First record of *Acanthococcus azaleae* (Comstock) (Hemiptera: Coccomorpha: Eriococcidae) on *Helianthemum oelandicum* (Cistaceae) in Sweden

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Gertsson, C.-A. Widén, B.: First record of *Acanthococcus azaleae* (Comstock) (Hemiptera: Coccomorpha: Eriococcidae) on *Helianthemum oelandicum* (Cistaceae) in Sweden. [**Första fyndet av *Acanthococcus azaleae* (Comstock) (Hemiptera: Coccomorpha: Eriococcidae) på solvändan *Helianthemum oelandicum* (Cistaceae) i Sverige.**] – Entomologisk Tidskrift 140 (3–4): 157–165. Björnlunda, Sweden 2020. ISSN 0013-886x.

The felt scale *Acanthococcus azaleae* (Comstock) is recorded for the first time on *Helianthemum oelandicum* (L.) Dum. Cours. in Sweden. Information concerning morphology, host plants, distribution patterns worldwide and biology are included. In Sweden *H. oelandicum* subsp. *oelandicum* is endemic to the island, Öland, in the Baltic sea. Öland has a steppe-like vegetation (the Alvar) on limestone bedrock, which is known for its interesting diversity of insects as well as plants.

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In January 2019 the scale insect *Acanthococcus azaleae* (Comstock) (Hemiptera: Coccomorpha: Eriococcidae) was collected from potted plants of the genus *Helianthemum* (Cistaceae) in a greenhouse at Lund University, southernmost Sweden (Fig. 1). The species had not been recorded from Sweden previosly. The genus *Acanthococcus* Signoret belongs to the family Eriococcidae (felt scales), which is the fourth richest family of scale insects in the world. This family is considered to be one of the oldest in the Coccomorpha (Foldi 1997, Miller & Kosztarab 1979). *Acanthococcus* comprises 120 species worldwide, of which 37 are known from the Palaearctic region (Kozár 2009, Kozár et al. 2013).

The following species of *Acanthococcus* and *Rhizococcus* have been reported from Sweden: *Rhizococcus devoniensis* (Green), *R. greeni* (Newstead), and *A. uvaeursi* (Linnaeus). *Rhizococcus devoniensis* is by far the most common species, collected from five provinces in Sweden (Gertsson 2001). In total, 78 species of scale insects have been found in the wild (i.e. not in greenhouses) in Sweden (Gertsson 2001, 2004, 2011).

The scale insects, infraorder Coccomorpha, include more than 8000 described species in over 34 families worldwide (García Morales et al. 2020). Many species are agricultural pests and/or invasive (Ouvrard et al. 2013). They are small, sap-sucking true bugs, sister group to the clade including Aphidoidea, Aleyrodoidea and Psylloidea (Gullan

& Cranston 2005). Scale insect taxonomy is generally based on the microscopic cuticular features of the adult females (Kosztarab & Kozár 1988).

Plant material and botanical background

Members of the *Helianthmum oelandicum* complex (comprising *H. oelandicum* subsp. *oelandicum, H. oelandicum* subsp. *incanum, H. oelandicum* subsp. *alpestre, H. oelandicum* subsp. *italicum* and *H. oelandicum* subsp. *rupifragum*) have been cultivated in the common garden at Lund University since the early 1970s. *Helianthemum oelandicum* subsp. *oelandicum* is endemic to the Baltic Island of Öland in the southern Baltic sea (Widén 2010) and is one of the dominant plant species on the Great Alvar – a more or less bare, horizontal limestone plateau in the southern third of the island (Sterner 1938, Bengtson et al. 1988). The other taxa are distributed in south and central Europe. The cultivated plants are brought to the common garden at Lund University, Sweden as seeds (rarely as cuttings or living plants). The plants are normally kept outdoors but are brought into a greenhouse when used in experimental studies. The first observation of *A. azaleae* was made in 2017 indoors on F2 plants in crosses between taxa from different parts of Europe. The felt scale survived the winter 2017/18 outdoors but were restricted to the originally infested plants outdoors during 2018. Parental, F1 and F2 plants were transferred to the greenhouse in autumn 2018 for experimental studies during the winter. An increase in the frequency of the insect was observed after a couple of months when the infestation had spread among parental plants of all taxa as well as to F1 and F2 plants. *Acanthococcus azaleae* was observed on parental plants outdoors for the first time in June 2019. An ongoing field study of diversity in *H. oelandicum* was used in 2019 to search for *A. azaleae* on the island Öland.

