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A new record of the armored scale genus *Carulaspis* MacGillivray (Hemiptera: Diaspididae) from Korea, and its aphelinid parasitoids (Hymenoptera: Aphelinidae)

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Abstract. *Carulaspis juniperi* (Bouché) is newly documented as occurring in the Korean fauna of armored scales (Hemiptera: Diaspididae). The characters of this genus and species are redescribed based on specimens collected in Korea. In addition, four species of aphelinids (Hymenoptera: Aphelinidae) associated with *C. juniperi* were collected in Korea during the survey. Of these, *Aphytis japonicus* DeBach and Azim and *Encarsia explorata* (Silvestri) are recorded for the first time from *C. juniperi*.

Key words. *Aphytis japonicus*, *Carulaspis juniperi*, *Encarsia explorata*

Introduction

Carulaspis MacGillivray (Hemiptera: Diaspididae) was described in 1921 with *Aspidiotus juniperi* Bouché as the type species, and currently contains seven species known worldwide (Ben-Dov et al. 2015). Of these, six species have been documented from the Palaearctic and three species from the Australasian region (*Carulaspis juniperi* (Bouché) and *Carulaspis minima* (Signoret) occur in both regions). This genus is closely related to *Diaspis* Costa, but differs mainly by possessing gland spines between the median lobes and submarginal dorsal macroducts absent from abdominal segment 6 (Gill 1997). Species belonging to *Carulaspis* occur on conifers only, and are regarded as Palaearctic in origin (Williams and Watson 1988; Miller and Davidson 2005).

Knowledge of the Korean fauna of the armored scales (Diaspididae) began in 1928 with the publication of Machida and Aoyama [cited from the publication of Paik (2000)]; so far, eighty five species have been documented (Paik 1978; Paik 2000; Suh and Hodges 2007; Lee 2010; Suh 2011, 2012, 2013, 2014, 2015; Yu and Suh 2013), but until now the genus *Carulaspis* has not been documented in Korea. In a recent survey (2015) of Chungcheongnamdo, one species of *Carulaspis* occurring on white cedars [*Thuja occidentalis* L. (Cupressaceae)] was recorded. It was identified as the juniper scale, *Carulaspis juniperi* and this species is newly reported from the Republic of Korea. In this paper, a diagnosis, photographs, host plants and distribution of *C. juniperi* are provided for the correct identification of this species.

In addition, we conducted a survey of the aphelinid parasitoids of the juniper scale in Korea. Currently, seven species of Aphelinidae (Hymenoptera) associated with *C. juniperi* have been reported in the scientific literature (Noyes 2015). During this survey, the following four species of aphelinids were collected and identified as: *Aphytis japonicus* DeBach and Azim, *Encarsia citrina* (Craw), *E. explorata* (Silvestri) and *Encarsia* sp. nr. *perniciosi* (Tower). Of these, *A. japonicus* and *E. explorata* are herein recorded for the first time from *C. juniperi*.

Materials and Methods

All slide mounted in Canada balsam and dry specimens of the juniper scale used for this paper are deposited in the Collection of Plant Quarantine Technology Center (CPQTC), QIA, in Korea. Terminology for morphological structures used in a diagnosis follows that of Miller and Davidson (2005). Some of the aphelinid specimens reared from the juniper scale were mounted in Hoyer's medium and the others were preserved in alcohol and deposited in the CPQTC. Terminology for the morphological structures

used in the diagnoses follows that of Hayat (1998). Photographs were taken using an AxioCam MRc5 camera through a ZEISS Axio Imager M2 Microscope and a Leica M165C microscope with a Delta pix camera. An asterisk (*) is used to indicate a new host and distribution record.

Results

Systematic accounts

Genus *Carulaspis* MacGillivray, 1921

Carulaspis MacGillivray 1921: 305. Type species: *Aspidiotus juniperi* Bouché.

