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First records of *Erysiphe corylacearum* (*Erysiphales*, *Ascomycota*) on *Corylus avellana* in Ukraine

Vasyl P. HELUTA¹, Nataliya V. MAKARENKO², Galeb A. AL-MAALI¹

¹M.G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine
2 Tereshchenkivska Str., Kyiv 01004, Ukraine
vheluta@botany.kiev.ua

²M.M. Gryshko National Botanical Garden, National Academy of Sciences of Ukraine
1 Tymiryazevska Str., Kyiv 01014, Ukraine
mmnv@ukr.net

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Abstract. Information on the records of a new adventive powdery mildew fungus *Erysiphe corylacearum* (*Erysiphales*, *Ascomycota*) in Ukraine is provided. The fungus was found on *Corylus avellana* (*Betulaceae*) in Kyiv, as well as in Crimea. Current distribution of this species outside its primary range is analyzed. It has been shown that the fungus came to Ukraine from the East through the Caucasus. Ukrainian specimens were compared with samples collected in the Far East of Russia. It was found that Ukrainian specimens have slightly larger chasmothecia, somewhat more numerous asci, which are slightly more elongated and often short stalked. It is noted that the fungus has a great invasive potential and in the future can cause considerable damage to the forestry of European countries. The article is illustrated with micrographs obtained under light and scanning electron microscopes.

Keywords: alien species, *Erysiphe corylicola*, hazelnut, invasion, powdery mildew

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Гелюта В.П.¹, Макаренко Н.В.², Аль-Маалі Г.А.¹ 2019. **Перші знахідки *Erysiphe corylacearum* (*Erysiphales*, *Ascomycota*) на *Corylus avellana* в Україні.** *Український ботанічний журнал*, 76(3): 252–259.

¹Інститут ботаніки ім. М.Г. Холодного НАН України
вул. Терещенківська 2, Київ 01004, Україна

²Національний ботанічний сад ім. М.М. Гришка НАН України
вул. Тимірязевська 1, Київ 01014, Україна

Реферат. Наводиться інформація про знахідки в Україні нового адвентивного борошністоросяного гриба *Erysiphe corylacearum* (*Erysiphales*, *Ascomycota*). Гриб виявлено на *Corylus avellana* (*Betulaceae*) у м. Києві, а також в Криму. Аналізується новітнє поширення цього виду поза межами його первинного ареалу. Показано, що грибок потрапив в Україну зі Сходу через Кавказ. Порівнюються українські матеріали зі зразками, зібраними на Далекому Сході Росії. Встановлено, що вони мають дещо більші хазмотеції, більшу кількість сумок, останні більш витягнуті, частіше на маленькій ніжці. Зазначається, що грибок має значний інвазійний потенціал і в майбутньому може завдавати помітної шкоди лісовому господарству європейських країн. Стаття проілюстрована зображеннями, отриманими за допомогою світлового та скануючого електронного мікроскопів.

Ключові слова: адвентивний вид, борошніста роса, інвазія, ліщина, *Erysiphe corylicola*

Introduction

The list of powdery mildews (*Erysiphales*, *Ascomycota*) in Ukraine is being continuously expanded both through the study of complex species and their subsequent splitting, as well as through the migration to Europe of the alien representatives of this order,

primarily from North America and East Asia. Thus, for example, within the species complex *Golovinomyces cichoracearum* (DC.) Heluta, a several segregate species have been proposed (Cook, Braun, 2009; Braun, Cook, 2012), of which *G. ambrosiae* (Schwein.) U.Braun & R.T.A.Cook, *G. asterum* (Schwein.) U.Braun,

