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Original scientific paper

Species of the genus *Parthenolecanium* (Hemiptera: Coccidae) in urban environments in Serbia

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SUMMARY

Four species of soft scales from the genus *Parthenolecanium* have been registered in urban areas in Serbia: *Parthenolecanium corni*, *P. fletcheri*, *P. pomeranicum*, and *P. rufulum*. They all develop one generation annually and overwinter as second-instar nymphs on host twigs. *P. corni* reproduces by gamogenesis, while the other three species reproduce by parthenogenesis. The species were recorded on the territory of Serbia in 22 locations on 20 host plants, whereby *P. corni* was identified on 8 new host plants, and *P. fletheri* on one new host. The intensity of scale attacks and damage symptoms on the infested plants were variable. *P. corni*, *P. fletcheri*, and *P. rufulum* formed numerous colonies on some woody and bushy plants, causing branches of individual plants to dry and decay.

Keywords: scale insects, *Parthenolecanium*, urban trees, ornamental plants, Serbia

INTRODUCTION

The family Coccidae (Hemiptera: Coccoidea) includes many, primarily polyphagous, species that inhabit mainly perennial plants, including fruit trees, vines, forest trees, shrubs, and ornamentals worldwide (García-Morales et al., 2016). In tropical and subtropical regions, they are economically significant pests as they limit the production of citrus, olives, tea, and vines. However, in recent years, an increasing economic importance of these insects has been recorded in countries with temperate climate, which is probably a consequence of global warming and milder winters, as well as intensified transportation of plants and plant material (Goliszek et al., 2011).

Species of this family suck the sap from aboveground plant parts, causing premature drying and falling of leaves, drying of twigs, and the whole plant may decay due to long-term and continuous feeding (Japoshvili et al., 2008). In addition, Coccidae secrete large amounts of honeydew, which is a suitable substrate for development of sooty mold. As a result, photosynthesis and transpiration in plants are reduced, and plants look unsightly and dirty, spoiling their aesthetic value as ornamentals, and accelerating their decay (Basheer et al., 2011).

According to literature data, the family Coccidae includes over 1,230 species, 16 of which belong to the genus *Parthenolecanium* (García-Morales et al., 2016). In Serbia, the family Coccidae is represented with 17 species, and the genus *Parthenolecanium* with five species

(Kozarževskaja & Vlainić, 1982; Dervišević, 2019). Certain species of this genus occasionally start overpopulating when they cause significant damage to plant production. Thus, the European fruit lecanium, *P. corni*, is an important pest of grapevines in Croatia and Portugal (Masten-Milek et al., 2007; Silva et al., 2016), and it has also been recorded on many fruit species in Poland and Turkey, where it can cause minor or major damage (Tartanus et al., 2023; Gülmez et al., 2023). *P. corni* is one of the most common scales inhabiting ornamental plants in urban environments (Johnson & Lyon, 1991). Significant damage has been recorded in Georgia and the USA on plants in the genera *Quercus* and *Fraxinus* (Hodges & Braman, 2004; Japoshvili et al., 2008; Robayo-Comacho, 2015). In Turkey, *P. rufulum* has been registered as a significant pest of hazel (Saruhan & Tuncer, 2001) and oak in urban areas (Ülgentürk & Çanakçıoğlu, 2004).

In Serbia, *P. corni* was the most harmful species in fruit orchards and forest stands until the mid-20th century (Mitić-Mužina, 1960; Mitić-Mužina, 1964), while the peach scale, *P. persicae*, was registered as a grapevine pest (Graora et al., 2012). Studies of this group of insects in urban areas are few and date from about 40 years ago when data on host plants and the biology of scales were reported for *P. corni*, *P. pomeranicum*, *P. rufulum*, and *P. fletcheri* (Kozarževskaja & Vlainić, 1982).

Considering that there is no detailed literature on *Parthenolecanium* species on forest and ornamental plants in Serbia, the need for a comprehensive study of these insects has arisen. Therefore, this work aimed to determine the distribution of these species in Serbia, to study their life cycle, host plants, infestation intensity, and symptoms of damage in urban areas.

MATERIALS AND METHODS

The study of soft scales from the genus *Parthenolecanium* were executed from 2014 to 2017 in the field and in the Laboratory of Entomology and Agricultural Zoology of the Faculty of Agriculture in Belgrade, Serbia.

