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BIONOMY OF SPRUCE BUD SCALE, *PHYSOKERMES PICEAE* (SCHRANK) (HEMIPTERA: COCCIDAE) IN THE BELGRADE AREA, SERBIA

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Abstract – Spruce bud scale, *Physokermes piceae*, develops on the genus *Picea*. Large colonies of this species are constantly present on *Picea abies* in green areas in the Belgrade territory, causing the drying of needles, branches and whole plants. Therefore, *Ph. piceae* is a significant spruce pest. Spruce scales attract many entomophagous insects able to reduce pest population. Parasitoid wasps *Coccophagus lycimnia* (Walk) (Aphelinidae) and *Microterys lunatus* (Dalm.) (Encyrtidae) were reared. Predators *Exochomus quadripustulatus* L., *Scymnus abietis* Paykull (Coccinellidae) and *Anthribus nebulosus* Forster (Anthribidae) were determined. Both species of ladybird were confirmed as predators of *Ph. piceae* for the first time in Serbia, while *S. abietis* is a new species for the fauna of Serbia. The most effective natural enemy of *Ph. piceae* was *A. nebulosus*, reducing populations by 68-80%.

Key words: *Physokermes piceae*, *Picea abies*, parasitoids, predators, Belgrade, Serbia

INTRODUCTION

Physokermes piceae, spruce bud scale, belongs to the family Coccidae, order Hemiptera. It has been mentioned under the synonyms *Coccus piceae* Sch., *C. racemosus* Ratz. and *Physokermes latipes* Borch. It is distributed throughout Europe, North America and Mongolia (Kozar, 1998). In the whole distribution area, it inhabits spruce (*Picea* spp.), while in Turkey it has been found on plants from the genus *Abies* (Ulgenturk and Canakcioglu, 2004). It is present in forests, nurseries and urban areas. As a pest, it is significant in urban areas where it often overmultiplies.

Sucking sap from all aboveground parts of spruce, *Ph. piceae* causes direct damage such as the physiological weakening of the plant, disorder in the development of needles and shoots, discoloration and drying of needles, drying of branches and even whole plants. There is also indirect harm due to honeydew excretion. It covers the above-ground organs of the plant, giving them a characteristic polish at first and then a grayish black color due to the presence of sooty mold, leading to the reduction of photosynthesis and further physiological weakening of the plant. These plants not only lose their aesthetic value, but also often completely dry up because of continuous infestation, causing serious damage. Significant damage to spruce has been registered in Hungary (Kosztarab and Kozar, 1978), the northern part of the USA (Wallner, 1978), Romania (Kozar, 1985), Poland (Logowska, 1986), Turkey (Ulgenturk et al., 2004; Ulgenturk and Canakcioglu, 2004), Italy (Hallrigl, 2004), Croatia (Diminić and Hrašovec, 2005), Slovakia (Kolar, 2007) and Lithuania (Malumphy et al., 2008).

In Serbia, *Ph. piceae* is present on spruce in forests, but more frequently and in larger numbers in nurseries, parks, gardens and other green surfaces in urban habitats (Mihajlović, 2008). According to available data, significant damage on spruce has been registered on Mt. Kopaonik at an altitude above 1100 m (Maksimović, 1960), and in the Belgrade area on *Picea abies* and *P. pungens* (Kozarževskaja and Vlainić, 1981, 1982; Mihajlović and Kozarževskaja, 1983; Galečić et al. 2007).

The presence of numerous colonies of *Ph. piceae* on spruce attracts many entomophagous species (parasitoids and predators) feeding on scale specimens, but also other species of insects (wasps, bees, ants, flies) feeding on honeydew.

According to literature data, 28 species of parasitoid wasps from the families Encyrtidae, Aphelinidae, Eulophidae, Pteromalidae, Signiphoridae, and three predatory species from the families Anthribidae and Coccinellidae (Trjapitzin, 1989; Kosztarab and Kozar, 1988; www.nhm.ac.uk) have been known on spruce bud scale so far.

Among the natural enemies of *Ph. piceae* in Serbia, five species of parasitoid wasps have been known (*Cheiloneurus elegans, Ch. paralia, Pseudorhopus testaceus, Microterys lanatus, Coccophagus lycimnia*), as well as one predator species (*Anthribus nebulosus*) (Bouček, 1977; Mihajlović and Kozarževskaja, 1983).