Material and methods

Adult females were collected from the potted plants in Lund and preserved in 70% ethanol. The specimens were slide mounted using the method described by Danielsson (1985) and Kosztarab & Kozár (1988). The females were dewaxed for 3 days in a solution of 40% xylene, 40% ethylacetate and 20 % ethanol (96%). The specimens were then heated gently in 96% ethanol, 10% KOH and 50% lactic acid. The cleared insects were placed in Essig's Aphid Fluid with staining solution according to the method of Kosztarab & Kozár (1988). After clearing in clove oil they were mounted in Euparal®.

Keys used for identification were those in Gill (1993), Merchant et al. (2014) and Miller & Miller (1992). Morphological terminology follows that of Gill (1993), information concerning distribution and host plants are from García Morales et al. (2020) and Kozár et al. (2013). Measurements were taken using an ocular micrometer on an interference contrast microscope. Two slide mounted specimens were photostacked at the Biological Museum (Entomology), Lund University. Slide-mounted material is deposited at the Biological Museum, Lund University, Lund, Sweden.

Field studies

The diversity and population dynamics of *H. oelandicum* on Öland have been studied since the early 1970s (Widén 1980, 1988, 2017, 2018). No searches for *A. azaleae* were made in the field until 2019. Using a census program described in Widén (1980, 2018) permanent plots and transects across the Great Alvar on Öland were investigated 2019, when the insect was found for the first time. Living plants were examined by BW in 103 1-square meter plots distributed across the Great Alvar from Vickleby in the north to Albrunna in the south in late June 2019. Another 230 plots (1-m^2) were investigated in the southern part of the Great Alvar (Albrunna region) in early September. CAG spent 5 days looking for *A. azaleae* in September 2019.

Morphology and biology

Family Eriococcidae (females)

Species in the family Eriococcidae produce a white, gray or yellowish ovisac that encloses the body of the adult female. The posterior end of the sac has a small opening that allows the first-instar nymphs to escape. Body color varies from pink or red, green or brown. The family is characterized by spinose seta, often numerous, in transverse bands or rows on dorsal surface and along body margin. Each anal lobe has a long apical seta and 3 short conical seta on dorsal surface. Ventral seta mainly hair-like. Antennae 6 or 7 segmented. Legs normally deve-

Figure 1. A felt scale *Acanthococcus azaleae* colony on *Helianthemum oelandicum*. Photo: C.-A. Gertsson.

Figur 1. Filtsköldlusen *Acanthococcus azaleae*, kolonier på solvända, *Helianthemum oelandicum*. Foto: C.-A. Gertsson.

loped; claw with a denticle. Macrotubular ducts with cupshaped internal invagination.

***Acanthococcus azaleae* (adult females)**

Adult females of *A. azaleae* are oval with an ovisac enclosing the body. Slide-mounted females 1.09–3.14 mm long, 0.61–2.06 mm wide. Anal lobes are often heavily sclerotized with 0 to numerous teeth on mesal margin. *Venter.* Legs are small, tarsi always longer than tibae, claws with small denticles near the tip. Disc pores of three kinds, usually 5-locular pores, present over entire venter, 3-locular pores sparse scattered over entire ventral surface, cruciform pores present along lateral marginfrom abdominal segment 5 through head on venter. Macrotubular ducts of 2 sizes. Microtubular ducts absent on venter. Antennae usually 7-segmented, with apical segment with 4 sensory seta, second segment from apex with only 1 sensory seta. *Dorsum*. Enlarged setae slender, usually of 2 sizes, with 2 or 3 larger setae along margin of each abdominal segment and on margin of thorax and head. Macrotubular ducts present over dorsum. Microtubular ducts numerous, scattered over dorsum (Figs 2, 3).

