s.l. The CLB is assumed to have originated in Pakistan and western India, from where it spread west to Afghanistan and Iran, then north to the central Asian nations of the former Soviet Union, where it was first discovered in 1911 in Samarkand, Uzbekistan (Stebbing 1914; Orlinskii et al. 1991) (Table 2; Figure 2). In the mentioned countries, the pest's range is broadening (Orlinskii et al. 1991; EPPO 2005). In Pakistan, the CLB is distributed in all the big cities of the Balochistan, Khaber-Pakthoon Khwa and Punjab provinces, and also in Islamabad (the capital city) (Stebbing 1914; Ah-

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Table 2. Global distribution of *Aeolesthes sarta*

Country	Place	Reference
Pakistan	**Baluchistan province:** Quetta, Karez Inayatullah, Kalat, Ziarat, Mastung, Zhob, Fortsandeman **KPK province:** Peshawar, Bannu, Kohat, Kalam, Hassanabdal, Abbottabad, Paeachinar, Mingora Islamabad (capital city) **Punjab province:** Rawalpindi, Sialkot	Stebbing (1914); Ahmad et al. (1977); Hanif and Chaudhry (1992); Kamran et al. (2017); EPPO (2021); Hoskovec et al. (2021); CABI (2022)
Iran	Mashhad, Sabzevar, Tehran, Zahedan, Kohgiluyeh and Boyer Ahmad, Khurasan, Sarakhs, Bojnord, Esfaraien, Chenaran, Fariman, Qouchan, Kashmar	Awal (1997); Farashiani et al. (2001); Emami and Nematollahi, (2004); Modarres Awal (2005); Mazaheri et al. (2006); EPPO (2021b); Hoskovec et al. (2021); CABI (2022)
India	Western Himalayas, Himachal Pradash, Jammu and Kashmir, various states and provinces	Bhat et al. (2010); Khan et al. (2013); Khan and Kundoo (2018); EPPO (2021); Hoskovec et al. (2021); CABI (2022)
Afghanistan	various states and provinces	Ahmad et al. (1977); EPPO (2021); Hoskovec et al. (2021); CABI (2022)
China	Xizhang (Tibet)	EPPO (2021); CABI (2022)
Kyrgyzstan	–	EPPO (2021); Hoskovec et al. (2021); CABI (2022)
Tajikistan	Iskanderkul, Tojikobod, Takob, Garm, Karatag, Romit, Shahrinav, Dushanbe, Arykboshi, Kangurt, Sarichashma, Garavuti	EPPO (2005); Kadyrov (2007); Kadyrov et al. (2016); Hoskovec et al. (2021); CABI (2022)
Turkmenistan	Central Kopetdag	Yagdyev (1979, 1987); EPPO (2021); Hoskovec et al. (2021); CABI (2022)
Uzbekistan	–	EPPO (2021); Hoskovec et al. (2021); CABI (2022)
Kazakhstan	–	EPPO (2021); CABI (2022)

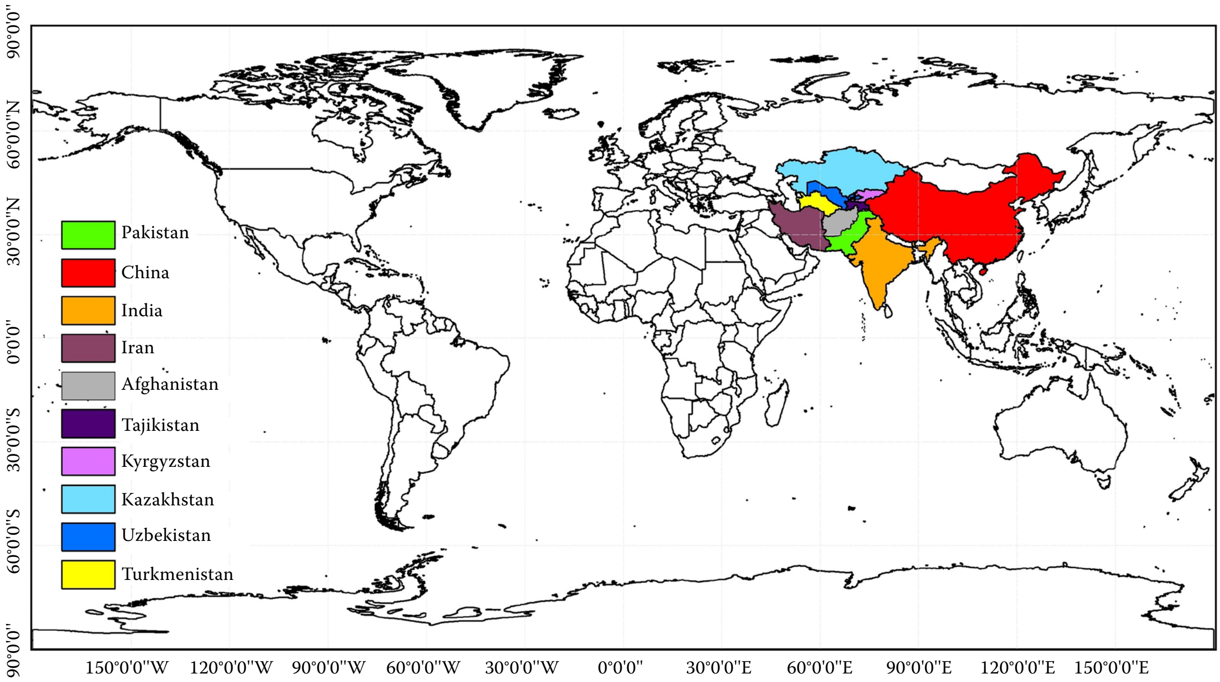

Figure 2. Global distribution of *Aeolesthes sarta* according to EPPO (2021), GBIF (2021) and CABI (2022)