Diagnosis. Cover of adult female white, circular. Body circular to turbinate in shape, with the pygidium slightly pointed at apex, with median lobes rounded, separated by a space, lobe 2 bilobate with medial lobule almost as large as median lobe and lateral lobule smaller than median lobule, lobe 3 bilobate or simple and smaller than lobe 2. Short gland spines present between lobes and on abdominal margins. Marginal macroducts barrel shaped, 4–6 pairs present, with or without a macroduct in medial space. Dorsal ducts arranged in short submedial and submarginal rows, with a few similar ducts on ventral submargin of abdomen. Anal opening located slightly posterior of mid pygidium. Microducts present on submedial dorsum and venter. Antenna with one seta. Anterior spiracles each usually with one or two trilocular pores, posterior spiracles without pores. Perivulvar pores in five well-separated rounded groups (Miller and Davidson 2005; Ben-Dov et al. 2015).

Carulaspis juniperi (Bouché, 1851)

Aspidiotus juniperi Bouché, 1851 [Germany: on *Juniperus communis*].

Diagnosis. Field characters (Fig. 1): Adult female cover convex, circular, white; shed skins central, yellow. Male cover elongate, parallel sided, felted, with 3 longitudinal ridges, white; shed skin marginal yellow. Slide-mounted characters (Fig. 2–5): Adult female with two pairs of well-developed lobes, lobes 3 and 4 represented by sclerotized raised area; paraphyses absent; median lobes separated by space about 0.6 times width of median lobes, without sclerotized area anterior of lobe, without yoke, medial margin parallel or slightly divergent apically; lobe 2 bilobate, about same size or slightly larger than median lobes; with two gland spines between median lobes, about same length as median lobes; macroducts of two sizes, larger size in marginal areas of abdominal segments 5 to 8; smaller size in submarginal and submedial areas of abdominal segments 1 to 5; with macroduct between median lobes, with about 13 on each side of pygidium on abdominal segments 5 to 8; ducts in submarginal and submedial areas, with a total of 72 macroducts on each side of body; perivulvar pores in five groups; anterior spiracle with 2 pores, posterior spiracle without pores; adult female broadly pyriform; antennae each with one seta.

Material examined. Korea. Chungcheongnamdo (CN): 187, Cheollipo 1-gil, Sowon-myeon, Taean-gun (36°48'03.25"N/126°09'08.64"E), 16 females, 3 males, on *Thuja occidentalis* L. (Cupressaceae), 22-vii-2015 (S.J. Suh).

Hosts. Found on conifers of the following host genera: *Callitris* Vent., *Calocedrus* Kurz, *Chamaecyparis* Spach, *Cryptomeria* (L.f.) D. Don, *Cupressocyparis* A. B. Jacks. and Dallim., *Cupressus* L., *Juniperus* L., *Libocedrus* Endl., *Picea* Mill., *Pinus* L., *Platycladus* Spach, *Sequoia* Endl., *Sequoiadendron* J. Buchholz, *Taxodium* Rich., *Taxus* L., *Thuja* L. (Ben-Dov et al. 2015).

Distribution. Australasian: Australia, New Zealand. Nearctic: Canada, USA. Neotropical: Argentina, Brazil, Chile. Palaearctic: Algeria, Austria, Azores, Bulgaria, Canary Islands, Croatia, Czechoslovakia, Egypt, France, Georgia, Germany, Greece, Hungary, Iran, Italy, Madeira Islands, Malta, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russia, Sicily, Spain, Switzerland, Turkey, Turkmenistan, Ukraine, UK, Uzbekistan, Yugoslavia. (Ben-Dov et al. 2015), Korea*.

Biology. The juniper scale has one generation per year. Mated adult females overwinter and begin laying eggs in March in warm areas to May in cooler regions (Miller and Davidson 2005).

Economic Importance. Heavy juniper scale infestations cause foliage to turn yellow, however, it is not a pest and seems to prefer the cooler parts of USA (Gill 1997; Miller and Davidson 2005). In Korea, it has a restricted host range occurring on conifers and on white cedar [*Thuja occidentalis* L. (Cupressaceae)], a tree commonly planted for landscaping and fence trees. We did not observe this scale to be causing serious damage to the white cedar during the survey.