To determine the presence and distribution of scales, the material was sampled from 22 locations in Serbia: Ada Ciganlija (44°47′30″N, 20°24′45″E), Aranđelovac (44°18’28”N, 20°33’07”E), Banjica (44°46′18″N, 20°28′16″E), Bežanijska kosa (44°49′50″N, 20°22′31″E), Blok 45 (44°47′48″N, 20°22′45″E), Galenika (44°51’27”N, 20°21’54”E), Čukarica (44°41′30″N, 20°23′50″E), Konjarnik (44°46′54″N, 20°30′31″E), Kosmaj (44°28′17″N, 20°34′32″E), Košutnjak (44°45′53″N, 20°26′11″E), Novi Beograd (44°49′11″N, 20°23′56″E), Pančevo (44°51′53″N, 20°39′23″E), Radmilovac (44°45′15″N, 20°34′59″E), Svilajnac (44°13′54″N, 21°11′32″E), Topola (44°14’25”N, 20°40’47”E), Ušće (44°49′36″N, 20°26′13″E), Voždovac (44°46’25.8”N, 20°28’17.6”E), Vračar (44°47′51″N, 20°28′35″E), Zemun (44°50′26″N, 20°24′31″E), Zemun Polje (44°52′19″N, 20°19′27″E), Zvezdara (44°46′36″N, 20°31′56″E), Žagubica (44°11′51″N, 21°47′18″E).

Methods of visual examination of plants were determined, infested plant material was sampled from parks and tree rows, and infestation intensity and damage symptoms evaluated. The intensity of scale attacks on plants was assessed according to the Borchsenius (1963) scale. The life cycle of scales was monitored in different locations and on different host plants. Thus, the development of *P. corni* on *Ulmus minor* was monitored (location Radmilovac), *P. fletcheri* on *Thuja occidentalis* var. Tiny-Tim (location Pančevo), *P. pomeranicum* on *Taxus baccata* (location Svilajnac), and *P. rufulum* on *Quercus robur* (location Ada Ciganlija). Throughout the year, plant material was sampled at intervals of 7 to 10 days during the vegetation season and once a month during vegetative rest. Five two-year or one-year old twigs of 20 cm length were collected from each infested plant. The twigs were packed in labeled plastic bags with detailed information on the sampling location, date, and host plant, and then stored in a fridge until further examination in the laboratory.

The sampled plant material was examined in the laboratory, permanent microscopic slides were made, and the soft scales were reared and identified. To analyze their morphological characters, permanent microscopic slides of females were made according to the relevant method of Kosztarab and Kozár (1988), and species were identified based on the keys of Gill (1988), Kosztarab & Kozár (1988), and Stepaniuk & Łagowska (2006).

To rear the scales, the sampled twigs with scale colonies were placed in glass cylinders covered with dense synthetic mesh. The time and number of eggs laid, and duration of embryonic and post-embryonic development of scales on twigs were examined daily. The average number of eggs laid by females per species was determined based on counting the eggs of 10 females.

RESULTS

During the three-year research in urban areas in Serbia, four *Parthenolecanium* species were registered: *Parthenolecanium corni* (Bouché) (Figure 1), *Parthenolecanium fletcheri* (Cockerell) (Figure 2), *Parthenolecanium pomeranicum* (Kawecki) (Figure 3), and *Parthenolecanium rufulum* (Cockerell) (Figure 4).

Figure 1. Females of *P. corni* (orig.)

Figure 2. Female of *P. fletcheri* (orig.)

Figure 3. Females of *P. pomeranicum* (orig.)

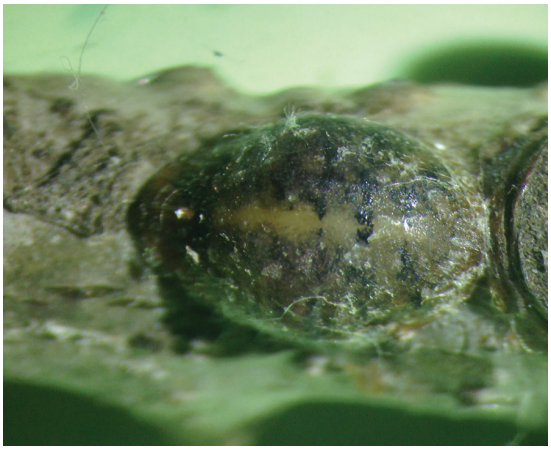

Figure 4. Female of *P. rufulum* (orig.)

Life cycle of *Parthenolecanium* species

All four identified species develop one generation per year and overwinter as second-instar nymphs on host twigs. They reproduce by gamogenesis or parthenogenesis. Since the life cycle of the four species was very similar during the three-year research, while the timing of emergence of all development stages differed by no more than a few days per year, the obtained results are presented only for the year 2017.