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mad et al. 1977; Gul, Chaudhry 1992; Kamran et al. 2017; EPPO 2021b; Hoskovec et al. 2021; CABI 2022). In Iran, the distribution of the CLB covers more than a dozen cities, including the capital city Tehran (Awal 1997; Farashiani et al. 2001; Emami, Nematollahi 2004; Modarres Awal 2005; Mazaheri et al. 2006; EPPO 2021b; Hoskovec et al. 2021; CABI 2022). Various states of India, i.e. estern Himalayas, Himachal Pradesh, Jammu and Kashmir, have a well-established CLB population (Bhat et al. 2010; Khan et al. 2013; Khan, Kundoo 2018; EPPO 2021b; Hoskovec et al. 2021; CABI 2022). Many states of Afghanistan also have established CLB populations (Ahmad et al. 1977; EPPO 2021b; Hoskovec et al. 2021; CABI 2022). More than 12 cities of Tajikistan are reported to have established CLB populations (EPPO 2005; Kadyrov 2007; Kadyrov et al. 2016; Hoskovec et al. 2021; CABI 2022). In Turkmenistan, Central Kopetdag has an established CLB population (Yagdyev 1979, 1987; EPPO 2021b; Hoskovec et al. 2021; CABI 2022). In the early seventies, some evidence of *A. sarta* (Solsky) were found in Europe according to a field survey (Oelschlager 1971).

DAMAGE CAUSED BY THE CLB

The city longhorn beetle is a polyphagous, stemboring longhorn beetle that is a serious pest of the forest, as well as ornamental and fruit trees across its distribution range (Kulinich 1965; Duffy 1968; USDA 1968; Ahmad et al. 1977; Yagdyev 1979, 1987; Sengupta, Sengupta 1981; Krivosheina, Tokgaev 1985; Orlinski 2000, 2003; EPPO 2005; Khan et al. 2013). This beetle has become well-known in Quetta and across Baluchistan (where it is known under the name "borer") where it has impacted negatively on the poplar, willow, and elm trees, e.g. in the area from 1900 to 1907, where over 3 000 trees were killed by CLBs (Stebbing 1914). The CLB is one of the most devastating borers of poplar (Ahmad et al. 1977) that have caused serious damage to the number of *Populus* plantations in the whole country (Ahmad et al. 1977; Arshad, Hafiz 1983; Gul, Chaudhary 1992). This beetle is also listed as "one of the most devastating pests of walnut trees (*J. regia*)" in India (Gaffar, Bhat 1991). In Kashmir and Iran, the CLB is also a serious economic pest (Duffy 1968, Farashiani et al. 2001). The CLB has been found to target stressed and seemingly healthy trees, with as few as three larvae per tree causing death (Kulinich 1965; Orlinski 2000). Shelter belts and fruit (mainly apple) orchards have also suffered significant damage (Krivosheina 1984; EPPO 2005). Kamran et al. (2017) reported damage to several apple trees (*Malus domestica*) due to a high level of CLB invasions in Quetta, Baluchistan. The spread of CLB and its harm to trees in nature are typically determined by the site of the plant's growth. *Aeolesthes sarta* is more widespread in valleys (plain terrain) than in the mountains (sloping terrain), and it wreaks havoc on valley trees in particular (EPPO, 2005). It is rare to identify trees that have not been harmed by this pest in the Beshkent and Vakhsh Valleys (Tajikistan) (350–450 m a.s.l.), according to Kulinich (1965). There were less pest-damaged trees in the Gissar Valley (800–850 m a.s.l.). The tree infestation rate by CLBs reduces as the altitude increases. However, individual affected trees have been discovered at altitudes above 1 800 m a.s.l. (Kulinich 1965). The CLB causes the most significant damage in urban sites, where trees grow in difficult climatic circumstances (limited drainage, proximity to a road, etc.) and are less pest immune. The CLB, for example, decimated a large number of tall trees in Tashauz (Turkmenistan) (Orlinski et al. 1991).

HOST TREE PREFERENCE OF THE CLB

The CLB (*Aeolesthes sarta*) is a polyphagous pest (Hoskovec et al. 2021), and it has the ability to attack and develop on a variety of deciduous hardwood trees species (EPPO 2005; Hoskovec et al. 2021) (Table 3).

In Pakistan, the CLB development is confirmed in *Platanus orientalis*, *Populus alba*, *P. euphratica*, *Salix alba*, *S. babylonica*, *Ulmus* sp., *Acer cultratum*, *Aesculus indica*, *Corylus colurna*, *Juglans regia Prunus racemose*, *P. communis*, *Pyrus makus*, *Ulmus wallichiana* (Stebbing 1914; Beeson 1941; Janjua, Chaudhary 1962; Chaudhary et al. 1966, 1969; Chaudhary, Ahmad 1972; Ahmad et al. 1977; Gul, Chaudhary 1992). Besides that, the CLB is also considered a serious pest of *Populus* plantations in different parts of Pakistan (Chaudhary et al. 1966, 1969; Chaudhary, Ahmad 1972; Ahmad et al. 1977; Gul, Chaudhary 1992). In Iran, the has frequently been recorded on *Elaeagnus angustifolia*, *Populus alba*, *P. nigra*, *Salix* spp., *Ulmus* spp., *Platanus orientalis*, *Amygdalus* spp., *Morus alba*, *Alnus cordata*, *Juglans regia*, *Robinia pseudoacacia*, *Malus* sp., *Pyrus* sp. (Awal 1997; Farashiani et al. 2000; Emami, Nematollahi 2004; Modarres Awal 2005). Accord-