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G. inulae U.Braun & H.D.Shin, *G. macrocarpus* (Speer) U.Braun, *G. senecionis* U.Braun, *G. sonchicola* U.Braun & R.T.A.Cook, and *G. spadiceus* (Berk. & M.A.Curtis) U.Braun are also recorded in Ukraine. In less than two decades of the 21st century, such species as *Erysiphe azaleae* (U.Braun) U.Braun & S.Takam. (Heluta et al., 2004a), *E. elevata* (Burrill) U.Braun & S.Takam. (Heluta et al., 2009a), *E. flexuosa* (Peck) U.Braun & S.Takam. (Heluta, Voytyuk, 2004), *E. platani* (Howe) U.Braun & S.Takam. (Heluta et al., 2013), *E. salmonii* (Syd. & P.Syd.) U. Braun & S.Takam. (Heluta et al., 2017), *E. symphoricarpi* (Howe) U.Braun & S.Takam. (Heluta et al., 2016b), *Golovinomyces greeneanus* (U.Braun) Heluta (Heluta, Korytnianska, 2011) and *Podosphaera amelanchieris* Maurizio (Heluta, Hirylovich, 2016) have been introduced to Ukraine from North America, but on the other hand, *E. kenjiana* (Homma) U.Braun & S.Takam. (Heluta et al., 2009b), *E. macleayae* R.Y.Zheng & G.Q.Chen (Heluta, Kravchuk, 2015; Heluta et al., 2016a), *E. magnifica* (U.Braun) U.Braun & S.Takam. (Palahecha, Chumak, 2011), *E. syringae-japonicae* (U. Braun) U.Braun & S.Takam. (Seko et al., 2008, 2011), *Neoerysiphe geranii* (Y.Nomura) U.Braun (Heluta, 2001; Heluta et al., 2010) and *Podosphaera parietariae* (Schwarzman) U.Braun & S.Takam. (Heluta et al., 2004b) originated from East and Central Asia. Nowadays, the process of expansion of the species diversity of powdery mildews continues. In this paper, we report another new alien (adventive) species in Ukraine, *Erysiphe corylacearum* U.Braun & S.Takam. found by the authors in 2017 and 2018 (two localities) on *Corylus avellana* L. (*Betulaceae*) in Kyiv.

Materials and methods

In 2017, during the survey of ornamental plantings in the M.M. Gryshko National Botanical Garden, National Academy of Sciences of Ukraine, the authors of the article collected leaves of *Corylus avellana* amphigenously infected with powdery mildew. Almost simultaneously, similar specimens were collected in another locality, in the courtyard of M.G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine, where this plant has been cultivated for many years as ornamental. For comparison, samples of *Erysiphe corylacearum* from the Far East of the Russian Federation were also examined. They were collected by the first author in late September – early October 1989 near Vladivostok and in Kedrovaya Pad Nature Reserve on *Corylus heterophylla*, which is a typical host plant for this powdery mildew fungus. To study the

fungus, herbarium materials were used. Samples for light microscopy were prepared by standard methods in distilled water. However, in order to restore the original shape and size of conidia, they were put in a droplet of 40% lactic acid solution on a microscope slide, covered with a cover glass, gently heated to boiling point, then studied and photographed under a light microscope "Primo Star" (Carl Zeiss, Germany) with the camera "Canon A 300" and the software "AxioVision 4.7". The SEM micrographs were obtained with a Jeol JSM–6060LA (Tokyo, Japan) scanning electron microscope (SEM). Dry pieces of leaf with mycelium and ascomata were glued to metallic stubs and sputter-coated with gold under vacuum. The obtained digital data were processed statistically. For each morphological feature, 30 structures were measured. Limits of variation were determined as $M \pm 1.96 \sigma$, where M is a simple average and σ is a standard deviation. The specimens were deposited at KW-M (abbreviation according to *Index Herbariorum*, <http://sweetgum.nybg.org/science/ih/>) and in personal mycological herbarium of N.V. Makarenko (M.M. Gryshko National Botanical Garden, National Academy of Sciences of Ukraine).

Results and discussion

Common hazel (*Corylus avellana* L.) is naturally distributed throughout Ukraine and in other European countries, in Asia Minor, and in northern Iran. This plant is widely used in forestry as an underwood species in forest stands. In addition, it is grown as an ornamental crop in botanical gardens and parks of settlements. Hazelnuts are used for food (Kokhno et al., 1986; Kosenko, 2002; Slyusarchuk, 2005).

In Ukraine, common hazel is very often infected by powdery mildew caused by *Phyllactinia guttata* (Wallr.) Lév. Mycelium of this fungus develops initially endophytically, in the leaf mesophyll. Only at the end of summer, through stomata, it grows out to the lower surface of the leaf. Right here the mycelium forms the conidial stage of the fungus, and later produces fruiting bodies known as chasmothecia. In these two stages, the fungus is easily detected, since it forms large, grayish spots that can merge into one continuous mycelial layer. Obviously, this disease does not cause significant damage to the host, as it develops intensively only in the autumn, at the end of plant vegetation. However, examining the green plantations of the M.M. Gryshko National Botanic Garden of the National Academy of Sciences of Ukraine, we discovered the common hazel bush with the leaves affected by a powdery mildew on

