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The Biology of *Exechesops foliatus* Frieser, 1995 (Coleoptera, Curculionoidea, Anthribidae) in the European Part of Its Range

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Abstract—The life cycle, host plants, distribution, and economic importance of *Exechesops foliatus* Frieser, 1995 in the European part of its range was studied. The species has a one-year generation. Its larvae feed and develop in the seeds of *Acer tataricum* and *A. ginnala*. Adult beetles are active from early June to mid-August, and oviposition continues from late June to early July. Larvae develop from the end of June to mid-August; late instar larvae hibernate, and pupation begins in May of the following year. From 1.5 to 97.0% of maple seeds were damaged. No parasites were found but up to 25% of the weevil larvae were infested with predatory mites of the genus *Pyemotes*, with 1 to 15 mites per larva.

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Fungus weevils belong to the family Anthribidae (Curculionoidea, Coleoptera) that is best represented in the subtropical and tropical areas. To date, 77 species of this family have been recorded in the fauna of Russia, most of them in the Far Eastern region (Egorov, 1996; Legalov, 2009, 2011). The family is insufficiently studied in European Russia, with faunistic records available only for some administrative regions (Vlasov, 2003; Tsurikov, 2009; Kovalenko, 2010; Nikitskii and Korotyaev, 2010). No reviews of the fungus weevils of the fauna of Ukraine have been published either. According to the data of Yunakov and co-authors (2018), the presence of 25 species of Anthribidae in the territory of Ukraine has been confirmed. One of the species recently found in Ukraine is *Exechesops foliatus* Frieser, 1995 (Fig. 1), whose biology has not been specially studied. The goal of this work was to characterize the life cycle, host plants, distribution, and pest status of this species.

Adults were collected by net-sweeping of the crowns of the Tatarian maple *Acer tataricum* and the Amur maple *Acer ginnala*, and also by shaking the weevils off branches onto a cloth sheet. The infestation intensity was determined using samples of at least 200 maple samaras from each of the studied localities. To assess the species' biology, no less than 200 samaras were collected monthly from July to November off a group of model maple trees in Amvrosievskoe Forestry (Amvrosievka). Samples were taken every ten days during the first month after the recorded onset of oviposition, and every month afterwards: 6.VII.2015, 13.VII.2015, 23.VII.2015, 4.VIII.2015, 21.VIII.2015, 9.IX.2015, 11.X.2015, and 19.XI.2015. In 2016, the biology of *E. foliatus* was studied in the territory of the Donetsk Botanical Garden; the samples were taken on 16.VI.2016, 21.VI.2016, 24.VI.2016, 28.VI.2016, 30.VI.2016, 7.VII.2016, 21.VII.2016, and 6.IX.2016. Eggs, larvae, and pupae were preserved in 96% ethanol for later examination. To determine the overwintering stage, maple samaras were collected after the setting of stable below-zero temperatures in November, in particular on 19.XI.2015. Some of the infested seeds were kept in cages in an unheated room, and some, in the heated laboratory. To determine the rate of infestation of weevil larvae with *Pyemotes* mites, maple samaras were collected in winter and dissected in the laboratory immediately after collection. The larvae leaving the samaras were placed in 0.5-l plastic containers half-filled with soil collected under the model plants off which the samaras had been sampled. The eggs, larvae, and pupae were examined using Carl Zeiss Stemi 2000-C stereomicroscope.