Aphelinid parasitoids (Hymenoptera: Aphelinidae) associated with *C. juniperi* in Korea

1. *Aphytis japonicus* DeBach and Azim* (Fig. 6)

Material examined. Korea. CN: same locality as *C. juniperi*, 10 females and 2 males, ex. *Carulaspis juniperi* (Bouché) on *Thuja occidentalis* L. (Cupressaceae), 22-vii-2015 (S.J. Suh).

Diagnosis. Body entirely yellow; forewing with a linea calva; antenna 6-segmented; head without distinct black bars and margins; mesoscutum with usually 10 setae; propodeal crenulae nonoverlapping; tarsi 5-segmented.

2. *Encarsia citrina* (Craw) (Fig. 7)

Material examined. Korea. CN: same data as *A. japonicus*, except 2 females.

Diagnosis. Body brown to dark brown; head almost light yellow; fore wing with an asetose area around stigmal vein; fore wing more or less parallel-sided beyond venation; marginal fringe longer than width of wing; submarginal vein with two setae; antenna 8-segmented; mid lobe of mesoscutum with four setae; petiole with distinct sculpture; all tarsi 5-segmented.

3. *Encarsia explorata* (Silvestri)* (Fig. 8)

Material examined. Korea. CN: same data as *A. japonicus*, except 5 females and 3 males.

Diagnosis. Body generally yellow except pronotum, anterior mesoscutum, axillae, posterior mesosoma, T1, T4-T6 and lateral sides of T7 brown to dark; placoid sensilla on scutellum separated by more than twice their diameter; F1 quadrate and F1 shorter than F2; F2-F6 with longitudinal sensilla; mid lobe of mesoscutum with four setae; ovipositor shorter than middle tibia and basitarsus combined, third valvulae pale; all tarsi 5-segmented.

4. *Encarsia* sp. nr. *perniciosi* (Tower) (Fig. 9)

Material examined. Korea. CN: same data as *A. japonicus*, except 6 females.

Diagnosis. Body generally yellow except pronotum, anterior mesoscutum, axillae, posterior mesosoma and lateral sides of T1-T2 (tergite of gaster), T4-T6 and base of hind coxae brown to dark; placoid sensilla on scutellum separated by more than 2x their diameter; F1 (flagellar segments) quadrate and F1 shorter than F2 and F3; F2-F6 with longitudinal sensilla; mid lobe of mesoscutum with 6-8 setae; ovipositor shorter than middle tibia and basitarsus combined, third valvulae dark brown; all tarsi 5-segmented.

Discussion

Carulaspis juniperi is newly reported for the Korean armored scale fauna through the recent survey conducted in Chungcheongnamdo. This species resembles those of the genus *Diaspis* which are already known in Korea; however, it is diagnosed by the presence of gland spines between the median lobes and submarginal dorsal macroducts absent from abdominal segment 6. The information provided in this paper should help understand the Korean fauna of armored scales and identify related species correctly.

Also an updated list of aphelinids associated with *C. juniperi* should become useful in determining potential biological control agents for controlling armored scale pests. Of the four species of aphelinids, the ectoparasitic *A. japonicus* was an abundant parasitoid of *C. juniperi* in Korea, thus it should be considered as a potential candidate for introduction into other areas for biological control of this and related species of scale insects.

