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Bionomy of small spruce bud scale, *Physokermes hemicryphus* (Dalman) (Hemiptera: Coccidae) in Serbia

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SUMMARY

Small spruce bud scale, *Physokermes hemicryphus* (Dalman) (Hemiptera: Coccidae), is a Holarctic, oligophagous species developing on plants of the genera *Picea* and *Abies* (Pinaceae). It is a serious pest of *Picea abies* in Serbia, which causes drying and falling of needles, branches and even drying of entire plants.

A study of the bionomy of *Ph. hemicryphus* was carried out at five locations in Serbia in 2016 and 2017. *Ph. hemicryphus* was found to develop one generation annually and to overwinter as second-instar larvae on spruce branches. Adults emerge at the beginning of April and oviposition takes place at the beginning of May. Larvae hatch in the second half of May; during summer they feed on spruce needles and moult into second-instar larvae in September.

Scale populations are controlled by a number of natural enemies. Five species of parasitoid wasps were reared: *Coccophagus lycimnia* (Walker) (Hymenoptera: Aphelinidae), *Metaphycus unicolor* Hoffer, *Microterys lunatus* (Dalman), *Pseudorhopus testaceus* (Ratzeburg) (Hymenoptera: Encyrtidae) and *Pachyneuron muscarum* (L.) (Hymenoptera: Pteromalidae), as well as five predatory species: *Anthribus nebulosus* Forster (Coleoptera: Anthribidae), *Exochomus quadripustulatus* L., *Scymnus abietis* Paykull, *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae) and *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). The most efficient parasitoid of *Ph. hemicryphus* was *P. testaceus*, reducing scale populations up to 28.97%, while the most efficient predator was *A. nebulosus* with an efficacy of up to 51.72%.

Keywords: Small spruce bud scale; *Picea abies*; Bionomy; Natural enemies; Serbia

INTRODUCTION

The small spruce bud scale, *Physokermes hemicryphus*, is found throughout Europe, North America and Mongolia (Kosztarab & Kozár, 1988). It inhabits plants of the genera *Picea* and *Abies*, most frequently *Picea abies* (L.) Karst. It is frequent in forests, plant nurseries, parks and other urban environments (Kozár, 1998).

The small spruce bud scale causes direct damage by sucking plant sap from all plant aboveground parts, and causing physiological weakening of its plant host, drying and falling of needles, branches, and even drying of whole plants. Indirect damage emerges from abundant excretion of honeydew, and covering of plant aboveground parts. Then sooty mold develops, causing photosynthesis and transpiration reduction, as well as faster deterioration of the whole plant. Damage on spruce trees has been reported in Germany (Schmutterer, 1965), Spain (Soria Cabrera et al., 1998) and North America (Furniss, 2004). In Serbia, periodical harmful activity was recorded on *Picea* species (Kozarževskaja & Vlainić, 1982; Mihajlović & Kozarževskaja, 1983).

Scale populations are regulated by a large number of natural enemies. According to literature data, 18 parasitoid species have been detected on *Ph. hemicryphus* so far, belonging to the families Aphelinidae, Encyrtidae, Eulophidae and Pteromalidae (Noyes, 2017), while predators included species from the families Anthribidae, Coccinelidae (Coleoptera) and Chrysopidae (Neuroptera) (Schmutterer, 1965; Förster, 1973; Klausnitzer & Förster, 1976; Kosztarab & Kozár, 1983; Santas, 1988; Stathas et al., 2011). In Belgrade, Serbia, three parasitoid species have been found: *M. lunatus*, *C. lycimnia* and *P. testaceus*, and the predator *A. nebulosus* (Mihajlović & Kozarževskaja 1983).

Although *Ph. hemicryphus* is an autochtonous species, it hasn't been sufficiently researched in Serbia and data referring to a period of thirty years ago or more are very scarce (Kozarževskaja & Vlainić, 1982; Mihajlović & Kozarževskaja, 1983). The aim of this study was to determine the presence, intensity of infestation and harmfulness of small spruce bud scales, to study their life cycle more thoroughly, and to identify natural enemies and their roles in reducing scale populations.

