Can the western conifer seed bug *Leptoglossus occidentalis* (Heidemann, 1910) threaten coniferous forests in Poland?

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Abstract. This is a review article. It discusses the current state of knowledge of the biology of *Leptoglossus occidentalis* (Heidemann, 1910) [Hemiptera: Heteroptera: Coreidae], direct and indirect damage caused by the pest, the dangers of its rapid expansion and possible biological control. The paper presents new reports of *L. occidentalis* in Poland (Szczecin, north-west Poland). This pest shows great ecological flexibility, has adapted well to the climatic conditions prevailing in Europe and is spreading rapidly across the continent. The rate of its expansion is also influenced by a wide range of potential host plants that also occur in Poland at natural sites and in artificial afforestations. Due to the type and scale of damage caused by *L. occidentalis*, its fast reproduction rate and possibly severe losses in forest management, potential feeding grounds of *L. occidentalis*, such as forests in which coniferous seeds are sourced and forest nurseries, should be monitored and protected. This insect may also pose a threat to protected plant communities, for example the coastal crowberry coniferous forest (*Empetro nigri-Pinetum* Wojt. 1964) occurring only in north-western Poland, lichen Scots pine forest (*Cladonio-Pinetum* Juraszek 1927) or marshy pine forests (*Vaccinio uliginosi-Pinetum* Kleist 1929). Two biological agents: the egg parasitoid *Gryon pennsylvanicum* (Hymenoptera: Scelionidae) and entomopathogenic fungi, are currently used in biological control against this pest in Europe.

Key words: *Leptoglossus occidentalis*, invasive alien species, pest, conifers.

1. Introduction

As defined in the Nature Conservation Act, an alien species is a species that occurs outside its natural distribution range either as individuals or as survivable forms such as gametes, spores, seeds, eggs or other parts by which it can reproduce (Nature Conservation Act of 16 April 2004, Journal of Laws of 2009, No 151, item 1220, with later amendments). Colonization effects of alien introduced species, either deliberately or accidentally, can vary. The majority of introduced species are believed to perish during acclimatization. Some victorious species are mildly expansive while others become invasive and, by definition, biologically aggressive (CBD, 2009b). To date, over 140 alien insect species have been recorded in Poland, that is 0.5% of all species of insects occurring in Poland (Głowaciński et al., 2011).

This paper presents the current state of knowledge on the biology, invasion and damage caused by the western conifer seed bug *Leptoglossus occidentalis* (Heteroptera) in Poland, and gives new positions for its occurrence. Potential threats to primary and economic coniferous forests in Poland posed by *L. occidentalis* are discussed and possible uses of the environment's natural resistance to control it are considered.

2. Material and methods

The direct visual observations in the field of *L. occidentalis* were conducted in 2018-2019 during warm and sunny autumn and winter days (from September to February), near residential buildings. The research covered mainly building walls, terraces, balconies, fences, handrails. Coniferous stands located in the urban agglomeration (gardens, city parks and urban forests) and around agricultural areas were also observed. Identification of *L. occidentalis* was based on the morphometric characteristics of the insect (after Gierlasiński & Taszakowski, 2013-2019).

3. Results and discussion

3. 1. Reasons for the expansion of alien species

An invasion takes place when a species colonizes an area that was not previously inhabited by it and survives in it. An invasion of an either intentionally or inadvertently introduced species is defined as a biological invasion resulting from the movement beyond geographical and ecological barriers that separate species belonging to different biogeographical formations (CBD, 2009a). The settlement of new areas by foreign species often takes place in stages, and its spread accelerates the intensive and rapid movement of people to different regions of the world (Lesieur et al., 2018). This movement of non-native species frequently disturbs local ecosystems and drives out some indigenous species (Lipa, 2004; Kenis, 2008).

Intensified expansion of alien insect species is underpinned by a number of factors. A rapid development of international transport routes, especially trade passageways, and an increased number of means of communication, are the main reasons (Seebens et al., 2017). As well as improved transport logistics, increasingly transparent climate changes (such as global warming, floods, strong winds) that facilitate the adaptation of alien species in Europe (Altizer et al., 2003) have a considerable impact on the spread of alien species in Europe. Some authors suggest that the ease of movement of alien species in Europe may be associated with a reduction in phytosanitary control at borders after the creation of the European Union and the successive inclusion of new Member States (Roques et al., 2016). The availability of

the preferred host and competition in the new area also play an important role (Manchester & Bullock, 2000). At present, the forestation rate in Europe is 45%. Coniferous forests dominate in the tree stand at 50%, followed by deciduous forests at 27% and mixed forests at 23%. Forest distribution in Europe is not uniform, reaching the highest value in Russia and falling to 11%, in Holland and in Ireland (Linser & Wolfslehner, 2015).