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Table 3. Host preferences of *Aeolesthes sarta* [modified and supplemented from CAPS (2020)]

Genus	Species	Reference
Acer	maple (*Acer* sp.)	Gressitt (1951); Duffy (1968); Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
	bakimu (*A. cultratum*)	Ahmad et al. (1977); Sengupta and Sengupta (1981); Hoskovec et al. (2021)
Alnus	Caucasian alder (*A. subcordata*)	Farashiani et al. (2001)
Aesculus	Indian horse-chestnut (*A. indica)*	Duffy (1968); Ahmad et al. (1977); Sengupta and Sengupta (1981)
Betula	birch (*Betula* sp.)	Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
Carya	pecan (*Carya sp.*)	Gaffar and Bhat (1991)
Castanea	chestnut *(Castanea* sp.*)*	Gaffar and Bhat (1991)
Corylus	Turkish hazelnut (*C. colurna*)	Gressitt (1951); Duffy (1968); Ahmad et al. (1977); Sengupta and Sengupta (1981)
Cydonia	quince (*Cydonia* sp.)	Duffy (1968); USDA (1968); Gaffar and Bhat (1991)
Elaeagnus	Elaeagnus (*Elaeagnus* sp.)	Orlinski (2000); Farashiani et al. (2001); EPPO (2005); Hoskovec et al. (2021)
Fraxinus	ash (*Fraxinus* sp.)	Duffy (1968); Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
Gleditisa	locust (*Gleditsia* sp.)	Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
Juglans	walnut (*Juglans* sp.)	Gressitt (1951); USDA (1968); Gaffar and Bhat (1991); Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
	English walnut (*J. regia*)	Duffy (1968); Yagdyev and Tashlieva (1976); Ahmad et al. (1977); Sengupta and Sengupta (1981); Orlinski (2000); Farashiani et al. (2001); EPPO (2005); Mir and Wani (2005); Hoskovec et al. (2021)
Malus	apple (*Malus* sp.)	USDA (1968); Gaffar and Bhat (1991); Orlinski (2000); EPPO (2005); Kamran et al. (2017); Hoskovec et al. (2021)
	paradise apple (*M. pumila* = *M. domestica*)	Ahmad et al. (1977); Orlinski (2000); EPPO (2005); Kamran et al. (2017)
	European crabapple (*M. sylvestris* = *Pyrus malus*)	Duffy (1968); Ahmad et al. (1977); Sengupta and Sengupta (1981)
	mulberry (*Morus* sp.)	Duffy (1968); Orlinski (2000); Farashiani et al. (2001); EPPO (2005); Hoskovec et al. (2021)
Platanus	plane (*Platanus* sp.)	Gressitt (1951); Ahmad et al. (1977); Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
	London planetree (*P. acerifolia* = *P. hybrida*, = *Platanus* × *hispanica*)	Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
	Oriental planetree (*P. orientalis*)	Stebbing (1914); Duffy (1968); Ahmad et al. (1977); Sengupta and Sengupta (1981); Orlinski (2000); Farashiani et al. (2001); EPPO (2005); Hoskovec et al. (2021)
Populus	poplar (*Populus* sp.)	Gressitt (1951); USDA (1968); Ahmad et al. (1977);Sengupta and Sengupta (1981); Orlinski (2000); EPPO (2005)
	silver poplar (*P. alba*)	Stebbing (1914); Duffy (1968); Ahmad et al. (1977); Sengupta and Sengupta (1981); Arshad and Hafiz (1983); Orlinski (2000); Farashiani et al. (2001); EPPO (2005); Hoskovec et al. (2021)
	Himalayan poplar (*P. ciliata*)	Ahmad et al. (1977)
	Huyang (*P. diversifolia*)	Orlinski (2000); EPPO (2005)