MATERIAL AND METHODS

Visual examination and sampling were carried out on scale-infested plants of the genus *Picea* in parks, yards and other green areas on five locations in Serbia (Belgrade, Blace, Valjevo, Jagodina and Osečina) in 2016 and 2017. More detailed observations were carried out in Belgrade, where plant material was sampled on 15 locations (Borča, Voždovac, Vračar, Grocka, Zvezdara, Zemun, Zemun polje, Jakovo 1, Jakovo 2, Konjarnik, Medaković, Mirijevo, Novi Beograd, Novi Železnik and Surčin).

The intensity of infestation was determined using the Borchsenius scale (1963). Every 7-10 days during the vegetative period (from March to October), and once a month in the dormancy period of plants (from November to February), four one- or two-year-old branches, 20 cm long, were sampled from each side of the crown of each infested spruce tree.

The samples of infested branches were immediately used to examine the scale life cycle. Sexual index was calculated using the following formula: $\mathbf{I = f / f + m}$; where **I** - sexual index, **f** – number of females, **m** – number of males (Ciglar, 1975).

Infested branches that contained both parasite and predator larvae were placed in glass cylinders and kept under laboratory conditions. The collected predatory larvae were reared individually in petri dishes in order to prevent canibalism. The shields together with larvae or pupae of parasitoids were isolated in separate glass tubes in order to determine the number of ecloded adults. Parasitism/predation percentage was calculated using the formula: $\mathbf{P = B \times 100 / a}$; where **P** - percent of parasitism/predation, **B** – number of parasitized scales/with predatory larvae, **a** – total number of examined scales in a sample (Hadzibejli, 1983). Parasitoids were identified by Aleksandar Stojanović, of the Natural History Museum, Belgrade.

Permanent microscopic slides were made according to a method proposed by Kosztarab and Kozár (1988) to analyze the morphological traits of scale. Species were identified using the following determination keys: Schmutterer (1956), Kosztarab and Kozár (1988) and Gill (1988).

RESULTS

The study of *Ph. hemicryphus* was carried out in 2016 and 2017 and it included examination of its morphology, distribution, life cycle, intensity of infestation, damage symptoms of attack, and presence of natural enemies.

Morphology of Ph. hemicryphus

Based on an analysis of female morphology on microscope slides, it was confirmed that the specimens belonged to the species *Ph. hemicryphus.* In this species,

as well as other representatives of the Coccidae family, the shield is an integral part of the body, and sexual dimorphism is clearly expressed. The body of a young female has a bud shape and yellowish-brown basic colour, and is dark brown around the anal ring (Figure 1), while the body of an adult female is more sclerotized and brown. A male has an elongated-oval body shape with developed antennae, eyes, legs and one pair of wings (Figure 2). Eggs are elipsoid, pink and covered with white powdery wax. First-instar larvae are flat, elongated-oval, pink, with developed antennae and legs, and clearly visible eyes. Second-instar females are round, and excrete thick, waxy, white coloured fibres (Figure 3). Second-instar males are elongated, and produce a transparent white cover under which they undergo prepupal and pupal stages, and later turn into males (Figure 4).

Figure 1. Female of *Ph. hemicryphus* (orig.)

Figure 2. Male of *Ph. hemicryphus* (orig.)

Figure 3. Second-instar females of *Ph. hemicryphus* (orig.)

Figure 4. Wax cover produced by second-instar males (orig.)

Distribution, infestation intensity and damage symptoms

During this study, *Ph. hemicryphus* presence was detected on all inspected locations in Serbia. In Blace, Valjevo, Osečina and Jagodina, as well as on 12 Belgrade locations (Borča, Vračar, Grocka, Zvezdara, Zemun, Zemun polje, Jakovo 2, Konjarnik, Mirijevo, Novi Beograd, Novi Železnik and Surčin), the species was found on *P. abies* (Tables 1 and 2), while on three Belgrade locations (Voždovac, Jakovo 1 and Medaković) it was discovered on *P. pungens* (Table 2). The intensity of infestation on the examined infested plants varied from 1 to 4, i.e. from sporadic specimens to large scale colonies.