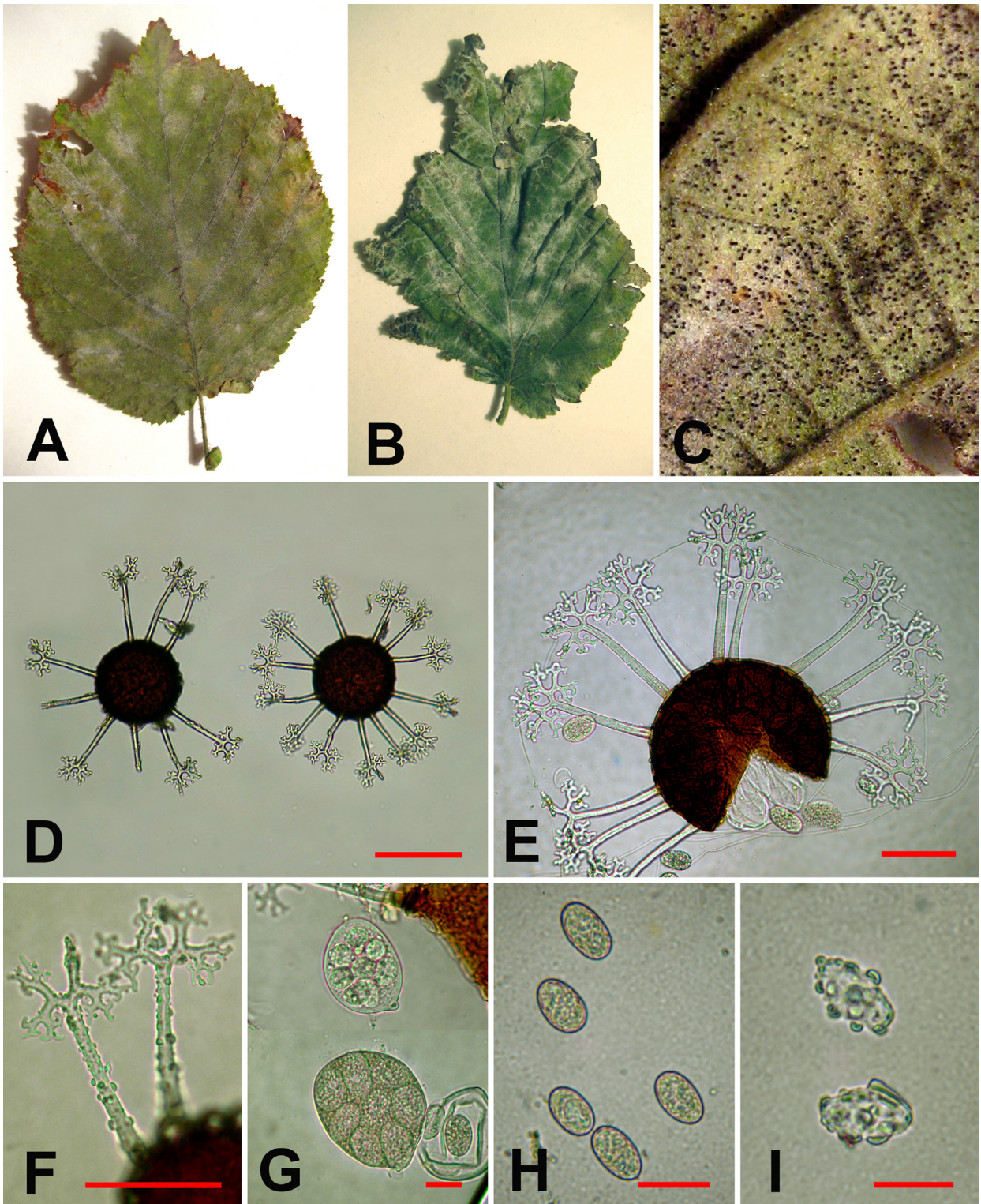


Fig. 1. *Erysiphe corylacearum* on *Corylus avellana*. A, B: infected leaves; C: chasmothecia on the underside of the leaf; D, E: chasmothecia with appendages; F: appendages after heating in a solution of lactic acid; G: asci (the lower ascus is flattened by a cover glass); H: ascospores; I: conidia after heating in a solution of lactic acid. Bars: 100 μm (D), 50 μm (E–F), 20 μm (G–I)