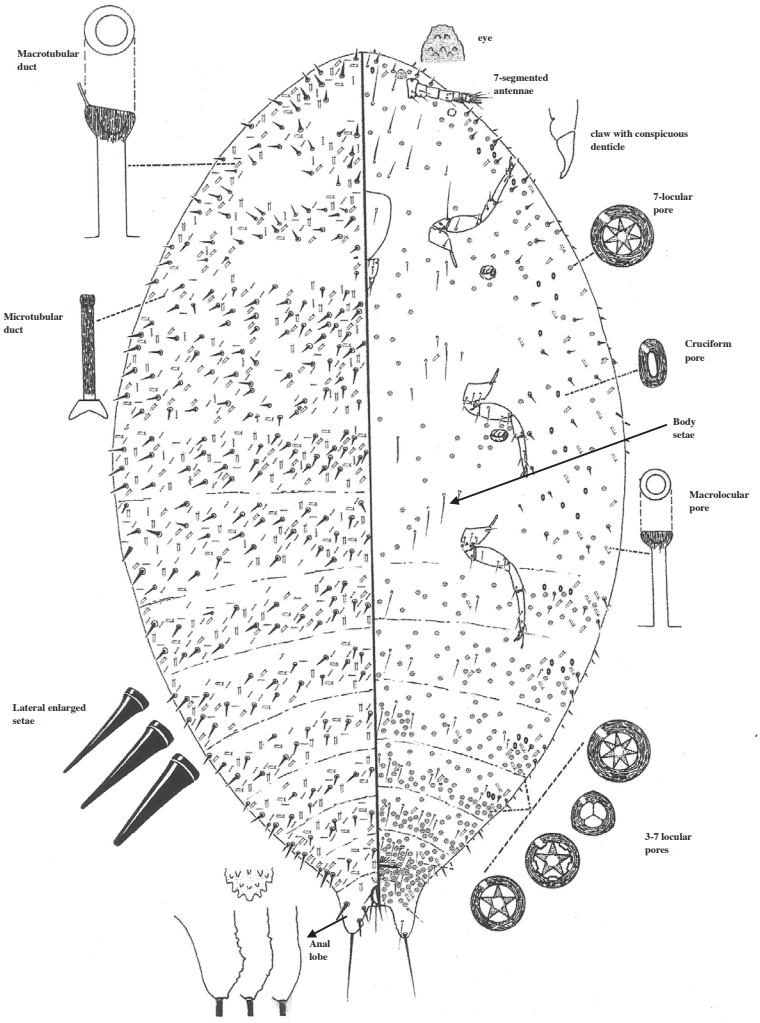

Figure 2. Morphology of *Acanthococcus azaleae*, female. After Miller & Miller (1992) with modifications.

Figur 2. Morfologi av *Acanthococcus azaleae*, hona. Delvis efter Miller & Miller (1992).

Acanthococcus azaleae has been found on many different host plants (see below) but prefers azalea and rhododendron. It is a widespread economic pest, particularly on azaleas. Adult females are normally found on the twigs, although nymphs may feed on leaves for a time. This species has one generation per year in colder climates, such as in Sweden. Females lay 50–250 reddish purple eggs in spring. Hibernation stages are either as eggs or as first instar nymphs. (Gill 1993, Kozár et al. 2013, Miller & Miller 1992).

Biogeographical distribution and host plants

The distribution of this species is Holarctic, across two zoogeographical regions: the Nearctic: Canada, United states (35 states) (García Morales et al. 2020) and the Palearctic: Belgium, Czech Republic, Germany, Russia and Sweden (present study) (Fauna Europea 2019, García Morales et al. 2020, Kozár et al. 2013).

Acanthococcus azaleae has been found on the following hosts: *Acer* sp., *Azalea* sp., *Azaleae* hybrid "hino de giri", *A. indica*, A. *nudiflora*, *Celtis* sp., *Crataegus coccinea*, *Fremotodendron* sp., *Gaylussacia* sp., *Helianthemum oelandicum* (present study), *Liquidambar* sp., *Populus* sp., *Rhododendron* sp., *R. catawbiense*, *R. indicum*, *Ribes* sp., *Salix* sp., *Thuja* sp., *Vaccinium* sp., and *V. macrocarpa* (García Morales et al. 2020, Kozár et al. 2013). According to Miller & Miller (1992),