P. corni reproduces by gamogenesis. During development, females pass through two nymphal stages, while males go through prepupal and pupal stages in addition to two nymphal stages. In the spring, the overwintering second-instar nymphs (Figure 5) become active and resume feeding. They usually concentrate around leaf buds on younger twigs. The nymphs of future males form a wax covering to undergo prepupal and pupal transformation underneath. The appearance of prepupae (Figure 6) was recorded in mid-March, and pupae at the end of March. Males (Figure 7) ecloded in the first decade of April. After intensive feeding, the nymphs of future females molted to become females (Figure 8). Females were found to appear in the first decade of April, 3-4 days after the eclosion of males (Table 1). Females laid an average of 924.3±14.1 eggs (Figure 9). After embryonic development, which lasted about 20 days, first-instar nymph hatching (Figure 10) was recorded in mid-May. The hatched nymphs remained under the scales of females for a variable period of time before leaving and moving to young twigs and leaves to feed during the summer months. Second-instar nymphs formed at the end of August, and fed until October, when they usually retreat to tree forks or cracks on thicker branches to overwinter.

P. fletcheri, *P. pomeranicum*, and *P. rufulum* reproduce by parthenogenesis. Overwintering second-instar nymphs feed intensively in the spring, especially on young twigs whose bark is thin and juicy, thus significantly increasing their body size, and after molting, they form females. The appearance of *P. rufulum* and *P. pomeranicum* females was noted in April and *P. fletcheri* in early May (Table 1). The females started oviposition in May, and the number of eggs laid depended on scale species. On the average, the highest number of eggs was recorded in *P. pomeranicum* (1001.1±3.7), followed by *P. rufulum* (694.6±19.8), and *P. fletcheri* (350.3±4.1). First-instar nymphs hatched after 3-4 weeks, which is the duration of embryonic development. During the summer months, from June to August, they sucked plant sap, usually on the apical, young parts of the host plants. In September, they formed second-instar nymphs which continued feeding until the beginning of October, when they migrated to thicker branches to overwinter.

Table 1. The life cycle of *Parthenolecanium* species in Serbia in 2017

Development stage	Species				
	P. corni		*P. fletcheri*	*P. pomeranicum*	*P. rufulum*
	Female development	Male development			
prepupa	-	15.03.	-	-	-
pupa	-	27.03.	-	-	-
male	-	07.04.	-	-	-
female	10.04.	-	03.05.	29.04.	10.04.
eggs	25.04.	25.04.	18.05.	16.05.	03.05.
N_1	16.05.	16.05.	14.06.	12.06.	02.06.
N_2	27.08.	27.08.	12.09.	14.09.	03.09.

N_1 – first-instar („crawler")
N_2 – second-instar

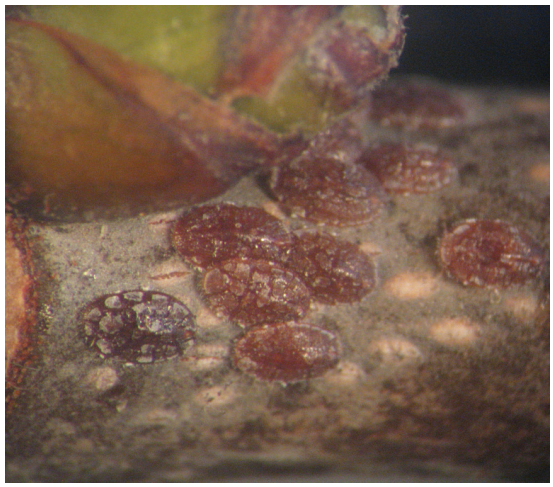

Figure 5. Overwintering second-instar nymphs of *P. corni* (orig.)

Figure 6. Prepupa of *P. corni* (orig.)

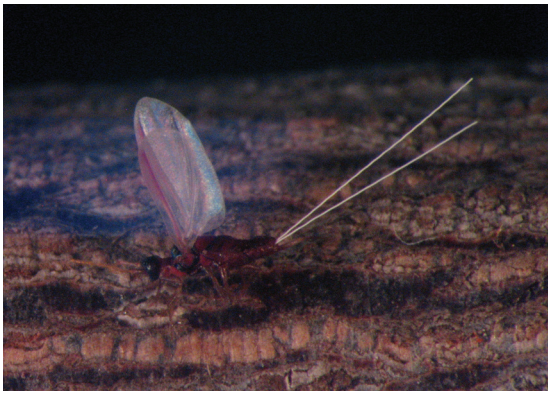

Figure 7. Male of *P. corni* (orig.)