In recent years, *Ph. piceae* has become a frequent and significant pest on spruce in many localities in Serbia, especially in urban habitats, such as Belgrade, where spruce is an ornamental plant in parks, gardens and other green areas. Consequently, a more detailed research of the development cycle, infestation intensity, harmfulness and natural enemies of the species has been initiated.

MATERIALS AND METHODS

During years 2006 and 2007, examination of plants from the genus *Picea* regarding the presence, infestation intensity and harmfulness of *Ph. piceae,* was carried out in parks, gardens and other green areas in the wider Belgrade territory. Every 7-15 days during vegetation and once a month in the dormancy period, 4 one- or two-year-old branches, 25 cm long, were sampled from each infested plant. In the laboratory, the number of scales and development stage were investigated; the infestation intensity was assessed according to Borchsenius scale (1963) for the presence of parasitized scales, as well as predator prepupal and pupal stages. The percent of parasitized scales and predator effectiveness were calculated by examination of 100 specimens.

In order to follow the developmental cycle of scales, after being examined the sampled branches were put in glass cylinders or photoeclectors, where the scales and their natural enemies found in colonies were reared. The oviposition, number of laid eggs, duration of embryonic and post-embryonic development, number of generations and overwintering mode of the scales were examined, as well as development cycle of some predatory species.

For the purpose of analyzing the morphological traits, permanent microscopic slides were made of the scales, using the method of Kosztarab and Kozar (1988).

Collected and reared imagos of entomophagous insects were mounted, or after being macerated in 5% KOH solution put in Hoyer's solution and determined until species level.

RESULTS

During the examination of spruce in parks, gardens and other green areas in Belgrade, the species *Ph. piceae* was determined on *Picea abies* on nine localities: Banovo Brdo, Bežanijska Kosa, Dorćol, Miljakovac, Novi Beograd, Surčin, Vidikovac, Zemun, Zvezdara.

Morphology of Ph. piceae

Both this species and all representatives of the family Coccidae, or pseudo-scales, have a shield and clearly expressed sexual dimorphism. The adult female body is strongly sclerotized, very convex, radius 8mm, yellow-brown, resembling a bud (Fig. 1). The male body is elongated with developed antennae, legs and one pair of wings (Fig. 2). Eggs ellipsoid, pink, covered with white powdery wax (Fig. 3). First and second instar of larvae with flat pink bodies, developed antennae and legs (Fig. 4). Young females form from second instars after molting, with flat bodies at the beginning and during the feeding period, enlarging and gaining a round shape. Male second instars form an elongated, transparent white shield under which they pass through prepupal and pupal stages developing into an adult.

Development cycle of Ph. piceae

In the wider Belgrade territory, *Ph. piceae* has one generation per year and overwinters as a second-instar larva on spruce. Overwintering female larvae mostly colonize the branching parts, while male larvae can be found on the lower side of the needles.

The activation time of overwintering larvae depends on meteorological conditions, primarily temperature. In 2006, the average monthly temperatures from January to March were low, from -1.9 to +5.4°C (Tab. 2), so the larvae became active in March, while in 2007 activation started in February due to higher temperatures from 5.8 to 8.8°C. After activation, female larvae feed intensively during the following two to three weeks, increasing their body dimensions and excreting white wax fibres around themselves, gaining a round form, and after molting the female appears. Male larvae feed for a short time and then pass through the prepupal and pupal stages. In 2006, prepupae were determined at the beginning of March (04.03), and pupae mid-March (16.03), but in 2007 prepupae were registered at the end of February (21.02), and pupae at the beginning of March (05.03). Each of these stages took 10-12 days after which the male formed, leaving the shield with the hind part of the body. Emergence of males was registered 2-3 days before females. In 2006, the first males appeared on March 29th, females on April 1st, while in 2007 males were registered on March 16th and females on March 19th (Tab. 1). Male eclosion takes two weeks. After eclosion, they fly around the branches actively searching for females, and after copulation, they die. Females continue post-metabolic development, which includes further enlargement of the bodies and egg forming. Eggs were registered in female bodies on April 25th, 2006 and on April 13th, 2007. The number of eggs per one female was 514-838. Larvae hatched after approximately one month of embryonic development. In 2006, this was on May 27th and in 2007 on May 15th. First-instar larvae leave the shields of dead females looking for a suitable place for feeding, often inhabiting spruce needles (Fig. 6). This period of active moving and feeding takes around one month and in July and August, with average temperatures above 20°C, larvae were found in dormancy, one next to another on the needles. In September, first-instar larvae become active again, move on the plant for a short time and molt; thus, the second-instar larvae were found on September 12th in 2006 and on September 2nd in 2007. These larvae feed until October when they withdraw to the branches or lower side of needles to overwinter.