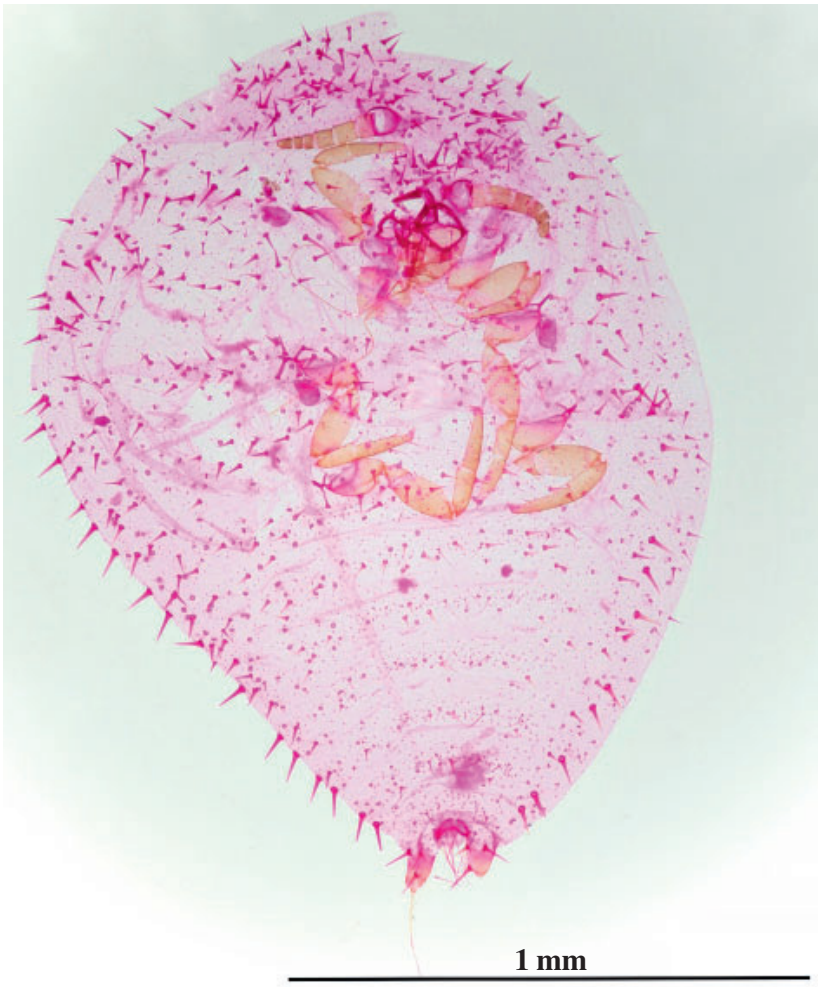

Figure 3. Slide-mounted female of *Acanthococcus azaleae*. Bar: 1.0 mm. Photo: C. Fägerström.

Figur 3. Ljusmikroskopisk bild av *Acanthococcus azaleae*. Skalstreck: 1,0 mm. Foto: C. Fägerström.

this species seems to prefer plants belonging to families Ericaceae and Salicaceae.

Result and discussion

Unmounted female specimens from Sweden has a white ovisac and the body color is pink to red (Fig. 1). Slide mounted adult females are oval, 1.7–2.3 mm long, 1.0–1.6 mm wide. The antennae are 7-segmented, whith the 3rd and 4th segments longest. Five-loculars pores are the most numerous over the entire venter, while 7-locular pores are absent (Fig. 2, 3). The antennae has a long single seta on segments 5 and 6. An important diagnostic character are the seta on antennal segment 5 (Fig. 4). *Acanthococcus azaleae* is very similar to the species *A. lagerstroemiae* (Comstock) (D. Miller pers. comm.). A comparison of morphological characters of *A. azaleae* with *A. lagerstroemiae* collected in the USA based on the relative length of hind tarsus and presence of an antennal sensillum) with *A. lagerstroemiae* collected in the USA agrees with *A. azaleae* (Table 1). The specimens from the greenhouses in Lund have several teeth on mesal margin on anal lobes (Fig. 5). In addition the number and shape of the dorsal enlarged seta on abdominal segments VI-VII are different between the two species according to the key of Kozár et al. (2013) (Table 1).

The distribution of the two species is different. *Acanthococcus azaleae* is an Holarctic species (see above), while *A. lagerstroemiae* is an Holarctic and Oriental species reported from: China, India,

Table 1. Comparison of the relative lengths of hind tibia and tarsus, shape of antennal sensilla and dorsal enlarged setae on *Acanthococcus azaleae* and *A. lagerstroemiae* from USA and the Swedish specimens of *A. azaleae*.