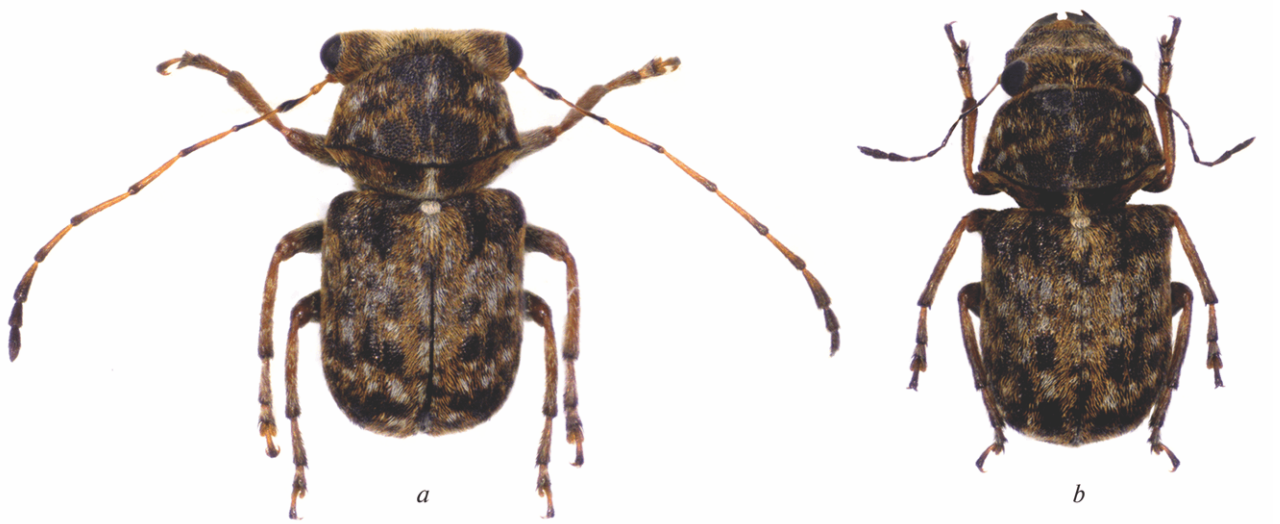

Fig. 1. *Exechesops foliatus*, adults, habitus: (*a*) male; (*b*) female.

The number of larval instars was determined based on the height and width of the head capsule. Measurements were made using ZEN 2012 software in images obtained with the Axiocam ER digital microscope camera.

MATERIAL

Donetsk Prov., Donetsk, arboretum of Donetsk Botanical Garden: 3 ♂♂, 2 ♀♀, 11.VII.2015, T.V. Nikulina; 5 ♂♂, 5 ♀♀, 21.VII.2016, V.V. Martynov; Artemovsky Distr., env. of Dronovka: 1 ♀, 25.VI.2000, M.E. Sergeev; 2 ♂♂, 27.VII.2002, V.V. Martynov; ravine forest, on *Acer tataricum*: 1 ♂, 2 ♀♀, 25.VI.2011, V.V. Martynov; to light: 1 ♂, 26.VI.2011, V.V. Martynov; Amvrosievka Distr., env. of Rodniki, ravine forest, on *Acer tataricum*: 16 ♀♀, 12 ♂♂, 06.VII.2015, V.V. Martynov; Amvrosievka, forest belt in forestry base, on *Acer tataricum*: 19 ♂♂, 17 ♀♀, 05–07.VII.2015, V.V. Martynov; Novoazovsk Distr., env. of Sedovo, Krivaya Kosa: 1 ♀, 16.VII.2015, V.V. Martynov; Khomutovskaya Steppe Nature Reserve, late instar larvae and pupa in seeds of *Acer tataricum*, 11.V.2016, V.V. Martynov; Yasinovatsky Distr., env. of Yasinovataya, ravine forest, net-sweeping: 1 ♂, 06.VI.2011, M.E. Sergeev; 1 ♀, 11.VI.2011, M.E. Sergeev; Krasnoliman Distr., Torskoe: 2 ♀♀, 28.VI.2008, M.E. Sergeev; Slavyansk Distr., env. of Bogorodichnoe: 1 ♂, 09.VIII.2002, V.V. Martynov; 2 ♀♀, 10.VIII.2002, M.E. Sergeev; 3 ♂, 2 ♀♀, 27.VI.2010, M.E. Sergeev. **Lugansk Prov.,** Lugansk, Ostraya Mogila, late instar larvae in seeds of *Acer tataricum*: 27.IX.2016, V.V. Martynov; Stanichno-Lugansky Distr., Kondrashevskaya Novaya station: 1 ♀, 02.VI.2001, M.E. Sergeev, 1 ♂, 18.VI.2001, M.E. Sergeev; 1 ♀, 26.VI.2005, V.V. Martynov; Stanichno-Lugansky Reserve: 2 ♂♂, 06.VI.2000, V.V. Martynov; Pridontsovskaya Poyma Reserve: 1 ♂, 1 ♀, 02.VI.2001, A.G. Maltseva; 1 ♀, 17.VI.2001, M.E. Sergeev; 1 ♂, 1 ♀, 18.VI.2001, M.E. Sergeev; 1 ♂, 01.VI.2002, V.V. Martynov; Sverdlovsky Distr., Provalskaya Steppe Reserve, ravine forest: 3 ♂♂, 4 ♀♀, 20.VI.2002, T.A. Pisarenko; 3 ♂♂, 2 ♀♀, 22.VI.2002, V.V. Martynov; 1 ♂, 29.VI.2005, A.G. Maltseva; env. of Provalie, 2 ♂♂, 1 ♀, 20.VI.2003, M.E. Sergeev. **Rostov Prov.,** Millerovsky Distr., env. of Olkhovyi Rog, ravine forest, *Acer tataricum*: 11 ♂♂, 14 ♀♀, 19.VII.2017, V.V. Martynov; Kasharsky Distr., env. of Kamenka, ravine forest, *Acer tataricum*: 8 ♂♂, 7 ♀♀, 20.VII.2017, T.V. Nikulina.