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Table 3 to be continued

Genus	Species	Reference
Populus	*P. euphratica*	Stebbing (1914); Duffy (1968); Yagdyev (1975); Ahmad et al. (1977); Arshad and Hafiz (1983); Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
	Lombardy poplar (*P. nigra*)	Duffy (1968); Ahmad et al. (1977); Farashiani et al. (2001)
	Populus × *canadensis*	Ahmad et al. (1977); Arshad and Hafiz (1983); Gul and Chaudhry (1992); Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
	Populus × *euramericana*	Ahmad et al. (1977); Gul and Chaudhry (1992); Arshad and Hafiz (1983); Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
Prunus	stone fruit (*Prunus* sp.)	Gressitt (1951); Duffy (1968); Gaffar and Bhat (1991); Orlinski (2000); EPPO (2005); Kadyrov et al. (2016); Hoskovec et al. (2021)
	almond (*P. amygdalus* = *Amygdalus communis*)	Mustafa and Janjua (1942); Duffy (1968); USDA (1968); Ahmad et al. (1977); Gaffar and Bhat (1991); Farashiani et al. (2001)
	apricot (*P. armeniaca*)	Duffy (1968); USDA (1968); Ahmad et al. (1977); Sengupta and Sengupta (1981); Gaffar and Bhat (1991)
	bird cherry (*P. racemosa*)	Duffy (1968); Ahmad et al. (1977)
Pyrus	pear (*Pyrus* sp.)	Gressitt (1951); Ahmad et al. (1977); Gaffar and Bhat (1991); Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
	pear (*P. communis*)	Duffy (1968); Ahmad et al. (1977); Hoskovec et al. (2021)
Quercus	oak (*Quercus* sp.)	Orlinski (2000); EPPO (2005); Hoskovec et al. (2021)
Robinia	locust (*Robinia* sp.)	Duffy (1968); Orlinski (2000); Farashiani et al. (2001); EPPO (2005); Hoskovec et al. (2021)
	false acacia (*R. pseudoacacia*)	Awal (1997); Modarres Awal (2005)
Salix	willow (*Salix* sp.)	Gressitt (1951); USDA (1968); Ahmad et al. (1977); Sengupta and Sengupta (1981); Awal (1997); Orlinski (2000); Farashiani et al. (2001); EPPO (2005); Modarres Awal (2005)
	S. acmophylla	Duffy (1968); Orlinski (2000); EPPO (2005)
	white willow (*S. alba*)	Stebbing (1914); Duffy (1968); Ahmad et al. (1977); Sengupta and Sengupta (1981); Hoskovec et al. (2021)
	weeping willow (*S. babylonica*)	Stebbing (1914); Duffy (1968); Ahmad et al. (1977); Hoskovec et al. (2021)
	S. songarica	Orlinski (2000); EPPO (2005)
	S. tetrasperma	Duffy (1968)
	S. turanica	Orlinski (2000); EPPO (2005)
Ulmus	elm (*Ulmus* sp.)	Stebbing (1914); Gressitt (1951); Duffy (1968); USDA (1968); Ahmad et al. (1977); Orlinski (2000); Farashiani et al. (2001); EPPO (2005); Modarres Awal (2005); Hoskovec et al. (2021)
	European field elm (*U. minor*)	Orlinski (2000); EPPO (2005)
	dwarf elm (*U. pulmila*)	Orlinski (2000); EPPO (2005)
	Himalayan elm (*U. wallichiana*)	Duffy (1968); Ahmad et al. (1977); Sengupta and Sengupta (1981)

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ing to the findings of Mazaheri et al. (2011), *Ulmus carpinifolia* and *U. carpinifolia* var. *umbraculifera* are the most favoured and acceptable hosts for CLB adults and larvae. *Salix alba* is an appropriate adult oviposition host as well as a prospective larval development host. In Jammu and the Kashmir valley, the CLB preferred host tree is the walnut tree *J. regia* in several areas (Khan et al. 2013; Khan, Kundoo 2018). However, the CLB is a polyphagous species that prefers *Prunus* sp. in the Romit area in Tajikistan (Kadyrov et al. 2016).

MODE OF SPREADING OF THE CLB

Invasion causes might be natural, unintentional, or intentional. Accidental introductions are the by-product of the movement of persons or goods between different geographical areas (Burgiel et al. 2006; Schofield 2011). This would also include the unintended introduction of a non-native species into the globally traded items. The human need for internationally available products or services is one of the most common accidental causes (Schofield 2011). Non-natural channels, which might include canals, air routes, trains, or roadways, are often the product of travel, transportation, trade, or tourism (Schofield 2011). The greatest phytosanitary danger arises from untreated wood packing and dunnage, as there is currently maximal international traffic in the wood of CLB host plants (Khan, Kundoos 2018). In 2013, the CAPS intervened in two CLB incidents involving wood packing material coming from India and China in the United States ports (CAPS 2020). Infested wood, particularly wood packing material, is the most likely route for the CLB to spread (CABI 2022). Stems (the aboveground section of shoots/trunk/branches) and wood are the plant parts liable to transmit the eggs, larvae, pupa and adults of the CLB in international trade or transport (CABI 2022). Because the CLB does not target small branches or seedlings, it is unusual to be transmitted in small plants for planting (forest, ornamental, or fruit trees). On the other hand, adults may be transferred as contaminating pests on a range of merchandise (EPPO 2005; GBIF 2021; CABI 2022). It is still not confirmed whether CLB adults are good fliers or not, as till now, no comprehensive research has been conducted to observe the CLB flight ability; therefore, the pest's natural spread through adult flight is questionable (Kulinich 1965; EPPO 2005).

CONTROL MEASURES FOR THE CLB

General control measures. In regions where the CLB is found, massive control measures are often undertaken. Management efforts represent (*i*) the inspection and monitoring of woodlands and fruit orchards to identify the damaged/infected trees, (*ii*) he felling and burning of contaminated trees and their debris (Arshad, Hafiz 1983; Naves, de Sousa, 2009), (*iii*) cultivating highly resilient tree species (EPPO 2005; CABI 2022), (*iv*) in trade use of sanitary/phytosanitary measures involve debarking the stem and kiln drying before trading (EPPO 2005).

Biological control measures. Many studies on the biological and microbial pest management of the CLB have been conducted (Mamaev, Yagdyev 1981; Arshad, Hafiz, 1983; Gul, Chaudhry 1992). Research on the natural enemies has revealed that biocontrol agents, such as fungus, are efficacious singly and collectively in suppressing CLB borer populations (Gul, Chaudhary 1992).

Click beetle *Alaus* larvae are entirely predatory of *A. sarta* grubs, unlike most other click beetles (Gul, Chaudhary 1992). *Proctolaelaps* spp. (Acarina) feeds on *A. sarta* grubs (Gul, Chaudhary 1992). The parasitic fungus *Sclerodermus turkmenicus* parasitises CLB larvae (CABI 2022), whereas the pathogen *Beauveria bassiana*, a white muscardine fungus, assaults the adults and is useful in stem borer control (Arshad, Hafiz 1983; Khan, Kundoos 2018; CABI 2022). Under laboratory conditions, the pathogenicity of three local entomopathogenic fungal isolates, *Beauveria bassiana*, *B. brongniartii*, and *Metharhizium anisopliae*, was determined against *A. sarta* grubs. *B. bassiana* was shown to be the most effective against *A. sarta* grubs, trailed by *B. brongniartii* and *Metarhizium inosopliae* (Bhat et al. 2010).