Jämförelse i relativ längd av baktibia och tars, formen på antennens sensoriska borst och ryggsidans taggar på *Acanthococcus azaleae* och *A. lagerstroemi* från USA och svenska exemplar av *A. azaleae*.

Species	Relative length of hind tarsus (III) tarsus III/tibia III (ratio), mm.	Relative length of hind tarsus (III) tarsus III/femur III (ratio), mm.	Antennal sensillum on the 5th antennal segment (S5)	Dorsal enlarged setae **)
*Acanthococcus azaleae**) (USA)	1.3-1.5	1.1-1.2	Long and slender. Pointed apex which extends beyond the base of the S6 sensillum.	Pointed to truncated, numbering 10-12 (segment VII).
*Acanthococcus lagerstroemiae**) (USA)	1.0-1.4	< 1	Shorter, thicker with rounded apex which does not extend beyond the base of the S6 sensillum.	Not different shapes, numbering around 16 (segment VI-VII).
Acanthococcus azaleae (Sweden) N = 8	1.3-1.8	1.2-1.4	Long and slender. Pointed apex which extends beyond the base of the S6 sensillum.	Pointed to truncated, numbering 6-10 (segment VII).

*) According to Merchant et al. (2014). **) According to Kozár et al. (2013)

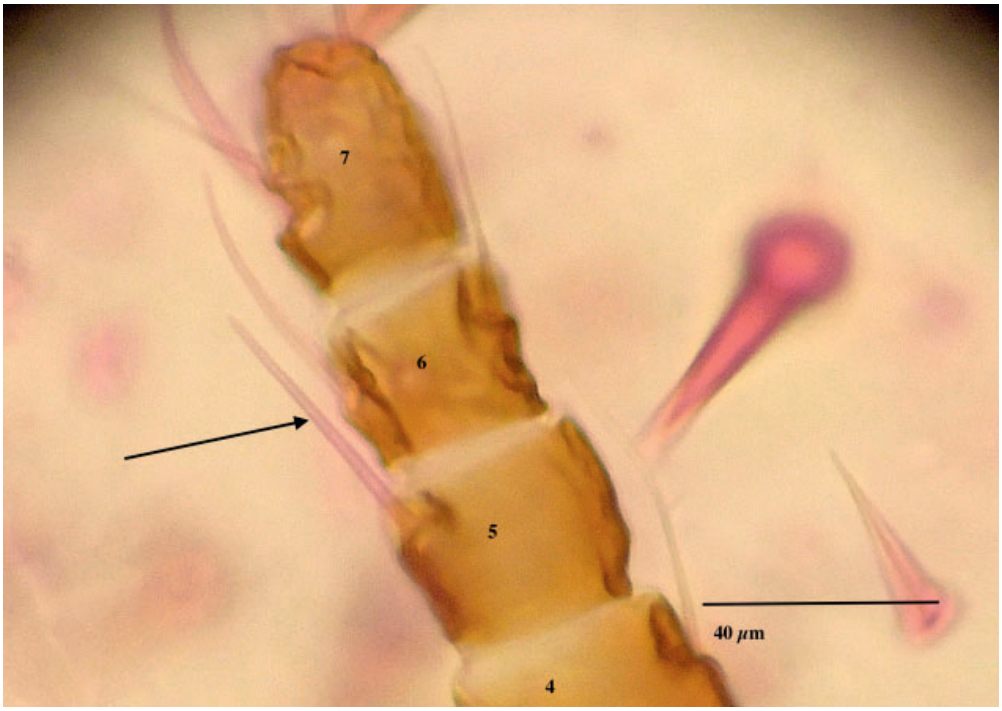

Figure 4. Antennal sensillum on the 5th antennal segment (5). Bar: 40 µm. Photo: C.-A. Gertsson.

Figur 4. Sensoriskt borst på antennens 5:e led (5). Skalstreck: 40 µm. Foto: C.-A. Gertsson.

Figure 5. Teeth on margin of the anal lobe. Bar: 100 µm. Photo: C. Fägerström.