Table 1. Distribution, infestation intensity and percent of parasitism/predation of *Ph. hemicryphus* on *P. abies* in Serbia

Location	Infestation intensity	Parasitoid *P. testaceus* (%)	Predator *A.nebulosus* (%)
Blace	1	10	-
Jagodina	4	14.63	34.15 - 40
Osečina	1	-	15.39
Valjevo	1	-	25

Table 2. Distribution, host plants, infestation intensity and percent of parasitism/predation of *Ph. hemicryphus* on Belgrade locations

Location	Host plant	Infestation intensity	Parasitoid *P. testaceus* (%)	Predator *A.nebulosus* (%)
Borča	*P. abies*	2	2.08	7.59
Grocka	*P. abies*	4	1	28
Jakovo 1	*P. pungens*	1	-	8.33
Jakovo 2	*P. abies*	3	-	11.29 - 17.14
Konjarnik	*P. abies*	4	28.97	51.72
Medaković	*P. pungens*	1	-	13.33
Mirijevo	*P. abies*	3	-	18.92 - 32
Novi Beograd	*P. abies*	4	4	15.56 - 24
Novi Železnik	*P. abies*	2	-	11.22
Surčin	*P. abies*	3	-	11.25 - 24.29
Voždovac	*P. pungens*	4	-	12
Vračar	*P. abies*	4	-	32
Zvezdara	*P. abies*	3	-	2 - 16.47
Zemun	*P. abies*	3	-	34.54
Zemun polje	*P. abies*	3	4	16.67 - 34

On *P. abies*, the highest intensity of infestation was level 4 on plants which were covered with scale colonies. That level of infestation was found in Jagodina and on four locations in Belgrade (Vračar, Grocka, Konjarnik and Novi Beograd). Intensive sucking of plant sap from needles, young shoots and branches resulted in the presence of chlorotic spots, drying and falling of needles, drying of branches, and even drying of entire plants (Figure 5). The scale excretes large amounts of honeydew, providing a suitable medium for sooty mold development (Figure 6) that reduces the assimilation area of plants, speeding up their deterioration. Infested plants have a dirty, black appearance and are easily noticed.

Figure 5. Damage caused by *Ph. hemicryphus* on *P. abies* (orig.)

Figure 6. A branch of *P. abies* covered with sooty mold (orig.)

Small and large colonies of spruce bud scale (infestation level 3) were found on six locations in Belgrade (Zvezdara, Zemun, Zemun polje, Jakovo 2, Mirijevo, Surčin) (Table 2), where drying and falling of needles were observed on infested plants. Small colonies or individual scale specimens (infestation level 2) were found on two locations in Belgrade (Borča and Novi Železnik), where discoloration of needles at branching positions was observed. Scale specimens (infestation level 1) were found on Blace, Valjevo and Osečina locations, but no visible symptoms of damage were observed.

On *P. pungens* found on Belgrade's Voždovac location, scales formed numerous colonies (infestation level 4), causing drying of aboveground plant parts, while scale specimens were present at infestation level 1 on Jakovo 1 and Medaković locations, causing no visible damage symptoms.