DISTRIBUTION

Asia: the Russian Far East (Amur Prov., Primorskii Territory and south of Khabarovsk Territory), NE China (Egorov, 1996; Legalov, 2010, 2011); Europe: European Russia: Belgorod, Lipetsk, Voronezh, and Saratov provinces (Tsurikov, 2009; Kovalenko, 2010, 2012; Zabaluev, 2012), Rostov Prov.; Ukraine: Poltava, Kharkov, and Lugansk provinces (Yunakov and Terekhova, 2012), Donetsk Prov. (Martynov and Nikulina, 2016). In the territory of Donbass, *E. foliatus* is widespread and common in the bottomland forests of the Severski Donets River, ravine forests, planted forests of the Donetsky Kryazh hill range, and urban greenery areas. It is still not clear whether *E. foliatus*

Table 1. Phenology of *Exechesops foliatus* in Donbass

Stage	April	May			June			July			August			September		
	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
L_3																
L_4																
Pupa																
Adult																
Egg																
L_1																
L_2																
L_3																
L_4																

is a relict or an invasive species in Europe. In the opinion of Kovalenko (2012), the fairly wide distribution of the species in East Europe and its preference for natural biotopes may indicate the relict status of the European part of its range. However, according to our data, high rates of infestation of Tatarian maple seeds in the territory of Donbass were recorded both in natural forests (up to 97.0%) and in planted stands (up to 91.0%).

HOST PLANTS

The Amur maple *Acer ginnala* was indicated as the host plant of *E. foliatus* in the Asian part of its range (Egorov, 1996). This weevil was first recorded for the fauna of Ukraine under the erroneous name *E. leucopis* (Jordan, 1928), and its hosts were supposed to be plants of the silver bells family (Styracaceae), namely *Styrax japonica* Siebold & Zucc. and *S. obassia* Siebold & Zucc., and also the maple *Acer ginnala* (Aceraceae) (Yunakov and Terekhova, 2012). This record was evidently a mistake since the Styracaceae are host plants of *E. leucopis* but not of *E. foliatus*. Besides, *Acer tataricum* and *A. campestre* were also assumed to be host plants of the latter species in European Russia and Ukraine (Yunakov and Terekhova, 2012; Zabaluev, 2012). According to our observations, in the European part of its range *E. foliatus* develops in the seeds of the Tatarian maple *Acer tataricum* and the Amur maple *Acer ginnala* (Martynov and Nikulina, 2016).

BIOLOGY

Adults of *E. foliatus* are active from early June to the middle of August. The peak of flight activity was observed in late June and early July and coincided with mating and the beginning of oviposition (Table 1).