Figur 5. Tänder på sidan av analloben. Skalstreck: 100 µm. Foto: C. Fägerström

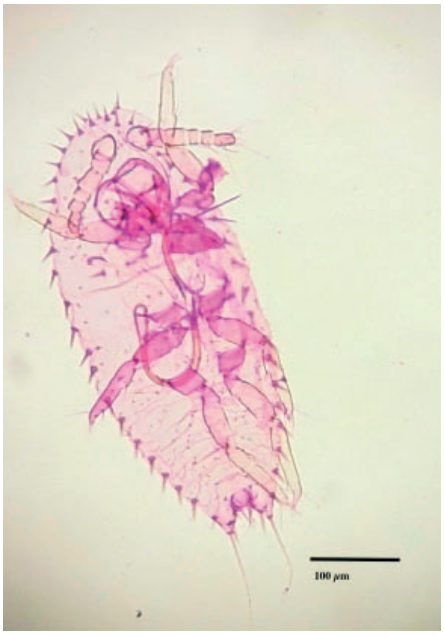

Figure 6. Slide-mounted first-instar nymph of *Acanthococcus azaleae*. Bar: 100 µm. Photo: C. Fägerström

Figur 6. Ljusmikroskopisk bild av första nymfstadiet hos *Acanthococcus azaleae*. Skalstreck: 100 µm. Foto: C. Fägerström.

Japan, Mongolia, South Korea, England and the United States (Fauna Europea 2019, García Morales et al. 2020). The host plants are different. *Acanthococcus lagerstroemiae* has never been collected on Ericaceae (e.g. *Rhododendron* spp.) and Salicaceae (García Morales et al. 2020).

In our studies the highest densities of *A. azaleae* were observed on weakened parental and hybrid plants in the greenhouse in spring and early summer of 2019. Not all cultivated plants were infected by the insects but most taxa of the *H. oelandicum* complex used in the study (see introduction) showed at least one infected plant. On the other hand, members of the *Helianthemum nummularium* complex growing in the greenhouse and in the common garden 2019 showed no sign of infection. No fresh ovisacs were observed outdoors in the autumn 2019, though a few plants that had been transferred from the greenhouse to the outdoor garden in mid-October showed signs of young nymphs.

After detecting the insects in the greenhouses we collected the first-instar nymphs (Fig. 6) on *H. oelandicum* on the island of Öland, at Mörbylånga, Klinta-Stora Smedby Alvar, 27.06 2019 (Fig. 7). In the field study of diversity of *H. oelandicum* 1930 plants (most samplings that were established in late autumn 2018 or early spring 2019) were scrutinized in late June and early September 2019 and only one plant was found to be infested with *A. azaleae* (0.05%). *Helianthemum oelandicum* is one of the dominant species on the Great Alvar (Sterner 1938) and it is found in a wide range of habitats (Bengtsson et al. 1988). It occurs in open, species-poor vegetation on weathered soil exposed to water logging during winter as well as in closed, species-rich, well-drained dry-meadows on glaciofluvial deposits. The alvar vegetation is subjected to periodic drought, such as the summer of 2018 when most individuals of *H. oelandicum* died (B. Widén, personal observation). The infested plant was one of the few individuals that survived the 2018 drought in the investigated plots and it was growing in a dry-meadow with a dense cover of mosses. The infested parts of the plant were hidden in the moisture-retaining mosses.

Branches *H. oelandicum* were brought from natural populations on Öland in 2016 in order to