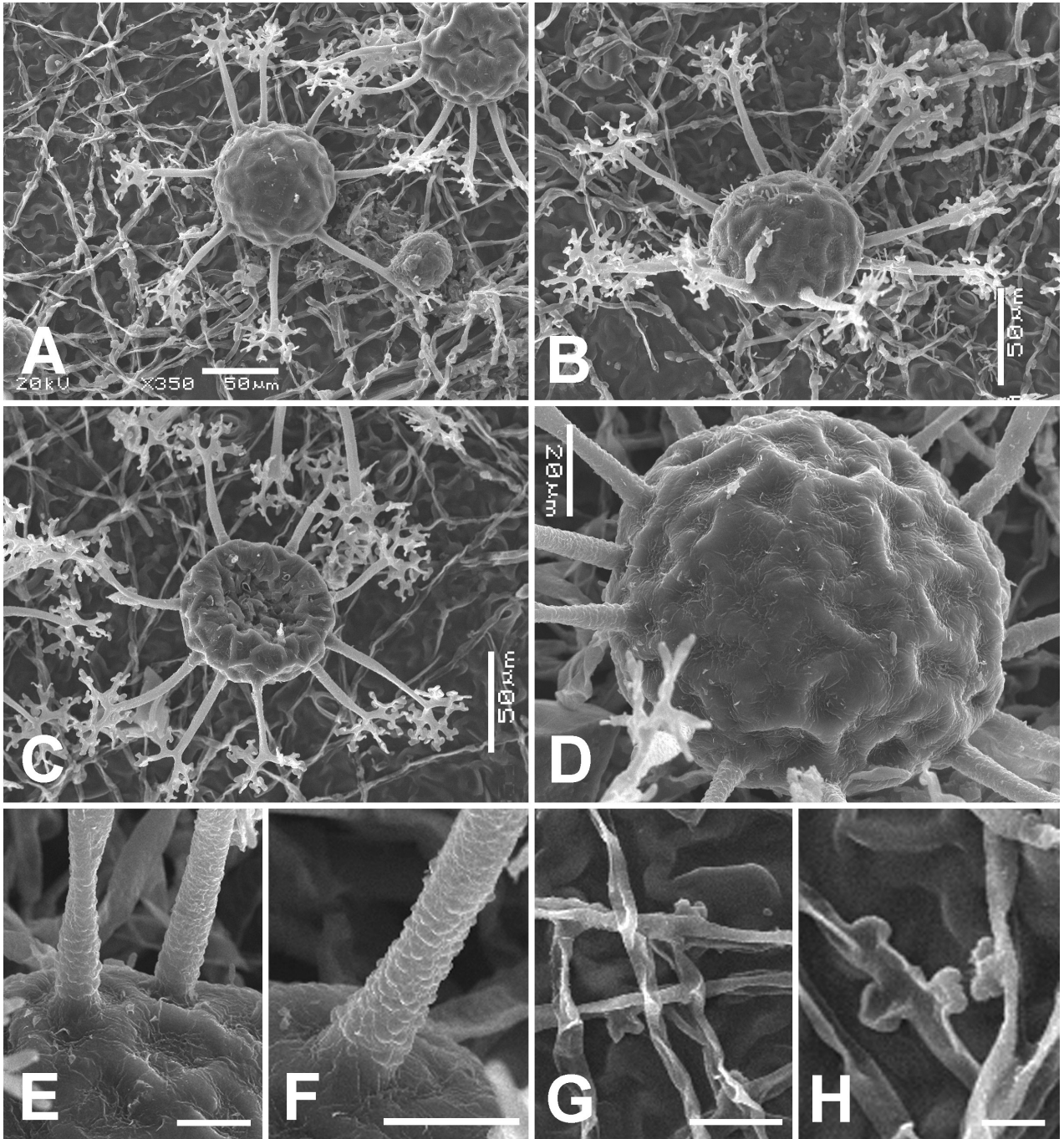


Fig. 2. *Erysiphe corylacearum* on *Corylus avellana* (SEM). A–C: chasmothecia with appendages, view from different angles (A: top view, B: slightly side view, C: bottom view); D: surface of the chasmothecium; E–F: basal parts of the appendages; G–H: mycelial hyphae with lobed (G) and unlobed (H) appressoria. Bars: 50 μm (A–C), 20 μm (D), 10 μm (E–H)

both sides (Fig. 1, A–C). It immediately became clear that we found another fungus causing this disease, still unknown in Ukraine. In a microscopic study, it was found that fruit bodies of the fungus have appendages with dichotomously branched apices and several asci in the chasmothecium (Fig. 1, D, E; 2, A–C). Thus, the species belongs to the section *Microsphaera* (Lév.) U.Braun & Shishkoff of the genus *Erysiphe* R.Hedw. ex DC., and it was identified as *E. corylacearum*. Below is a description of the material we have collected.