Chemical control method. Chemical pesticide solutions are all very effective control methods for managing the CLB population (Krivosheina 1984; Maslov 1988; Gaffar, Bhat 1991; Vorontsov 1995; Mohi-Uddin et al. 2009). Due to the high degree of infestations, insect repellent and pesticide implantation approaches were used on red delicious apple trees (*Malus domestica*) by Kamran et al. (2017) in Kashmir. During the pesticide implantation procedure, aluminium phosphide had the highest death rate, and the lowest mortality rate was recorded with petrol plugging. Kamran et al. (2017) concluded that insect repellents were shown to be absolutely ineffective in suppressing the pest's population density. Emami and Nema-

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tollahi (2004) stated that aluminium phosphide was completely effective in killing CLBs.

Chemical treatments are thought to be the most efficient way to reduce the adult and larval activity (Gaffar, Bhat 1991). Most pesticides have a better chance of controlling insect infestations on sapwood and cambium. The insecticide implantation approach was effectively employed against *A. sarta* in the field. This approach has also been used against other forms of borers, such as *Aeolesthes holosericea* Fabricius (Gupta, Tara 2014). The application of organophosphates and/or neonicotinoids through injection into predrilled holes significantly targeted the adults and young larvae of *A. sarta* (Wang 2017). Moreover, the application of organophosphates or phosphines through insertion/injection into frass holes significantly targeted the larvae of *A. sarta* (Wang 2017).

Mazaheri et al. (2015) found that the trunk injection of both imidacloprid and oxydemeton-methyl (organophosphates) are highly successful for the control of *A. sarta*, but that imidacloprid is preferred. A dichlorvos (organophosphates) injection into frass holes effectively controls *A. sarta* larvae for more than 45 days following treatment (Bhat et al. 2010). Stem borer holes are better when sealed using cotton treated with dichlorvos at a rate of 3 $mL \cdot L^{-1}$ of water or with one tablet of celphos in each hole to control stem borer population (Wang, 2017). During the first week of May, spraying the affected trees with dimethoate 0.03%, chlorpyriphos 20EC, or quinalphos 25EC (100 mL per 100 L of water) suppresses the egg-laying by the freshly emerging adults (Wang 2017). Lime (calcium carbonate) should be used to whitewash undamaged and young plantations since this stops females from ovipositing eggs and also protects the trees from sunburn (Khan, Kundoos 2018). However, it is highly advised against using chemicals in excess since they pollute the environment and have negative impacts on plant and human/animal health. Another control measure, such as a sex pheromone trap, can be used, as it causes adult mating disruption (Khan, Kundoos 2018).

The CLB was updated to the European and Mediterranean Plant Protection Organization (EPPO_ A2 List of pests advocated for administration as a quarantine pest in 2002, and it is now urged that vulnerable EPPO member nations monitor it as a quarantine pest (EPPO 2005). Phytosanitary controls might include mandating ensure shipments come from pest-free areas. The standards of the International Standards for Phytosanitary Measures (ISPM) No. 15 should be followed while using wood packing materials (ISPM 2018). Although the international transport of host plant wood from nations where the pest is now found is unlikely, debarking, being free of grub holes, heat treatment, fumigation, or other suitable treatments might be used in that scenario.

STUDY GAPS

Through the detailed review, important critical research gaps have been identified on which further research could possibly be undertaken, which are as follows:

1. Countries like Pakistan, Iran, Turkmenistan, India, and Tajikistan have reported the CLB, ecology, biology, damage, and host preference. However, countries like China, Afghanistan, Uzbekistan, Kazakhstan, and Kyrgyzstan (where this pest also has an established population) have not yet published data that can determine the exact distribution pattern to find out the precise nature of the damage to the host preferences of those areas.
2. No such study has yet been undertaken that forecast the distribution pattern of CLB globally; just one study by Vanhanen et al. (2008) has been published, but the study only highlights the possible endangered area of the European continent, in which they used the most probable figures related to the CLB biology. It could be undertaken in a better way if we use the biological values like the maximum, optimum and minimum temperature ranges reported by Ahmad et al. (1977), Mazaheri et al. (2011), and Khan et al. (2013). After finishing this review article, I plan to forecast the potential global distribution of the CLB using the CLIMEX model under the climate change scenario following Hayat et al. (2021).
3. There is further need of research that must be focused on: the detailed ecology (especially adult dispersal and phenology) of the CLB, the success rate of trapping methods for CLB adults (baited traps, light traps, pheromone traps), and determining the crucial characteristic of colonised trees.

CONCLUSION

The CLB is a serious pest of deciduous trees, whose life cycle comprises 2 years. The most damage-causing stage is the larva stage, when this pest starts feeding on the sap wood of a tree, making

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holes inside the tree, causing an interruption of the nutrient and water flow from the root to the top of the tree, weakening the tree and, in severe cases, causing tree mortality. The CLB is widely distributed in central and south Asian countries, and it is believed to have originated in sub-continent (Pakistan and India). The CLB is a polyphagous saproxylic beetle that prefers hot and dry regions; therefore, the Mediterranean region (e.g. Albania, northern Africa, Bulgaria, Greece, Italy, Portugal, and Romania) is likely the most vulnerable area to the possible spread that could occur due to the availability of the preferred host tree species and suitable climatic conditions. Plantations of hardwood species around urbanised sites, i.e. *Populus*, *Platanus*, *Ulmus*, *Juglans*, *Salix*, *Malus*, and other ornamental trees in towns and parks, would most likely be affected.