Figure 8. Females of *P. corni* (orig.)

Figure 9. Eggs of *P. corni* (orig.)

Figure 10. First-instar nymph of *P. corni* (orig.)

Distribution, host plants, infestation intensity, and damage symptoms of *Parthenolecanium* species in Serbia

Soft scales of the genus *Parthenolecanium* were recorded in Serbia on 22 locations and 20 host plants (Table 2).

P. corni was the most widespread species, infesting the largest number of host plants. It was detected on 14 locations and 18 plant species, of which 8 species, *Buxus sempervirens*, *Celtis australis*, *C. occidentalis*, *Rosmarinus officinalis*, *Styphnolobium japonicum*, *Syringa vulgaris*, *Tilia cordata* and *Tilia tomentosa*, were new hosts of this scale insect in Serbia.

P. fletcheri was registered on *Thuja occidentalis* on three locations. Also, this species was found on *Taxus baccata* L. (Kosmaj location), which is a new host in Serbia.

P. pomeranicum was identified only on *Taxus baccata* on the location Svilajnac.

P. rufulum was found on nine locations on *Quercus robur*. This species was also found on *Ulmus minor* (Ada Ciganlija location).

The listed species of soft scales most often inhabit woody and shrubby plants and occur much less on herbaceous plants. The intensity of attack on infested plants ranged from 1 to 4, i.e. from individual specimens being found on a plant to an entire plant being covered with colonies.

In cases where individual specimens and small colonies of scales were found (infestation intensity 1 and 2), the plants had no visible damage symptoms. On the other hand, when numerous scale colonies were found (infestation intensity 3 and 4) (Figures 11-12), symptoms of yellowing and falling of leaves, weak growth of shoots, and drying of individual twigs were observed. The presence of honeydew and sooty mold further impaired the aesthetic appearance of plants.

The greatest damage was recorded in Radmilovac, where the attack of *P. corni* caused branches of *Ulmus minor* to dry up, and in Ada Ciganlija, where an attack of *P. rufulum* caused the drying of individual branches of *Q. robur*. Similarly, *Thuja occidentalis* plants in Pančevo were found to have dirty appearance due to a strong infestation of *P. fletcheri* and the presence of sooty mold, which reduced their aesthetic value.

Table 2. Host plants, distribution, and infestation intensity of *Parthenolecanium* species in Serbia

Scale insects	Host Plant	Location	Infestation intensity
P. corni	*Acer negundo*	Bežanijska kosa	2
		Zemun	3-4
	Acer pseudoplatanus	Ada Ciganlija	3-4
		Aranđelovac	1-2
		Banjica	2-3
		Novi Beograd	3
		Topola	1-2
		Ušće	3-4
		Zemun Polje	3-4
	Aesculus hippocastanm	Blok 45	1-2
		Novi Beograd	1-2
	*Buxus sempervirens**	Žagubica	1
	Carpinus betulus	Zemun	4
	*Celtis australis**	Novi Beograd	1
	*Celtis occidentalis**	Novi Beograd	1
	Cercis siliquastrum	Novi Beograd	2
	Cornus sanquinea	Radmilovac	1-2
	Fraxinus excelsior	Zemun	3-4
	Prunus cerasus	Žagubica	1
	*Rosmarinus officinalis**	Bežanijska kosa	2
		Voždovac	1
	*Styphnolobium japonicum**	Blok 45	3-4
	*Syringa vulgaris**	Blok 45	1
		Galenika	1
	*Tilia cordata**	Novi Beograd	3-4
	*Tilia tomentosa**	Zemun	3-4
	Ulmus minor	Radmilovac	3-4
	Quercus robur	Ušće	1
P. fletcheri	*Taxus baccata**	Kosmaj	3-4
	Thuja occidentalis	Novi Beograd	1-2
		Zvezdara	1-2
		Pančevo	3-4
P. pomeranicum	*Taxus baccata*	Svilajnac	1-2
P. rufulum	*Quercus robur*	Ada Ciganlija	3-4
		Čukarica	1
		Konjarnik	1
		Kosmaj	1
		Košutnjak	3-4
		Novi Beograd	1
		Voždovac	1
		Vračar	3-4
		Zemun	3-4
	Ulmus minor	Ada Ciganlija	1

*plants first identified as hosts of species in the genus *Parthenolecanium* in Serbia

Figure 11. Colony of *P. corni* on *T. tomentosa* (orig.)