***Erysiphe corylacearum* U.Braun & S.Takam.**, in Braun, Schlechtendalia 8: 33. 2002 (Fig. 1, 2).

Syn.: *Microsphaera penicillata* f. *coryli* Jacz., Karm. opred. gribov. Vyp. 2. Muchnisto-rosianye griby. Leningrad: 350. 1927. – *Microsphaera coryli* (Jacz.) Golovin, Trudy Bot. inst. Akad. nauk SSSR, ser. 2, vyp. 10: 336. 1956, nom. illeg. – *Microsphaera hommae* U.Braun, Mycotaxon 15: 124. 1982. – *Erysiphe hommae* (U.Braun) U.Braun & S.Takam., Schlechtendalia 4: 9. 2000, nom. illeg.

Mycelium amphigenous, grayish, forming mostly indistinct, sometimes white, rather clear patches, on the lower side of the leaves less developed. Hyphae 4.0–6.5 µm thick, hyphal appressoria mostly solitary or occasionally in opposite pairs, simple or lobed. Conidia doliform, limoniiform, short, 20–29 × 10–16 µm, formed singly. Chasmothecia scattered to gregarious, hemispherical, depressed in the lower part, 82–113 µm in diam. Peridial cells polygonal, rounded, not very distinct, about 10–20 µm in diam. Appendages 6–14, equatorial, straight, short (0.6–1.2 times as long as the chasmothecial diam.), about 6.5–8.0 µm near the base and 4.5–6 µm in the apical part, colourless, more or less rough, aseptate, sometimes at the base dichotomously branched, apices 3–5 times densely and regularly branched, tips recurved. Asci 3–7, broadly-ellipsoid, obovoid, 44–55 × 33–41 µm, mostly sessile or on a very short stalk (up to 6.5 µm), 6–8-spored. Ascospores ellipsoidal, ovoid, 17–21 × 10.0–14.5, colourless.

Specimens examined. On *Corylus avellana* L.: Kyiv, M.M. Gryshko National Botanical Garden, 22.09.2017, V. Heluta, N. Makarenko (KW-M71165M); ibidem, 10.11.2017, N. Makarenko (KW-M71167M); 28 Velyka Zhytomyrska Str., courtyard of M.G. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine, 26.09.2017, G. Al-Maali (KW-M71172M). On *C. heterophylla* Fisch. ex Trautv.: Russian Federation, Primorsky Krai, outskirts of Vladivostok, coast of Lazurnaya Bay (Shamora), 26.09.1989, V. Heluta (KW-M71168M); Primorsky Krai, Khasan District,

Kedrovaya Pad Reserve, 02.10.1989, V. Heluta (KW-M71170M).

A comparison of the characteristics of the fungus collected on *C. avellana* in Ukraine with those in the description of *E. corylacearum*, as provided in the monograph by U. Braun and R. Cook (2012), shows that Ukrainian specimens are entirely within the range of variation of this species. We also compared these specimens with the samples collected in 1989 by the first author in the territory of the primary range of this species. As a result, it turned out that the Ukrainian and Far Eastern materials are slightly different according to some characters. Samples from Ukraine had somewhat larger fruit bodies, therefore, the ratio of the appendage length and the diameter of the chasmothecium varied and the appendages seemed to be shorter. In addition, we observed larger number of asci in the fruit body (3–7 instead of 2–4) and their slightly different shape: asci were slightly elongated and almost all of them had a short stalk (Fig. 1, G). When heated in a solution of lactic acid, conidia and stems of the appendages of *E. corylacearum* are covered with well-visible bubbles (Fig. 1, F, I). This phenomenon was observed only in a number of species of the genus *Leveillula* G.Arnaud.