The most considerable phytosanitary risk comes from untreated wood packaging and dunnage. Plant materials that are prone to disseminate the CLB in trade include the stems (aboveground section of the shoots/trunk/branches) and wood. Therefore, the strict inspection of trading wood material at airports and seaports are highly recommended to minimalise the risk of introduction.

Different control methods could be used to control the population of the CLB, i.e. regular monitoring of woodlands, removal and burning of infected tree/plant, planting of resistant tree species; for biological control methods, the use of *Sclerodermus turkmenicus* and *Beauveria bassiana* (white muscardine fungus) is suggested; for chemical control methods, the use of aluminium phosphide, organophosphates and/or neonicotinoids or phosphines, imidacloprid and oxydemeton-methyl, and dichlorvos is recommended.

In conclusion, the CLB represents a threat to the broad-leafed trees; therefore, strict quarantine policies should be formulated to control its introduction in new regions. Besides that, there is a great need to conduct multiple research studies to profoundly understand its ecology and transportation mode.

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REFERENCES

Ahmad M.I., Hafiz I.A., Chaudhry M.I. (1977): Biological studies on *Aeolesthes sarta* Solsky attacking poplars in Pakistan. Pakistan Journal of Forestry, 27: 123–129.

Arshad M., Hafiz I.A. (1983): Microbial trials of a pathogenic fungus, *Beauveria bassiana* (Bals.) Vuill. against the adults of *Aeolesthes sarta* Solsky (Cerambycidae: Coleoptera). Pakistan Journal of Zoology, 15: 213–215.

Awal M.M. (1997): List of agricultural pests and their natural enemies in Iran. Ferdowsi University Press, 147: 429.

Beeson C.F.C. (1941): Ecology and Control of Forest Insects in India and the Neighbouring Countries. Dehra Dun, Bishen Singh Mahendra Pal Singh: 1007.

Bhat M.A., Mantoo M.A., Zaki F.A. (2010): Management of tree trunk borer, *Aeolesthes sarta* (Solsky) infesting apple in Kashmir. Journal of Insect Science, 23: 124–128.

Bhawane G.P., Mamlayya A.B. (2013): *Artocarpus hirsutus* (Rosales: Moraceae): A new larval food plant of *Aeolesthes holosericea* (Coleoptera: Cerambycidae). Florida Entomologist, 96: 274–277.

Burgiel S., Foote G., Orellana M., Perrault A. (2006): Invasive Alien Species and Trade: Integrating Prevention Measures and International Trade Rules. Washington, D.C., The Center for International Environmental Law and Defenders of Wildlife: 54.

CABI (2006): Forestry Compendium. Available at: https://www.cabi.org/fc

CABI (2022): *Trirachys sartus* – Invasive Species Compendium. Available at: https://www.cabi.org/isc/datasheet/3430

CAPS (2020): *Aeolesthes sarta*. CAPS Program Resource and Collaboration Site. Available at: http://download.ceris.purdue.edu/file/3122

Chaudhary M.I., Ahmad M.I. (1972): Population Dynamics of Two Poplar Defoliator – Final Technical Report. Peshawar, Pakistan Forest Institute: 47.

Chaudhary G.U., Chaudhary M.I., Khan S.M. (1966): Survey of Insect Fauna of Forests of Pakistan: Final Technical Report. Peshawar, Pakistan Forest Institute: 60.

Chaudhary G.U., Ahmad M.I., Hafiz I.A., Moller O.Z. (1969): Insect Pests and Diseases of Poplar in West Pakistan – A Special Bulletin. Peshawar, Pakistan Forest Institute: 14.

Duffy E.A.J. (1968): A Monograph of the Immature Stages of Oriental Timber Beetles (Cerambycidae). London, Trustees of the British Museum: 434.

Emami M.S., Nematollahi M.R. (2004): Study on biology of elm borer and evaluating chemical control measures in Esfahan Province. Iranian Journal of Forest and Range Protection Research, 2: 143–154.

https://doi.org/10.17221/34/2022-JFS

EPPO (2005): *Aeolesthes sarta*. Datasheets on quarantine pests. EPPO Bulletin, 35: 387–389.

EPPO (2006): Data sheets on forest pests. *Aeolesthes sarta*. Available at https://www.eppo.int/RESOURCES/special_projects/forestry_project

EPPO (2021a): EPPO A2 List of pests recommended for regulation as quarantine pests. Available at: https://www.eppo.int/ACTIVITIES/plant_quarantine/A2_list

EPPO (2021b): EPPO Global database. Available at: https://gd.eppo.int/

EPPO (2022): *Trirachys sarta*. EPPO datasheets on pests recommended for regulation. Available at: https://www.eppo.int/media/uploaded_images/RESOURCES/eppo_standards/pm1/pm1-002-29-en.pdf

Farrashiani M.E., Shamohammadi D., Sadeghi S.E. (2000): Biological study of Sart long horn beetle, *Aeolesthes sarta* Solsky (Coleoptera: Cerambycidae) in the laboratory. Journal of Entomological Society of Iran, 20: 77–90. (in Persian)

Farashiani M.E., Sadeghi S.E., Abaii M. (2001): Geographic distribution and hosts of Sart longhorn beetle, *Aeolesthes sarta* Solsky (Col.: Cerambycidae) in Iran. Journal of Entomological Society of Iran, 20: 81–96.