Life cycle

In Serbia, *Ph. hemicryphus* develops one generation annually and overwinters as the second-instar larva on spruce branches (Table 3). With temperature increase at the end of February or beginning of March, activation of overwintering larvae begins. The second-instar females settle under flakes at branching positions where they intesively feed for two to three weeks, increasing their body dimension and excreting white waxy fibres in their surroundings and becoming young females after molting. Their emergence was recorded on April 8, 2016 and April 3, 2017. Male larvae become attached to spruce needles where they form white transparent cover, going through prepupal and pupal stages underneath it. The first prepupae were recorded at the beginning of March (March 9, 2016 and March 3, 2017), and pupae at mid-March (March 21, 2016 and March 15, 2017). Prepupal and pupal stages take 10-13 days each, and then males emerge. They emerge three to five days before females, so the emergence of first males in 2016 was recorded on April 3, while in 2017 it began on March 28. Sexual index amounted to 0.7. After emergence, the male actively flies around spruce branches looking for a female. After copulation, which takes approximately 20 minutes, the male usually stays pasted to the female body due to a large amount of honeydew, and dies there. The fertilised female lays between 360 and 650 eggs at the beginning of May (May 7, 2016 and May 3, 2017). After embrionic development, which lasts 21 days, larvae hatch, and their emergence was recorded on May 28, 2016, and May 24, 2017. Larval hatching extends into June. They leave the shield of dead females within one or two days and start moving towards spruce needles to start intensive feeding. In mid-September (September 19, 2016, and September 15, 2017), they molt into second-instar larvae which feed for a while before settling on spruce branches to overwinter.

Natural enemies of Ph. hemicryphus

During the research period, 10 species of natural enemies (five parasitoids and five predators) were sampled and reared from colonies of small spruce bud scale.

Five species of parasitoid wasps were found: *Coccophagus lycimnia* (Hymenoptera: Aphelinidae), *Metaphycus unicolor*, *Microterys lunatus*, *Pseudorhopus testaceus* (Hymenoptera: Encyrtidae) and *Pachyneuron muscarum* (Hymenoptera: Pteromalidae). The most efficient parasitoid was *P. testaceus,* detected on two locations (Blace and Jagodina) with parasitation level reaching 10-14.63%, and on five Belgrade locations, where parasitation level reached 28.97% (Tables 1 and 2)..

Table 3. The emergence time of *Ph. hemicryphus* development stages per year

Year	2016		2017	
Development stage	Female development	Male development	Female development	Male development
pn	-	09.03.	-	03.03.
n	-	21.03.	-	15.03.
Male	-	03.04.	-	28.03.
Female	08.04.	-	03.04.	-
Egg	07.05.	07.05.	03.05.	03.05.
N_1	28.05.	28.05.	24.05.	24.05.
N_2	19.09.	19.09.	15.09.	15.09.

N_1 – first instar, N_2 – second instar, pn - prepupa, n - pupa

Regarding predators, the following species were found: *Anthribus nebulosus* (Coleoptera: Anthribidae), *Exochomus quadripustulatus*, *Scymnus abietis*, *Harmonia axyridis* (Coleoptera: Coccinelidae) and *Chrysoperla carnea* (Neuroptera: Chrysopidae).

The species *A. nebulosus* was the most efficient predator of small spruce bud scale, and it was found on all inspected locations (except at Blace) (Tables 1 and 2). The life cycle of this predatory species and the scale is synchronized. The female of *A. nebulosus* lays eggs under the female shield of *Ph. hemicryphus*, and the hatched larvae feed on eggs of the scale. During its development, the predatory larva eats all scale eggs. This species reduced scale populations up to 51.72%. Other predatory species were present individually in the colonies of small spruce bud scale.

DISCUSSION

During this study, numerous colonies of *Ph. hemicryphus* were observed on *P. abies* and *P. pungens*. The presence of colonies led to the drying of needles, branches and, due to strong and long-term infestation, even to the drying of whole plants. Young spruce plants are partucularly prone to infestation. Sporadic harmful effects of this species on plants of the genus *Picea* were also observed in the territory of Belgrade back in the 1980s (Kozarževskaja & Vlainić, 1982; Mihajlović & Kozarževskaja, 1983). Damage on young plants of *P. abies*, *P. pungens* and *Abies alba* have also been reported in Germany, (Schmutterer, 1965) and Spain (Soria Cabrera et al., 1998), as well as in North America on *P. abies* (Furniss, 2004).