Erysiphe corylacearum has long been known in North America, where it was considered a part of the huge complex *Microsphaera penicillata* s.l. (Salmon, 1900). This fungus as a separate taxon was obviously first mentioned by A.A. Jaczewski (1927), who considered it as *M. penicillata* f. *coryli* Jacz. Later P.M. Golovin (1956), based on this form, proposed a new species-rank combination, *Microsphaera coryli* (Jacz.) Golovin. However, this combination was illegitimate, since at that time under the same name a morphologically different powdery mildew has already been described, namely *Microsphaera coryli* Homma, found in Japan on *Corylus heterophylla*. That is why U. Braun (1982), based on the Japanese specimen, validly described the fungus we report in this article, as *M. hommae*. Over time, due to the results of molecular phylogenetic studies, the genus *Microsphaera* Lév. was included in *Erysiphe* and a new combination *E. hommae* (U.Braun) U.Braun & S.Takam was proposed (Braun, Takamatsu, 2000). However, this combination also proved to be illegitimate, since at that time under the same name another powdery mildew fungus, *Erysiphe hommae* U.Braun, parasitizing a host from the *Lamiaceae* has been already described. In view of the above, for the fungus parasitizing hazel, a new name *E. corylacearum* U.Braun & S.Takam. has been proposed (Braun, 2002). Almost until recently, this

species was known in North America (Canada, USA) and Asia (China, Korea, Far East of Russia, Japan) on a number of species of the genus *Corylus* L., but *C. avellana* was not listed among the host plants (Braun, Cook, 2012). Thus, *E. corylacearum* is an East Asian-North American fungus by its origin.

As previously noted (Heluta et al., 2016b), alien species of powdery mildews enter the territory of Ukraine by different pathways. North American fungi migrate through Western Europe, and East Asian species from the opposite direction. As for *E. corylacearum*, we have a unique case, since it is at the same time an East Asian and a North American species. So, the question arises, where and how has this powdery mildew got to Ukraine?

Due to analysis of literature information, it becomes clear that over the past few years *E. corylacearum* has gone beyond its original range. In 2013, the fungus was recorded in Turkey (Sezer et al., 2017), in 2016 in Azerbaijan (Abasova et al., 2018), in 2017 in Iran (Arzanlou et al., 2018). It was noted that in Turkey, this powdery mildew spread very quickly in the Black Sea regions and now it causes significant damage to host plants. A similar pattern is observed in Iran, where the damage to plants is also significant. The fungus is found there in the provinces of Ardebil and Eastern Azerbaijan, which adjoin Azerbaijan and are located near Turkey. It is also reported that in 2016 *E. corylacearum* was found in Bakhchysaray District of the Autonomous Republic of Crimea (Ukraine), and from 2017 it is recorded in the north of Krasnodar and Rostov regions of Russia (Bulgakov, 2018). It is worth noting that the first three articles mentioned are well illustrated, the species was identified using molecular methods, and therefore it is undoubtedly the same fungus. Thus, over the large area we observe the invasion of the East Asian-North American powdery mildew fungus *E. corylacearum*.

In addition, there are several reports (Churakov et al., 2014, 2015; Khuseyin et al., 2014; Karpun et al., 2016) of the finds, also outside of the range, of another parasite of hazel, *E. corylicola* U. Braun & S. Takam. The fungus was reported from Turkey and the Russian Federation (two records in Ulyanovsk Region and extensive development in Adler, Krasnodar Region). However, taking into account that this species is endemic in Japan, its records beyond the native range should be considered extremely unlikely. Obviously, the materials on which these reports were based were incorrectly identified. Unfortunately, the authors did not give any description or illustrations of the collected

samples. However, Adler is not far from Azerbaijan and Turkey, and the distance from Adler to Ulyanovsk is not critical for distribution of powdery mildew fungi. Therefore, it is much more likely that in all cases the authors dealt with *E. corylacearum*, and not with *E. corylicola*. In any case, since representatives of the genus *Erysiphe* on hazelnut have not yet been recorded in the western part of Ukraine, we come to the conclusion that *E. corylacearum* migrated to Ukraine from the eastern or southeastern direction, through the Caucasus.

At present, we know only three localities of *E. corylacearum* in Ukraine. Additional search for this fungus in Kyiv and adjacent regions were unsuccessful. However, in accordance with the epiphytotic nature of the development of *E. corylacearum* in Iran and Turkey, we should expect a significant spread of powdery mildew of hazel in Ukraine.

Thus, another alien powdery mildew fungus with a high invasive potential, *E. corylacearum*, is recorded in Europe. The spread and development of this species can cause significant damage to ornamental plantations and lead to large losses on farms producing hazelnuts.

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