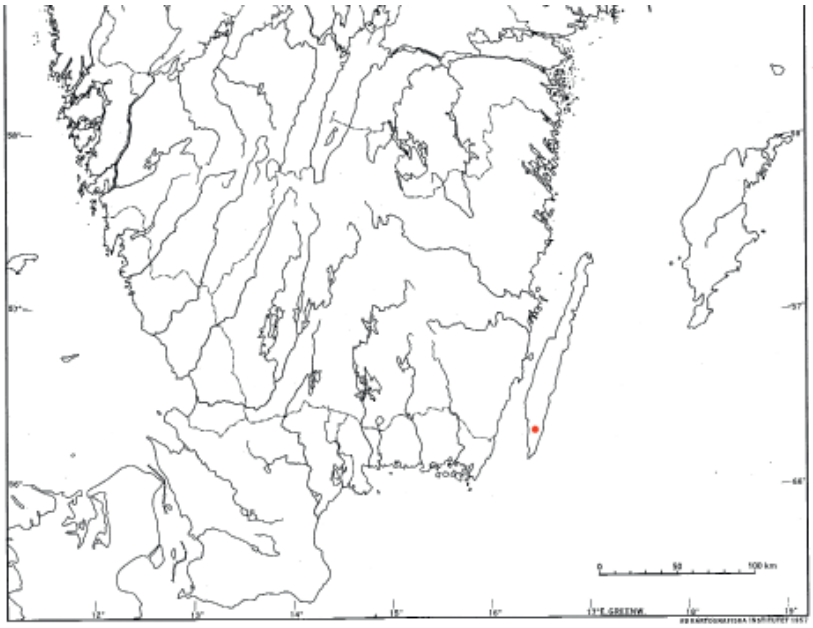

Figure 7. Map over southern Sweden with the locality of first-instar nymph of *Acanthococcus azaleae* on Öland (•).

Figur 7. Fyndplatsen på Öland av första nymfstadiet av *Acanthococcus azaleae*.

establish cuttings in the common garden at Lund University. One of the source areas was situated about 1 km east of the plot with the infested plant found in the field 2019. A plausible scenario is that some undetected eggs, instar nymphs, or ovisacs were hitch-hiked on the transplanted branches in 2016, thus establishing the insect in the common garden. This makes sense in that we detected *A. azaleae* for the first time in cultivation during 2017 despite several decades of keeping *H. oelandicum* in cultivation (mainly from seed sources). The low frequency of *A. azaleae* in the field in 2019 is probably a consequence of the extreme drought on Öland in 2018. No specimens of *A. azaleae* were found during the field studies on Öland in September. Perhaps there were, at that time, only eggs or first-instar nymphs- the hibernation stages for this species (Miller & Miller 1992). The first-instar nymphs are only around 1 mm (Fig. 6). A more accurate estimation of the frequency of *A. azaleae* on *H. oelandicum* should be possible in the future if the insect is searched for in a more normal year for the host plant.

Acknowledgements

We would like to thank Douglass Miller Gainesville, Florida, USA for studying the slides and verifying the species and our sincerest thanks to Christoffer Fägerström, Biological Museum, Lund University, Lund, Sweden, who the photostacked microscopic slides. Marie Widén assisted in the field work on Öland. Last but by no means least, we wish to express our sincere gratitude to Christer Hansson, Biological Museum, Lund University, Chris Hodgson, Department of Biological Systematics and Biodiversity, National Museum of Wales, Cardiff and Bora Kaydan, Çukurova University, Adana, Turkey for valuable comments and reviewers of the manuscript.

References

Bengtsson, K., Prentice, H.C., Rosén, E., Moberg, R., Sjögren, E. 1988. The dry alvar grasslands of Öland: ecological amplitudes of plant species in relation to vegetation composition. – Acta Phytogeographica Suecica 76: 2–46.

Danielsson, R. 1985. Polyviol as mounting medium for aphids (Homoptera: Aphidoidea) and other insects. – Ent. Scand 15: 383–385.

Fauna Europea. – http://www.fauna-eu.org (accessed October 2019).

Foldi, I. 1997. Defense strategies in scale insects: phylogenetic interference and evolutionary scenarios (Hemiptera, Coccoidea). – Memoires du Museum National d'Histoire Naturelle (N.S.). Serie a; Zoologie 173: 203–230.

García Morales, M., Denno B.D., Miller, D.R., Miller G.L., Ben-Dov, Y., Hardy, N.B. 2020. ScaleNet: A literature-based model of scale insect biology and systematics. – Database – http://scalenet.info (accessed January 2020). doi: 10.1093/database/bav118.