Farooqi T.J.A., Hayat U., Roman M., Abbas H., Hussain S. (2020): Comparative study determining the impacts of broadleaved and needle leaved forest harvesting on hydrology and water yield: State of knowledge and research outlook. International Journal of Biosciences, 16: 231–240.

Gaffar S.A., Bhat A.A. (1991): Management of stem borer, *Aeolesthes sarta*, infesting walnut trees in Kashmir. Indian Journal of Forestry, 14: 138–141.

GBIF (2021): *Aeolesthes sarta* (Solsky, 1871). Available at: https://www.gbif.org/species/1160956

Gressitt J.L. (1951): Longicorn Beetles of China. Paris, Paul Lechevalier: 667.

Gul H., Chaudhry M.I. (1992): Some observations on natural enemies of poplar borers in Pakistan. Pakistan Journal of Forestry, 42: 214–222.

Gupta R., Tara J.S. (2014): Management of apple tree borer, *Aeolesthes holosericea* Fabricius on apple trees (*Malus domestica* Borkh.) in Jammu Province, Jammu and Kashmir State, India. Journal of Entomology and Zoology Studies, 2: 96–98.

Haack R.A., Hérard F., Sun J., Turgeon J.J. (2010): Managing invasive populations of Asian longhorned beetle and citrus longhorned beetle: A worldwide perspective. Annual Review of Entomology, 55: 521–546.

Hayat U., Khan I., Roman M. (2020): A response of tropical tree *Terminalia arjuna* (Arjun) [Combretaceae – Myrtales] seeds and seedlings towards the presowing seed treatment in forest nursery of Sargodha, Pakistan. International Journal of Biosciences, 16: 495–505.

Hayat U., Qin H., Zhao J., Akram M., Shi J., Ya Z. (2021): Variation in the potential distribution of *Agrotis ipsilon* (Hufnagel) globally and in Pakistan under current and future climatic conditions. Plant Protection Science, 57: 148–158.

Hoskovec M., Navrátil D., Jelínek P., Rejzek M. (2021): Longhorn beetles (Crambycidae, Coleoptera) of the West Palaearctic region, neighboring territories and countries of the former Soviet Union. Available at: http://www.cerambyx.uochb.cz/

ISPM (2018): International Standards for Phytosanitary Measures. Guidelines for Regulating Wood Packaging in International Trade. Rome, FAO: 20.

Janjua N.A., Chaudhry G.U. (1964): Biology & Control of Hill Fruit Insects of West Pakistan. Karachi, Manager of Publications: 158.

Kadyrov A.K. (2007): The Cambioxylophagus Beetles of the South-Eastern part of Central Asia. Dushanbe, Tajikistan: 274.

Kadyrov A.K., Karpiński L., Szczepański W.T., Taszakowski A., Walczak M. (2016): New data on distribution, biology, and ecology of longhorn beetles from the area of west Tajikistan (Coleoptera, Cerambycidae). ZooKeys, 606: 41–64.

Kamran K., Kakar A., Arif S., Iqbal A. (2017): Evaluation of insect repellent and insecticide implantation techniques against *Aeolesthes sarta* Solsky in Quetta district of Baluchistan province, Pakistan. Pakistan Journal of Entomology and Zoology Studies, 5: 273–276.

Khan A.A., Kundoo A,A. (2018): Pests of walnut. In: Omkar (ed): Pests and Their Management. Singapore, Springer: 605–647.

Khan S.A., Bhatia S., Tripathi N. (2013): Entomological investigation on *Aeolesthes sarta* (Solsky), a major pest on walnut trees (*Juglans regia* L.) in Kashmir valley. Journal of Academia and Industrial Research, 2: 325.

Khan I., Hayat U., Mujahid A., Majid A., Chaudhary A., Badshah M.T., Huang J. (2021): Evaluation of growing stock, biomass and soil carbons and their association with a diameter: A case study from a planted Chir pine (*Pinus roxburghii*) forest. Applied Ecology and Environmental Research, 19: 1457–1472.

Krivosheina N.P. (1984): Role of the cerambycid *Aeolesthes sarta* in fruit orchards in Turkmenia. Izvestiya Akademii Nauk Turkmenskoi SSR, Biologicheskie Nauki, 8: 35–39.

Krivosheina N.P., Tokgaev T.B. (1985): The formation of trunk-insect complexes on irrigated areas in the Kopetdag foothills. Izvestiya Akademii Nauk Turkmenskoi SSR, Biologicheskikh Nauk, 5: 34-40.

Kulinich P.N. (1965): BZhuki, vredyashchie plodovym i orekho-plodnym kul'turam yuzhnogo sklona Gissarskogo khrebta. Dushanbe, Tajikistan: 172. (in Russian)

Mamaev B.M., Yagdyev A. (1981): Characteristics of development of the Turkmenian hymenopteran (*Scleroderma* *turcmenica*) on larvae of the cerambycid *Aeolesthes sarta* in experimental conditions. Izvestiya Akademii Nauk Turkmenskoi SSR, Biologicheskie Nauki 1: 88.

Maslov A.D. (1988): Guide to Forest Protection Against Pests and Diseases. Moscow, Agropromizdat: 414.

Mazaheri A. (2006): Study of some bioecological aspects of *Aeolesthes sarta* (Coleoptera: Cerambycidae) and evaluation of its chemical control in Isfahan. [M.Sc. Thesis.] Isfahan, Isfahan University of Technology.

Mazaheri A., Khajehali J., Hatami B. (2011): Oviposition preference and larval performance of *Aeolesthes sarta* (Coleoptera: Cerambycidae) in six hardwood tree species. Journal of Pest Science, 84: 355–361.