Global climate warming which is related not only to shortages of or excess water as well as temperature increases but also to the emergence of new plant pests and diseases may be another factor encouraging the expansion of the western seed bug *Leptoglossus occidentalis* (Hemiptera: Coreidae), which a native of North America. Especially that this polyphagous species can occur both in natural coniferous forests and in production stands (Lesieur et al., 2014; Strong, 2016). Western seed error was first observed in Europe in 1999 in Italy. Currently, the insect is recorded almost all over Europe, from Portugal to the United Kingdom, Scandinavia and Russia (Lesieur et al. , 2014, 2018).

3. 2. Species structure of forests in north-western Poland

Forests comprise over 29% of the total area of Poland. Coniferous species dominate in the tree stand, including the forest-forming species, *Pinus sylvestris* L., which covers ca. 60% of the forest area. Due to the predominance of the pine, conditions favourable for pest development and invasion are found in the same-age, monospecies coniferous forests growing on poor and degraded habitats (Głowacka, 2013). Coniferous forests with *P. sylvestris* L., covering 77.9% of the area, dominate in north-western Poland. The mild marine climate with its moderate temperatures and high air humidity promotes the development of vegetation. The mean annual temperature in the area averages at almost 9°C while the vegetative season lasts 215-220 days. Precipitation in Western Pomerania is 550 mm on average, reaching 650 mm in moraine hills and the coastal area (Stachak et al., 2009).

The risk of invasion by *L. occidentalis* in north-western Poland seems to be high in view of climatic conditions in the area, its mild and warm climate, and the domination of the pine *P. sylvestris* in the forest structure.

3. 3. The biology and development of the western conifer seed bug *L. occidentalis*

Leptoglossus occidentalis (Heidemann, 1910) is a large, 18-20 mm species of true bug (Heteroptera) of the family Coreidae. Morphologically it is distinguished by the presence of a white H-shaped pattern on the hemelytra and larger hind legs with leaf-like expansions on the tibiae. Like other species of this family, *L. occidentalis* hibernates as an imago or, less

frequently, in the last larval stage, that is as a nymph. It sometimes aggregates in clusters of up to 2000 individuals (Gall, 1992; Blatt, 1994). Our observations show that it can often be found indoors in winter, as is the case with the invasive harlequin ladybird *Harmonia axyridis* (Pallas, 1773), whose expansion in Poland has been observed since 2006. *L. occidentalis* was first recorded in Poland in 2007 also in a residential building (Lis et al., 2008). *L. occidentalis* has been reported to overwinter in anthropogenic shelters also in other parts of Europe and at other times in Poland (Blatt, 1994; McPherson et al., 1990; Gall, 1992; Dosoulier et al., 2007; Hebda et al., 2010; Werner, 2011; Holly, 2012; Zając, 2013; Gapon, 2013; Mjøs et al., 2010). These shelters usually provide stable conditions, especially during adverse weather fluctuations and sudden temperature drops below 0°C. In natural conditions *L. occidentalis* can overwinter under tree bark and dead stumps as well as in nests of birds of prey or of rodents (Gall, 1992).

In Central Europe, one full generation of the species per season is recorded. If the second generation emerges, it usually does not complete the development cycle that year. On the other hand, three generations per year are observed in Mexico, two generations in North America as well as in southern Europe in Sicily (Fent & Kment, 2011). The number of generations of *L. occidentalis* per year has been noted to change along the altitude gradient and depending on the climatic conditions in the area (Tamburini et al., 2012).

L. occidentalis begins its activity in spring (Fent & Kment, 2011). After fertilization, females lay eggs along the needles, between 31 and 78 eggs (Barta, 2016), which hatch after 10-15 days. Nymphs feed on needles and cones, sucking the sap. There are five nymphal instars in *L. occidentalis*. The development of each generation lasts between 35 and 40 days. Adults of the first generation emerge in late July.

3. 4. The occurrence of *Leptoglossus occidentalis* in Poland

To date, *L. occidentalis* has been recorded chiefly in southern and south-western Poland (after Gierlasiński & Taszakowski, 2013-2019 and the literature cited there; Fig. 1), and its occurrence in the north of Poland was reported only once from the area of Gdynia-Redłowo in the Baltic Coastal Region (Kowalczyk & Senn, 2016).