In Serbia, small spruce bud scale has one generation annually and overwinters as the second-instar larva on spruce branches. The same life cycle data have been recorded in Serbia (Kozarževskaja & Vlainić, 1982), Germany (Schmutterer, 1965), Greece (Santas, 1988; Stathas et al., 2011) and North America (Furniss, 2004). In Serbia, the species' reproduction is sexual, as it is in Greece as well (Santas, 1988), while in Germany (Schmutterer, 1956) and North America (Gill, 1988) its reproduction is parthenogenetic. The number of eggs laid by female varies. The data in this study show that a female lays between 360 and 650 eggs, while in Greece the number varies from 70 to 280 (Stathas et al., 2011) and from 82 to 1486 (Santas, 1988), in Germany from 38 to 335 (Schmutterer, 1956), and in North America from 290 to 858 (Furniss, 2004).

Eighteen parasitoids of *Ph. hemicryphus* have so far been detected worldwide (Noyes, 2017). During this study, five species were found, and *P. testaceus* was the most efficient of them with 28.97% parasitism. The efficacy percent reported in Germany was 70% (Schmutterer, 1965), and 76.5% (Santas, 1988) and 47.8% (Stathas et al., 2011) in Greece.

Out of the five determined predatory species, *A. nebulosus* was the most efficient. It was found on almost all locations and reduced the scale populations up to 51.72%. In Serbia, the recorded efficacy of this species was 20% on *Ph. hemicryphus* (Mihajlović & Kozarževskaja, 1983) and 68-80% on *Physokermes piceae* (Graora et al., 2012). Its efficacy in Germany was 7.2% (Klausnitzer & Förster, 1976), and 30.1% in Virginia (Kosztarab & Kozár, 1983).

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Bionomija male smrčine štitaste vaši, *Physokermes hemicryphus* (Dalman) (Hemiptera: Coccidae) u Srbiji

REZIME

Physokermes hemicryphus (Dalman) (Hemiptera: Coccidae), mala smrčina štitasta vaš, je holarktička, oligofagna vrsta koja se razvija na biljkama iz rodova *Picea* i *Abies* (Pinaceae). Na napadnutim biljkama vaš obrazuje brojne kolonije prouzrokujući fiziološko slabljenje, sušenje i opadanje četina, grana, pa čak i cele biljke. Zbog obilnog lučenja medne rose, na koju se naseljavaju gljive čađavice, procesi fotosinteze i transpiracije su smanjeni, kao i estetska vrednost biljaka, zbog čega *Ph. hemicryphus* predstavlja značajnu štetočinu smrče.

Proučavanje bionomije *Ph. hemicryphus* obavljeno je tokom 2016. i 2017. godine, na pet lokaliteta na teritoriji Srbije. Utvrđeno je da *Ph. hemicryphus* razvija jednu generaciju godišnje i da prezimljava kao larva drugog stupnja na granama smrče. Imago se javlja početkom aprila, a ovipozicija je početkom maja. Larve se pile u drugoj polovini maja, tokom leta se hrane na četinama smrče, a u septembru obrazuju larve drugog stupnja koje prezimljavaju.

Brojnost populacija ove štetočine reguliše veći broj prirodnih neprijatelja. Odgajeno je pet vrsta parazitoidnih osica: *Coccophagus lycimnia* (Walker) (Hymenoptera: Aphelinidae), *Metaphycus unicolor* Hoffer, *Microterys lunatus* (Dalman), *Pseudorhopus testaceus* (Ratzeburg) (Hymenoptera: Encyrtidae) i *Pachyneuron muscarum* (L.) (Hymenoptera: Pteromalidae), kao i pet vrsta predatora: *Anthribus nebulosus* Forster (Coleoptera: Anthribidae), *Exochomus quadripustulatus* L., *Scymnus abietis* Paykull, *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae) i *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). Najefikasniji parazitoid *Ph. hemicryphus* je *P. testaceus*, koji je redukovao brojnost populacija vaši do 28,97%, dok je najefikasniji predator *A. nebulosus* sa efikasnošću do 51,72%.

Ključne reči: Mala smrčina štitasta vaš; *Picea abies*; Bionomija; Prirodni neprijatelji; Srbija