Mazaheri A., Khajehali J., Marzieh K., Hatami B. (2015): Laboratory and field evaluation of insecticides for the control of *Aeolesthes sarta* Solsky (Col.: Cerambycidae). Journal of Crop Protection, 4: 257–266.

Mir G.M., Wani M.A. (2005): Severity of infestation and damage to walnut plantation by important insect pests in Kashmir. Indian Journal of Plant Protection, 33: 188–193.

Modarres Awal M. (2005): A contribution to the longhorned beetles fauna (Coleoptera: *Cerambycidae*) of Khorasan province, Iran. Turkish Journal of Entomology, 29: 273–278.

Mohi-Uddin S., Munazah Y., Ahmed M.D.J., Ahmed S.B. (2009): Management of apple stem borer, *Aeolesthes sarta* Solsky (Coleoptera: Cerambycidae) in Kashmir. Environment and Ecology, 27: 931–933.

Morewood W.D., Hoover K., Neiner P.R., McNeil J.R., Sellmer J.C. (2004): Host tree resistance against the polyphagous wood-boring beetle *Anoplophora glabripennis*. Entomologia Experimentalis et Applicata, 110: 79–86.

Mustafa A.M., Janjua N.A. (1942): Almond growing in Baluchistan. Indian Farming, 3: 539–542.

Naves P., de Sousa E. (2009): Threshold temperatures and degree-day estimates for development of post-dormancy larvae of *Monochamus galloprovincialis* (Coleoptera: Cerambycidae). Journal of Pest Science, 82: 1–6.

Oelschlager H. (1971): Ein Fund von Aeolesthes sarta (Solsky 1871) am Neusiedler See. Entomologische Blatter, 3: 132–136. (in German)

Orlinski A.D. (2000): EXFOR Database Pest Report: *Aeolesthes sarta*. Available at: http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=&langdisplay=english (accessed July 17, 2006).

Orlinski A.D. (2003): The EPPO Project on Quarantine Pests for Forestry. In: Fosbroke S.L.C., Gottschalk K.W. (eds): Proceedings, US Department of Agriculture Interagency Research Forum on Gypsy Moth and Other Invasive Species. Annapolis, Jan 15–18, 2002: 48.

Orlinskii A.D. (2006): Outcomes of the EPPO project on quarantine pests for forestry 1. Eppo Bulletin, 36: 497–511.

Orlinskii A.D., Shakhramanov I.K., Mukhanov S.Y., Maslyakov V.Y. (1991): Potential quarantine forest pests in the USSR. Zashchita Rasteniĭ, 11: 37–41. (in Russian)

Poland T.M., Haack R.A., Petrice T.R., Miller D.L., Bauer L.S., Gao R. (2006): Field evaluations of systemic insecticides for control of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in China. Journal of Economic Entomology, 99: 383–392.

Royals H. (2018a): USDA APHIS PPQ ITP, Bugwood.org Available at: https://www.invasive.org/browse/detail.cfm?imgnum=5574110

Royals H. (2018b): USDA APHIS PPQ ITP, Bugwood.org Available at: https://www.invasive.org/browse/detail.cfm?imgnum=5574112

Schofield J. (2011): Real-time acoustic identification of invasive wood-boring beetles. [Ph.D. Thesis.] York, University of York.

Sengupta C.K., Sengupta T. (1981): Cerambycidae (Coleoptera) of Arunachal Pradesh. Records of the Zoological Survey of India, 78: 133–154.

Stebbing E.P. (1914): Indian Forest Insects of Economic Importance: Coleoptera. London, Eyre & Spottiswoode: 648.

USDA (1968): Insects not known to occur in the United States. Quetta borer (*Aeolesthes sarta* (Solsky)). United States Department of Agriculture, Cooperative Economic Insect Report, 18: 717–718.

Vanhanen H., Veteli T.O., Niemelä P. (2008): Potential distribution ranges in Europe for *Aeolesthes sarta*, *Tetropium gracilicorne* and *Xylotrechus altaicus*, a CLIMEX analysis. EPPO bulletin, 38: 239–248.

Vorontsov A.I. (1995): Forest Entomology. Manual for Universities. 5th Ed. Moscow, Ekologiya Ltd: 352.

Wang Q. (2017): Chemical control of cerambycid pests. In: Wang Q. (ed.): Cerambycidae of the World. Boca Raton, CRC Press: 343–364.

Yagdyev A. (1979): A review of the xylophagous insects of the forests of the Central Kopet-dag. Entomologicheskoe Obozrenie, 58: 776–780.

Yagdyev A. (1987): Pests of ornamental plants in towns of Turkmenistan. Izvestiya Akademii Nauk Turkmenskoi SSR, Biologicheskie Nauki, 1: 47–50.

Yagdyev A., Tashlieva A.O. (1976): Beetle pests of walnut and oleaster in Turkmenia. Ekologicheskoe i Khozyaistvennoe Znachenie Nasekomykh Turkmenii: 83–92. (in Russian)

Zhaurova K. (2010a): USDA APHIS PPQ, Bugwood.org. Available at: https://www.invasive.org/browse/detail.cfm?imgnum=5408719

Zhaurova K. (2010b): USDA APHIS PPQ, Bugwood.org. Available at: https://www.invasive.org/browse/detail.cfm?imgnum=5408720

https://doi.org/10.17221/34/2022-JFS

Zhaurova K. (2010c): USDA APHIS PPQ, Bugwood.org. Available at: https://www.invasive.org/browse/detail.cfm?imgnum=5408721

Zhaurova K. (2010d): USDA APHIS PPQ, Bugwood.org. Available at: https://www.invasive.org/browse/detail.cfm?imgnum=5408722

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