During our studies representatives of the species were spotted directly on the walls of the buildings, or on the fences. The bug was found four times in central Szczecin (53°26′28″ N 14°31′53″ E; on the walls inside a building: 28.10.2018, 19.12.2018, 7.11.2019 and 17.12.2019), and three times in the Puszcza Wkrzańska primeval forest near Szczecin

(53°29′48″ N 14°33′41″ E, twice on the railing of a viewing deck in the Wodozbiór nature and landscape complex: 15.09.2018 and 19.10.2019; 53°28′14″ N 14°31′37″ E, on *Pinus sylvestris*, at the fork of a branch: 17.02.2019). Moreover, the western conifer seed bug was identified both on the outskirts of the city of Szczecin, near urban tree stands (Pomorzany District, 53°23′58″ N 14°31′34″ E; 14.10.2019) and in the agricultural areas located at the southern end of the Wkrzańska Forest, near the Świdwie Reserve (53°33′33″ N 14°22′20″ E; 23.10.2019). The presence of the bug around the inhabited areas (especially on the buildings) probably results from the fact that the walls of domiciled buildings heat up quickly and keep heat for long, attracting insects simultaneously. In addition, these areas offer many hiding places for the bug and thus provide safe conditions for wintering (Lis et al., 2008).

Figure 1. The occurrence of *Leptoglossus occidentalis* in Poland [● - locations known form the literature (after Gierlasiński & Taszakowski, 2013-2019 and the literature cited there); ■ - new reports]

3. 5. Damage caused by *Leptoglossus occidentalis*

Direct damage and host plants. *Leptoglossus occidentalis* is thought to be a pest of tree seeds, chiefly coniferous trees. The range of plants it attacks is very broad. It has so far been noted on over 40 species of coniferous plants of the genera: *Abies* (*A. concolor* and *A. magnifica*), *Calocedrus* (*C. decurrens*), *Cedrus* spp., *Cupressus* (*C. sempervirens*), *Larix* (*L. decidua*), *Libocedrus* (*L. decurrens*), *Picea* (*P. abies*, *P. asperata*, *P. engelmanii*, *P. glauca*,

P. orientalis and P. wilsonii), *Pinus* (*P. armandii*, *P. contorta*, *P. contorta* var. *latifolia*, *P. coulteri*, *P. densiflora*, *P. flexilis*, *P. griffithii*, *P. halepensis*, *P. heldreichii*, *P. jeffreyi*, *P. lambertiana*, *P. monticola*, *P. mugo*, *P. nigra*, *P. pinea*, *P. ponderosa*, *P. radiate*, *P. resinosa*, *P. rigida*, *P. sabiniana*, *P. strobus*, *P. sylvestris* and *P.* x *schwerinii*), *Pseudotsuga* (*P. macrocarpa and P. menziesii*) as well as *Tsuga* (*T. canadensis* and *T. mertensiana*) (McPherson et al., 1990; Connely & Schowalter, 1991; Blatt & Border, 1996; Bates et al., 2001; Kment & Baňař, 2008; Lis et al., 2008; Protić, 2008; Barta, 2009; Petrakis, 2011; Hizal, 2012; Tamburini et al., 2012; Gwardjan, 2017; Kulijer et al., 2017). The bug has also been noted in pistachio plantations (*Pistacia vera* of the cashew family) (Rice et al., 1985).

L. occidentalis poses a serious risk to tree nurseries and young forests (Barta, 2016). Its larvae and adult forms feed on sap from immature cones and needles while large infestations can cause gradual dieback of trees (FGC, n.d.; Kegley, 2019; Hizal & Inan, 2012; Pimpão et al., 2017; Farinha et al., 2018). The bug is also seminivorous. Endosperms of seeds damaged by it are strongly degraded, seeds degenerate and lose the ability to germinate (Koerber, 1963; Farinha et al., 2018). Due to the large size of this invasive bug, the number of larval stages and high ecological flexibility (Tamburini et al., 2012), the potential risk posed by this pest to coniferous tree stands in Poland can be high.