During oviposition the female gnaws out a rounded hole up to 1 mm in diameter in the wall of the new (current-year) samara near the wing base (Fig. 2*a*) without damaging the main veins and lays from 1 to 3 eggs on the seed or on the inner pericarp surface (Fig. 2*b*). The egg is oval, 0.56–0.72 (0.68) mm long and 0.22–0.33 (0.28) mm wide (n = 20), with white, semi-translucent, smooth chorion (Fig. 2*c*). Clutches with a single egg prevailed, comprising 75% of the total number, clutches with 2 eggs made up 20%, and those with 3 eggs, no more than 5% (n = 97). The seed proper was never damaged by the female. The injured plant tissues turned black, and the sites of oviposition were clearly visible on the samara surface; the hole was filled with solidified secretion (Fig. 2*a*). Only one clutch per samara was observed in most cases (n = 99), less frequently, two clutches occurred at the base and at the apex of the pericarp (n = 1). Mortality at the egg stage reached 21%.

Females could also lay eggs into dry samaras that remained on the tree from the previous year (Fig. 2*d*). The method of oviposition was the same as in the case of fresh samaras but 60% of eggs in such clutches died of desiccation within several days. The successfully hatched I instar larvae perished before or during the initial stage of penetration into the seed (37%). Besides, dead II instar larvae were occasionally recorded (3%). Successful completion of the life cycle in the dry seed is hardly possible. The biological significance of this phenomenon is unknown, especially since no shortage of infestable samaras was observed and the

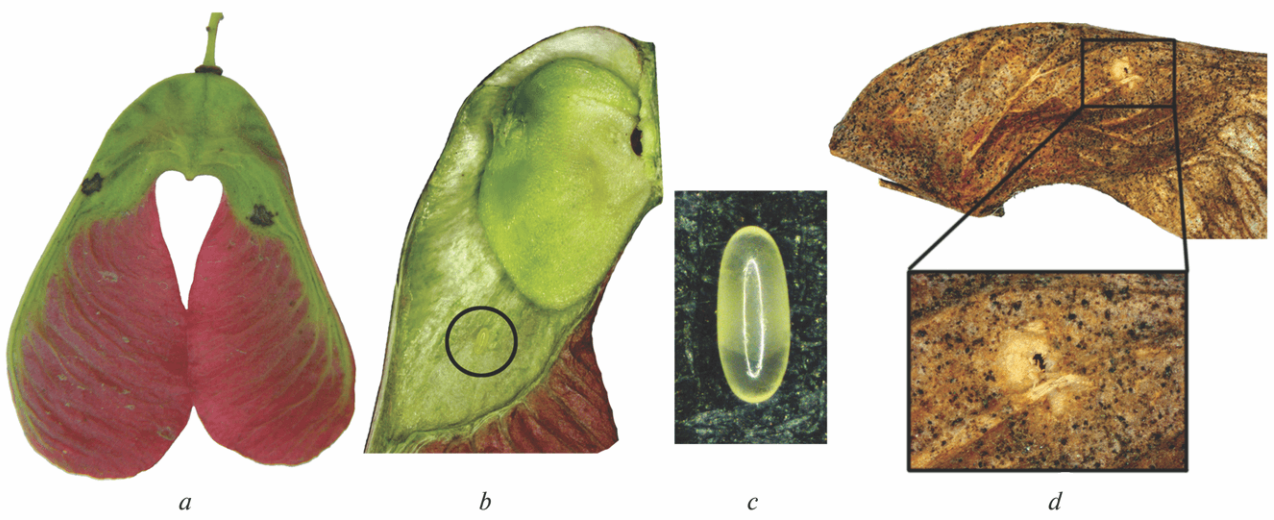

Fig. 2. Oviposition of *Exechesops foliatus*: (*a*) traces of oviposition on the Tatarian maple samaras of the current year; (*b*) position of the egg; the upper valve of the fruit is removed; (*c*) total view of the egg; (*d*) traces of oviposition on the samara of the previous year.

Fig. 3. Exit holes of *Exechesops foliatus*: (*a*) made by the adult; (*b*) made by the late instar larva.

presence of an earlier clutch did not prevent other females from laying eggs on the same samara.