Attack symptoms and harmfulness

Ph. piceae sucks saps from needles, young shoots and branches, causing physiological weakening of the plant, development and growth disorder, discoloration and drying of needles and even the whole plant. In addition, the scales produce large quantities of honeydew in the form of drops on their bodies and aboveground parts of the plant giving them specific polish (Fig. 5), then a grey-black color due to the development of a sooty mold (Fig. 6), causing the reduction in photosynthesis and further physiological weakening of the plant. These plants are often inhabited by wasps, bees, bumblebees, ants and flies feeding on the honeydew and indicating the presence of the scales. Infested plants lose aesthetic value and often completely dry up due to continuous infestation, so the damage is great.

On all investigated localities the spruce plants were covered with numerous colonies of scales, with levels of infestation 3 and 4 according to Borhsenius scale. This resulted in the yellowing of the needles and drying of some branches and the greatest dam-

Fig. 1. Female

Fig. 2. Male

Fig. 3. Eggs

Fig. 4. First instar larvae

Fig. 5. *P. abies* covered with honeydew

Fig. 6. Branches covered with sooty mold

Fig. 7. *Anthribus nebulosus*

Fig. 8. Larva of *A. nebulosus*

Table 1. The emergence time of *Physokermes piceae* development stages by year

Year	2006		2007	
Development stage	Female development	Male development	Female development	Male development
prepupa	-	04.03	-	21.02.
pupa	-	16.03.	-	05.03.
male	-	29.03.	-	16.03.
female	01.04.		19.03.	
eggs	25.04.	25.04.	13.04.	13.04.
N_1	27.05.	27.05.	15.05.	15.05.
N_2	12.09.	12.09.	02.09.	02.09.

N_1 – first instar larva, N_2 – second instar larva

Table 2. Meteorological data for the region of Belgrade in 2006 and 2007

Months	Temperature (°C)		Relative Humidity (%)		Precipitation (mm)	
	2006	2007	2006	2007	2006	2007
January	-1.9	6.0	92.3	92.0	44.4	65.2
February	0.6	5.8	92.3	95.1	62.6	61.6
March	5.4	8.8	84.0	90.5	61.4	92.4
April	12.2	12.8	79.6	81.8	84.4	100.0
May	15.7	17.8	77.4	84.2	48.8	95.6
June	18.7	21.4	79.9	81.0	126.8	108.0
July	22.6	23.5	74.1	76.4	16.8	18.0
August	19.6	22.6	85.0	78.1	110.8	69.0
September	17.3	15.2	84.8	83.4	45.8	80.0
October	13.0	10.4	83.7	88.4	23.8	96.0
November	7.2	3.7	88.5	85.6	31.0	127.0
December	2.4	-0.1	92.1	90.8	59.4	24.2

age was registered at the localities Bežanijska Kosa and Zemun, where the plants completely dried up due to a long-lasting infestation.

Natural enemies of Ph. piceae

During the period of research, five species of natural enemies were collected and reared, two species of parasitoid wasps and three species of predators. The determined species of parasitoid wasps were *Coccophagus lycimnia* from the family Aphelinidae, and *Microterys lunatus* from the family Encyrtidae. Among the predators, the species *Anthribus nebulosus* Forster from the family Anthribidae, and two species from the family Coccinellidae, *Exochomus quadripustulatus* L., and *Scymnus abietis* Paykull, were determined.

The parasitoid wasp *C. lycimnraried* was determined at all localities, with parasitism from 4 to 6%. The species *M. lunatus* was found in scale colonies at the localities Banovo Brdo, Bežanijska Kosa and Novi Beograd. It was determined that this wasp lays eggs inside the scale's body, always developing two larvae which eat all the host's eggs, reducing their number by 3%.