Indirect damage. The occurrence of *L. occidentalis* has been shown to aid the spread of diseases caused by the fungus *Sphaeropsis sapinea* (Fr.) Dyko & B. Sutton on coniferous trees. The presence of the DNA of the fungus on the cuticles of *L. occidentalis* shows that a mutualistic relationship exists between the two organisms: the insect actively participates in the dispersal of fungal spores (ectozoochory). It has also been noted that some fungal structures (filament or spore fragments) can penetrate the digestive system of *L. occidentalis* together with the main ingredient of its diet, that is the sap derived from needles and young cones of coniferous trees earlier infected by *S. sapinea* (Luchi et al., 2011), which may be a sign of endozoochory. This observation has considerable implications for forests: *S. sapinea* is a widespread fungal pathogen of many species of coniferous trees, including *Pinus sylvestris*, leading to severe damage. It causes necrotic changes of needles, bark and wood, resulting in withering and dieback of younger and older plants (Swart & Wingfield, 1991; Kwaśna & Łakomy, 2011). It can also cause a reduction in the number of seeds forming in cones (Santini et al., 2008). Outbreaks of *S. sapinea* are exacerbated by abiotic stressors: long-term droughts or frost, hail injury of needles and bark (Zwolinski et al., 1990). It seems plant damage caused by *L. occidentalis* infestations can open infection routes of this fungus. A similar relationship between damage caused by *L. occidentalis* on pistachio trees and the

occurrence of fungi of the genus *Botryosphaeria*, causing fruit blight (Rice et al., 1985) has been reported in literature data.

3. 6. Occurrence of *L. occidentalis* and the conservation of protected communities

L. occidentalis can potentially negatively affect forest and tree nurseries as it considerably reduces the number of seeds and the survivability of young seedlings of coniferous tree. This insect may threaten lichen Scots pine forest (*Cladonio-Pinetum* Juraszek 1927) or marshy pine forests (*Vaccinio uliginosi-Pinetum* Kleist 1929). Field studies show that lichen Scots pine forests are now disappearing in the scale of whole Poland (Zaniewski et. al., 2016). It is noted that as climate conditions change there is also a transformation of the structure of communities plant e.g. marshy pine forests, especially those directly dependent on the amount of precipitation that determines their durability (Czerepko, 2011). Weather anomalies, drought and lack of water in the environment adversely affect plant communities, but they favor the spread of alien species, including insects. Its occurrence can also threaten the conservation status of protected plant communities of coniferous species. These include the coastal crowberry coniferous forest (*Empetro nigri-Pinetum* Wojt. 1964), a plant association occurring on the coast of the Baltic Sea and protected by law. While the four subassociations within this community are distinguished by substrate moisture and the availability of ground waters, *Pinus sylvestris* is the dominant species in each. Importantly, the association is estimated to cover an area of only 50 km^2 in Poland (Matuszkiewicz, 2001). Zając (2013) also highlights the potential risk to dwarf pine associations [*Pinetum mugo* (*sudeticum*) W. Mat. 1960 and *Pinetum mugo* (*carpaticum*) Pawł. 1927], including partially protected *Pinus mugo* Turra.

3. 7. Environmental resistance and methods of biological control

Environmental resistance at recently colonized sites is not well established and new arrivals can spread rapidly. However, an increased number of species of beneficial organisms hunting or parasitizing on invasive species emerges after a while following introduction. Biological measures become an alternative method of controlling pest expansion (Hudson & Greeman, 1998). The parasitic hymenopteran *Gryon pennsylvanicum* Ashmead (Hymenoptera: Scelionidae), widespread in North America, is a natural parasitoid of eggs of the bugs belonging to the family Coreidae, including *L. occidentalis*. A mass culture of *G. pennsylvanicum* is currently undertaken in Italy as a method of biological control of *L. occidentalis* (Rovesi et al., 2011; Sabbatini Peverieri et al., 2012, 2013).

Entomophilous fungi *Beauveria bassiana*, *Isaria fumosorosea* and *Metarhizium anisopliae* have also been tested for biological control (Rumine & Barzanti, 2008; Barta, 2009, 2010a, 2010b). The best results (the highest effectiveness) were obtained using isolates of *I. fumosorosea* (Barta, 2010a, 2010b).

Cones of coniferous trees are protected against *L. occidentalis* in the USA by placing fine-mesh bags over cones at the early stage of their development (Kegley, 2019).

4. **Conclusions**

A very rapid spread of *Leptoglossus occidentalis* shows that is has adapted well to the climatic conditions in Europe. Its expansion in Poland is taking place from the south and south-west towards north-eastern Poland. A very wide range of its potential hosts determines the success of its invasion. These include many species of coniferous trees and shrubs of the genera *Abies*, *Picea* and *Pinus* which occur in Poland both at natural sites (in forests and parks) and in artificial afforestations. Due to its feeding patterns, the extent of plant damage and high reproduction rate, *Leptoglossus occidentalis* can contribute to severe losses in forest nurseries of coniferous trees and in forests where seeds are sourced. In view of this, such sites should be monitored and protected.

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