Eggs and I instar larvae were found from late June (21.VI.2016) to mid-July (15.VII.2015) (Table 1). During early development (the I instar), each seed contained several larvae corresponding to the initial number of eggs laid (1 to 3), but only one of these larvae completed development. The larvae molt three times during summer, reach the IV instar by the end of August, and overwinter at this stage. However, judging by the size of the head capsule, some larvae may overwinter at the III instar. Dissection of maple seeds in late autumn (November) showed that the larvae were in diapause; their intestines were empty while the seed had been consumed by no more than 50–60%. The overwintered larvae actively gnaw through the walls of the larval chamber, prepare the exit tunnel for the adult, and make the cocoon but do not extend into the pericarp. Some larvae leave the samara through an exit hole that is different in shape from the imaginal one (Fig. 3*b*). During our laboratory observations, none of the larvae was able to complete metamorphosis outside the seed (n = 18). The biological significance of this phenomenon remains obscure, but we

Table 2. Intensity of infestation of *Acer tataricum* and *Acer ginnala* seeds in the studied localities

Locality		Host plant	Date of survey	Seed infestation, % (n = 200)
Donetsk Province				
Amvrosievka District, Rodniki		*Acer tataricum*	7.VII.2015	95.5
Amvrosievka, forestry base		*A. tataricum*	8.VII.2015	79.5
Donetsk, Ilyicha Prospect, "Motel"		*A. tataricum*	10.VII.2015	40.0
Donetsk Botanical Garden, arboretum		*A. tataricum*	15.XII.2015	34.5
		A. ginnala	15.XII.2015	25.5
Telmanovsky District, Kalinino		*A. tataricum*	10.VII.2016	1.5
Donetsk Botanical Garden, northern tract		*A. tataricum*	6.IX.2016	76.5
Amvrosievka, forestry base		*A. tataricum*	11.V.2016	37.5
Lugansk Province				
Lugansk, Ostraya Mogila	sample 1	*A. tataricum*	27.IX.2016	91.0
	sample 2	*A. tataricum*	27.IX.2016	26.0
Rostov Province				
Millerovsky District, Olkhovyi Rog	ravine forest	*A. tataricum*	19.VII.2017	97.0
	edge of ravine forest	*A. tataricum*	19.VII.2017	91.5
Kasharsky District, Kamenka, ravine forest		*A. tataricum*	20.VII.2017	15.0

n is the number of seeds in the sample.

also observed similar behavior in the larvae of the seed beetle *Acanthoscelides pallidipennis* (Motschulsky, 1873) (Coleoptera, Chrysomelidae, Bruchinae).

Pupae were recorded from the beginning to the end of May. Adult weevils exit the samaras though rounded holes with uneven margins (Fig. 3*a*). The first adults appeared in early June, which phenologically corresponded to the end of flowering and the beginning of samara formation in the Tatarian maple.

PREDATORS AND PARASITES

Dissection of maple seeds during winter revealed a considerable level of infestation (25%; n = 100) of the weevil larvae with predatory mites of the genus *Pyemotes* (family Pyemotidae). The integuments of the infested larvae turned pale yellow and lost their pearly sheen; the larvae lost the body turgor, shrank, and died. Infestation intensity varied from 1 to 15 mites per larva. No mites were recorded on the larvae during spring and summer.

DAMAGE CAUSED BY THE PEST

The developing larva consumes 50–60% of the maple seed volume and makes its germination impossible; thus, at high infestation rates the weevil can considerably reduce seed regeneration of the Tatarian maple. In our material, the infestation rate of *A. tataricum* seeds reached 79.5% in planted stands of Amvrosievskoe Forestry, 97.0% in a ravine forest in Olkhovyi Rog (Rostov Prov., Millerovsky Distr.) (Table 2), and 40.0% in roadside plantings in Donetsk.

It should be noted that *E. foliatus* has a distinctly aggregated pattern of distribution, so that the seed infestation intensity may vary considerably between neighboring trees even under the same biotopic conditions. For example, in maples planted within the sanitary zone of Lugansk this parameter varied from 26.0 to 91.0% (Martynov et al., 2016).

The Tatarian maple is one of the dominant tree species forming a special class of maple-oak associations, Querceta acerosa (tatarici), which are widely distributed in the south of the forest-steppe and within the forb-fescue-feathergrass steppes of East Europe (Shelyag-Sosonko, 1974). Since *E. foliatus* is a specialized phytophage capable of reducing seed regeneration of the Tatarian maple, an increase in the abundance of this weevil may pose a serious threat to the whole forest ecosystem. Therefore, monitoring of *E. foliatus* populations should be established over the whole European part of its range.

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