Figure 12. Colony of *P. rufulum* on *Q. robur* (orig.)

DISCUSSION

Four species of the genus *Parthenolecanium* were identified in urban areas in Serbia: *P. corni*, *P. fletcheri*, *P. pomeranicum*, and *P. rufulum*. All of them develop one generation annually and overwinter as second-instar nymphs on twigs of their host plant. *P. corni* reproduces by gamogenesis, while *P. fletcheri*, *P. pomeranicum*, and *P. rufulum* reproduce by parthenogenesis. Data about the number of generations and the way of overwintering of soft scales are similar in most European countries (Kosztarab & Kozár, 1988; Ülgentürk et al., 2008). An exception is *P. corni*, which has been found to develop two generations on vines in Croatia and on peaches in Pennsylvania (Kosztarab, 1996; Masten-Milek et al., 2007). In Serbia, *Parthenolecanium* species are univoltine (Kozarževskaja & Vlainić, 1982; Graora et al., 2012), although *P. corni* can also develop a second generation on acacia (Mitić-Mužina, 1960).

The genus *Parthenolecanium* includes mainly polyphagous and less often monophagous species, which inhabit primarily perennial woody and shrubby plants. In the course of this study, four species of scales were found on 20 plants. *P. corni* was found on 8 new hosts, and *P. fletcheri* on one new host. In a previous research study in Serbia, *P. corni* was detected on plants from at least 13 plant genera, *P. rufulum* on 9 plant genera, and *P. fletcheri* and *P. pomeranicum* on one plant species each (Kozarževskaja & Vlainić, 1982).

P. corni, *P. fletcheri,* and *P. rufulum* were found in the present research to cause infestation intensity 3 and 4, resulting in the drying of branches and decay of individual ornamental plants.

There are similar data on the harmfulness of these species in urban areas in other European countries. Thus, *P. rufulum* is a significant pest of *Quercus* sp. in Georgia (Japoshvili, 2001), *P. corni* is the most abundant and economically important scale species on ornamentals in Poland (Goliszek et al., 2011), and *P. pomeranicum* is the most abundant species in Turkey (Ülgentürk et al., 2008). In England, *P. pomeranicum* was a serious pest of *Taxus baccata* in the 1930s. After that period, the species lost its importance, probably due to the actions of natural enemies (Malumphy et al., 2011). *P. fletcheri* has been recorded in the US as a pest of ornamental plants in the genera *Thuja* and *Taxus*, while in Europe, it does not cause significant damage. In some countries, such as Great Britain, this species occasionally forms numerous colonies on ornamental plants in urban areas without causing visible symptoms of damage (Malumphy, 2011).

CONCLUSION

In urban areas, plants grow under challenging conditions outside their natural habitats and are therefore more susceptible to harmful effects of many abiotic and biotic factors. Many of their pests are soft scales, which occasionally form dense colonies on plants. Considerable harmfulness of these species is due to their polyphagy, high fecundity, and ecological plasticity. As chemical control measures are rarely applied against these pests in urban areas, further research should focus on studying the complex of natural enemies and their role in regulating the abundance of *Parthenolecanium* soft scale species.

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Vrste roda *Parthenolecanium* (Hemiptera: Coccidae) u urbanim sredinama u Srbiji

REZIME

U urbanim sredinama u Srbiji registrovane su četiri vrste štitastih vaši iz roda *Parthenolecanium*, i to: *Parthenolecanium corni*, *P. fletcheri*, *P. pomeranicum* i *P. rufulum*. Sve utvrđene vrste razvijaju jednu generaciju godišnje i prezimljavaju u stadijumu larve drugog stupnja na grančicama domaćina. *P. corni* se razmnožava gamogenezom, dok se ostale vrste razmnožavaju partenogenezom. Utvrđene vrste zabeležene su na području Srbije u 22 lokaliteta na 20 biljaka domaćina, pri čemu je *P. corni* utvrđena na 8 novih biljaka domaćina, a *P. fletheri* na jednom novom domaćinu. Intenzitet napada vaši kao i simptomi oštećenja na infestiranim biljkama su se razlikovali. Na pojedinim drvenastim i žbunastim biljkama, vrste *P. corni*, *P. fletcheri* i *P. rufulum*, su obrazovale brojne kolonije prouzrokujući sušenje grana i propadanje pojedinačnih biljaka.

Ključne reči: štitaste vaši, *Parthenolecanium*, gradsko zelenilo, ukrasne biljke, Srbija