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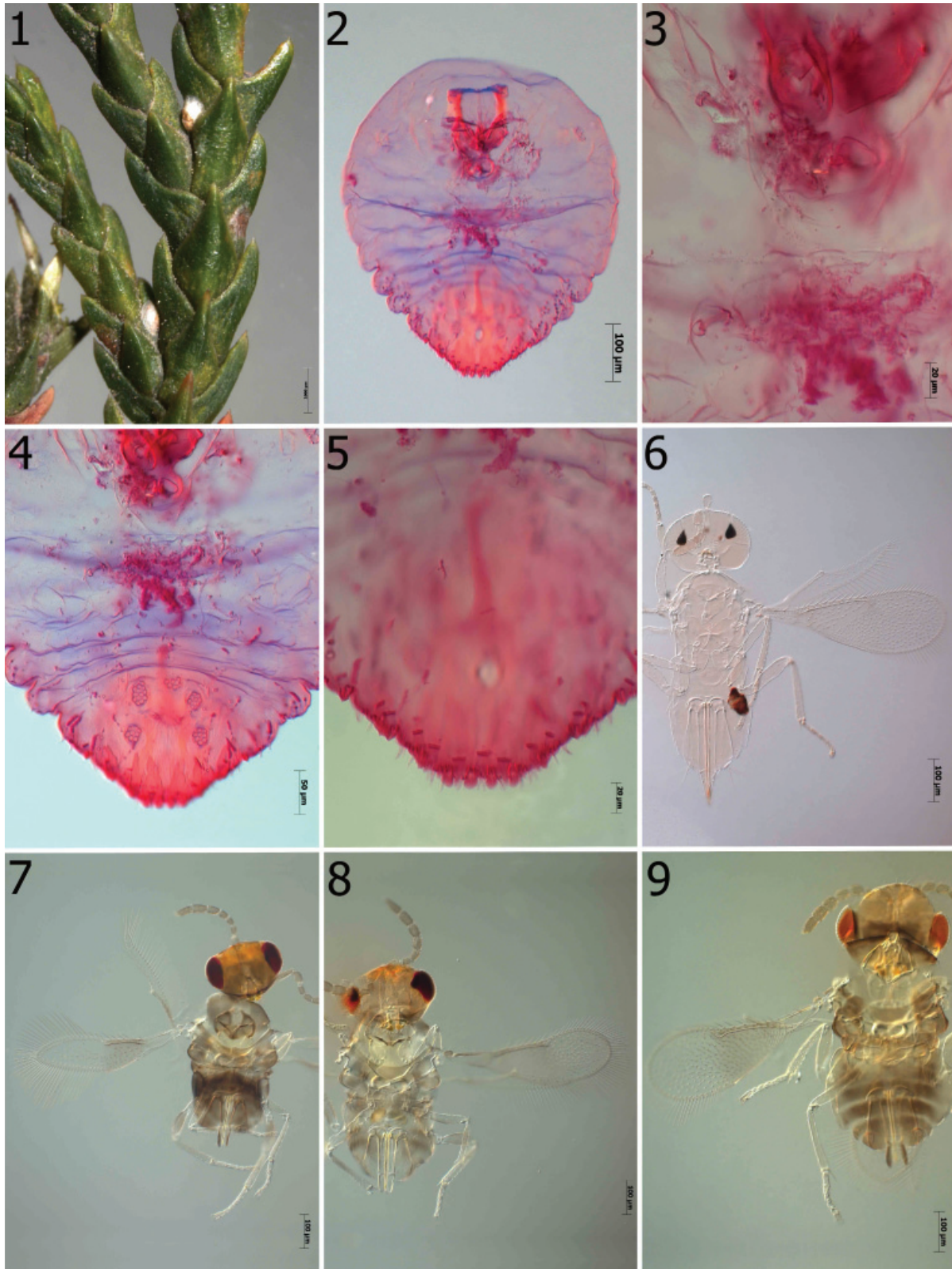
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Figures 1–9. *Carulaspis juniperi* (Bouché) and four species of aphelinids. 1–5, *Carulaspis juniperi* (Bouché); 1, habitus, 2, female, 3, anterior and posterior spiracles, 4, perivulvar pores, 5, pygidium. 6, *Aphytis japonicus* DeBach and Azim, female. 7, *Encarsia citrina* (Craw), female. 8, *Encarsia explorata* (Silvestri), female. 9, *Encarsia* sp. nr. *perniciosi* (Tower), female.