The predatory species of ladybird, *E. quadripustulatus*, and *S. abietis*, whose larvae and imagos feed on the larvae and females of scales, were determined for the first time in Serbia as natural enemies of *Ph. piceae*. The species *S. abietis* is new for the fauna of Serbia.

The most significant natural enemy of *Ph. piceae* is *A. nebulosus* (Fig. 7), which reduced the population of scales by 68 - 80% during the research. The development cycles of this predatory species and scales are completely synchronized. It has one generation per year and the imago overwinters under the bark of the spruce. The following year it activates at the end of February, feeding on honeydew and scale larvae. The largest number of predator imagos was registered at the end of March and beginning of April, i.e. at the time of female scale formation. Imagos gather around the females, copulate and lay one egg each (rarely 2 or 3 eggs) into the host. The predator's egg is white and several times bigger than the eggs of scales, which are pink and easily noticeable. Embryonic development takes 2 weeks and hatched larvae feed on the host's eggs (Fig. 8). Larvae pass through three stages of development, each taking 7 days, so the overall development lasts 21 days. The pupal stage lasts 7-10 days and overall development from egg to imago lasts 43-46 days. After eclosion, the imago stays inside the shield and at the end of summer it leaves the host's shield and withdraws under the bark to overwinter.

DISCUSSION

During our investigations, *Ph. piceae* was determined in the wider Belgrade territory only on *Picea abies,* with a high infestation level, causing the drying of needles, branches and whole plants. In the 90's, spruce bud scale, besides this species, was also registered on *Picea pungens*, causing significant damage (Kozarževskaja and Vlainić, 1981,1982; Mihajlović and Kozarževskaja, 1983).

In Slovenia, great damage was registered on *Picea excelsa* and *P. pungens* (Rihar, 1963), in Poland on *P. excelsa* (Logowska, 1986), in Italy on *P. abies* (Hellrigl, 2004), in Turkey on *P. excelsa, P. orientalis, P. pungens, Abies bornmülleriana, A. pinsapo* (Ulgenturk et al., 2004; Ulgenturk and Canakeioglu, 2004; Akkuzu et al., 2006; Kaydan et al., 2007), in Slovakia on *P. abies* and *P. pungens* (Kolar, 2007), and in Lithuania on *P. abies* (Malumpy et al., 2008).

Wasps, bees, ants, bumblebees and flies are regularly present on infested plants, feeding on honeydew, which is, according to Rihar (1963), a particularly suitable substrate for the feeding of bees.

Information about the development cycle of *Ph. piceae* in the Belgrade territory mostly corresponds with the results of other authors. There is a difference only in ovipositional activity, which in our research was determined in April, similarly to Germany (Schmurterer, 1956), while in the region of Hungary and Turkey it happens in May (Kosztarab and Kozar, 1988; Furguter and Ulgenturk, 2006).

According to foreign literature, 28 parasitoid species and 3 species of predators of *Ph. piceae* have been identified so far (Kosztarab and Kozar, 1988; www.nhm.ac.uk).

During our investigations, two species of parasitoid wasps and three species of predators, among which the species *Scymnus abietis* is new to the fauna of Serbia, were collected and reared. It was determined that the most significant natural enemy of *Ph. piceae* is the predatory species *Anthribus nebulosus*, which reduced the population of scales by 68- 80%. Similar data on this predator's efficacy can also be found in other authors' manuscripts; in the Dresden region of Germany, it is 38-59% (Kosztarab and Kozar, 1983). As this species is also a predator of other scales from the family Coccidae, e.g. in Hungary its efficacy in the reduction of populations of *Physokermes inopinatus* is 3-55%, so it was introduced into Virginia (USA) in order to control this scale biologically (Kosztarab and Kozar, 1983). However, many authors agree that the high efficacy of *Anthribus nebulosus* can sometimes be reduced due to predatory birds, especially the Great Tit, *Pa-*

rus major. During our research, the reduction in the number of predators by 70%, due to the increased presence of Great Tits, was registered (Stojnić et al., 2009). This corresponds with the data from foreign literature (Kosztarab and Kozar, 1983).

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