Gertsson, C.-A. 2001. An annotated checklist of scale insects (Homoptera: Coccoidea) of Sweden. – Entomologisk Tidskrift 122: 123–130.
Gertsson, C.-A. 2004. New species and new province-records of scale insects from Sweden (Hemiptera: Coccoidea) up to the year 2004. – Entomologisk Tidskrift 126: 35– 42.
Gertsson, C.-A. 2011. New species and new province-records of scale insects from Sweden (Hemiptera: Coccoidea) up to the year 2010. – Entomologisk Tidskrift 132: 39– 45.
Gill, R. 1993. The scale insects of California. Part 2: The minor families (Homoptera: Coccoidea). California Department of Food and Agriculture. Technical series in Agricultural Biosystematics and Plant Pathology, Sacramento.
Gullan, P.J. & Cranston, P.S. 2005. The insects. An outline of Entomology. 3 rd. Blackwell Publishing Ltd, Oxford.
Kosztarab, M. 1996. Scale Insects of northeastern North America. Virginia museum of natural history, Martinsville.
Kosztarab, M. & Kozár, F. 1988. Scale insects of central Europe. Akadémiai Kiadó. Budapest.
Kozár, F. 2009. Zoogeographical analysis and status of knowledge of the Eriococcidae (Hemiptera), with a World list of species. – Bollettino di Zoologia agraria e di Bachicoltura. Ser. II, 41 (2): 87–121.
Kozár, F., Kaydan, M.B., Benedicty Konczné, Z. & Szita, É. 2013. Acanthococcidae and related families of the Palaearctic region. Plant Protection Institute, Centre for Agricultural Research, Hungarien Academy of Sciences, Budapest.
Merchant, M.E., Vafaie, E., Barr, N., Szalanski, A.L. & Evans, G. 2014. Discovery and spread of *Eriococcus lagerstroemiae* Kuwana (Hemiptera: Eriococcidae), a new invasive pest of crape myrtie, *Lagerstroemia* spp. – Poster: http://bugwoodcloud.org/resource/pdf/ESAPosterDiscovAndSpread2014.pdf.
Miller, D.R. & Kosztarab, M. 1979. Recent advances in the study of scale insects. – Annual Review of Entomology 24: 1–27.
Miller, D.R. & Miller, G.L. 1992. Systematic Analysis of *Acanthococcus* (Homoptera: Coccoidea: Eriococcidae) in the Western United States. – Transactions of the American Entomological Society 118: 1–106.
Ouvrard, D., Kondo, T. & Gullan, P.J. 2013. Scale Insects: Major Pests and Management Encyclopedia of Pest Management. – In: Pimentel, D. (ed.). Encyclopedia of Pest Management. Taylor & Francis, New York. doi: 10.1081/E-EPM-120046899.
Sterner, R. 1938. Flora der Insel Öland. – Acta Phytogeographica Suecica 9: 1–169.
Widén, B. 1980. Flowering strategies in *Helianthemum oelandicum* (Cistaceae) complex on Öland, Sweden. – Botaniska Notiser 133: 99–115
Widén, B. 1988. Partitioning of variation in pubescence of a dwarf shrub, *Helianthemum oelandicum*. – Acta Phytogeographica Suecica 76: 133–156
Widén B. 2010. Cistaceae – In Jonsell B. & Karlsson T. (eds). Flora Nordica 6. Swedish Museum of National History, Stockholm.
Widén, B. 2017. Inheritance of a hair character in *Helianthmum oelandicum* var. *canescens* and allele frequencies in natural populations. – Plant Systematics and Evolution 304:145–161.
Widén, B. 2018. Inheritance of glabrous plants in *Helianthmum oelandicum* var. *oelandicum* and spatial patterns of allele frequencies in local populations. – Plant Systematics and Evolution: 1199–1219.

Sammanfattning

Sköldlusen *Acanthococcus azaleae* (Comstock) påträffades för första gången i Sverige på ölandssolvända *Helianthemum oelandicum* i form av första stadiets nymfer i juni 2019 på Stora Alvaret (öster om Klinta – Stora Smedby). Arten upptäcktes redan 2017 på plantor av solvända i experimentväxthus vid Lunds universitet. Sköldlössen klarade övervintringen 2017/2018 utomhus i bänkgårdar och artbestämdes på plantor i växthus i januari 2019. Studierna visade under våren och sommaren 2019 störst populationstäthet på försvagade föräldra- och hybridplantor.

Sköldlusen tillhör familjen filtsköldlöss (Eriococcidae). I artikeln presenteras viktiga morfologiska karaktärer hos familjen Eriococcidae respektive *A. azaleae*. Även skillnader i morfologi mellan den närbesläktade *A. lagerstroemiae* och *A. azaleae* redovisas.

Acanthococcus azaleae är rapporterad från två zoogeografiska regioner: Nearktis: Kanada och USA samt Palearktis: Belgien, Tjeckien, Tyskland och Ryssland. I Sverige har fyra arter av *Acanthococcus* respektive det närliggande släktet *Rhizococcus* påträffats. Totalt har vi i landet funnit 78 arter av sköldlöss utanför växthusmiljöer.