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The first records of *Bartheletia paradoxa* (*Bartheletiomycetes, Agaricomycotina*) in Ukraine

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Hayova V.P., Tykhonenko Yu.Ya. **The first records of *Bartheletia paradoxa* (*Bartheletiomycetes*, *Agaricomycotina*) in Ukraine.** Ukr. Bot. J., 2017, 74(6): 578–581.

Abstract. A new for Ukraine basidiomycete fungus, *Bartheletia paradoxa*, strictly confined to leaves of *Ginkgo biloba*, is reported. The species was collected on fallen leaves of *G. biloba* in November 2016 and 2017 in three localities within Kyiv city. Both conidial and telial stages were found. Morphological descriptions of conidial sori, conidia, secondary conidia, telia and teliospores are provided. More data on phenology of the fungus is added. Information about distribution of *B. paradoxa* is considered. To date, the species is known from several countries in Europe as well as from Korea and Japan in East Asia. Described from outside of the ancient distribution area of the host plant, *B. paradoxa* has not yet been reported within the presumptive native range of *Ginkgo* in China. Moreover, despite wide cultivation of *G. biloba* globally, this quite conspicuous fungus has not yet been recorded in some mycologically rather well studied regions, like North America or New Zealand. The article is illustrated by original micrographs.

Keywords: *Ginkgo biloba*, basidiomycete, morphology, phenology, distribution

Introduction

Bartheletia paradoxa G. Arnaud ex Scheuer, R. Bauer, M. Lutz, Stabenth., Melnik & Grube was briefly described in 1954 (Arnaud, 1954) based on collection made by Jean Jules Barthelet on leaves of *Ginkgo biloba* L. in France in 1932. However, the species was not validly described as the description lacked a Latin diagnosis required for new taxa at that time. The first valid publication of the fungus was provided only in 2008 (Scheuer et al., 2008).

Bartheletia paradoxa is an enigmatic fungus with a unique set of characteristics. Unlike any other basidiomycete, it has very unusual septal structure. While in most basidiomycetes, the septa dividing cells within the hyphae are perforated by a large central pore, hyphal septa of *B. paradoxa* exhibit multiple tiny plasmodesma-like pores (Scheuer et al., 2008). Conidia of *B. paradoxa* are able to produce secondary conidia surprisingly resembling basidiospores of *Agaricomycetes* (Koukol, Lotz-Winter, 2016). Phylogenetic analyses suggested *B. paradoxa* as the most basal member of the *Agaricomycotina* (Scheuer et al., 2008; Mishra et al., 2017), but at the same time its resting spores are very similar to teliospores of the rust fungi. Another distinctive feature is that being apparently saprotrophic, *B. paradoxa* is a strictly host-specific and widespread fungal associate of *Ginkgo biloba*. Most probably, just like its host plant, the fungus is also a living fossil, which "apparently used *G. biloba* as its Noah's Ark" (Scheuer et al., 2008).

Due to its unique combination of characters and unresolved position at the base of the *Agaricomycotina*, *B. paradoxa* was first assigned to the family *Bartheletiaceae* within the *Agaricomycotina* (Scheuer et al., 2008) and recently the order *Bartheletiales* and the class *Bartheletiomycetes* were introduced (Mishra et al., 2017).

Here we report the first for Ukraine records of this remarkable fungus and provide some data on its morphology, occurrence and life cycle.

Materials and methods

Freshly fallen and rotting leaves were collected in Kyiv in November 2016 and 2017: under several ginkgo trees planted in the M.M. Gryshko National Botanical Garden and the O.V. Fomin Botanical Garden in the city centre, and under a solitary tree in Feofania suburb. Leaf

specimens were studied under a dissecting microscope, labelled and dried for further treatment. Conidia and teliospores mounted in water or lactic acid were investigated by light microscopy. Photomicrographs were taken under Primo Star microscope, Canon A300 digital camera and AxioVision 4.7 software, used as well for measurements of microstructures. For scanning electron microscopy, samples were covered with an ultrathin coating of gold by ion beam sputtering unit JFC-1100. Images were obtained by scanning electron microscope JEOL JSM-6060 LA.

The specimens are deposited in the Mycological Herbarium of the M.G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine (*KW-M*).

Results and discussion

A new for Ukraine fungus, *Bartheletia paradoxa*, was recorded on fallen leaves of *Ginkgo biloba* in November 2016 and 2017 in three localities in Kyiv. The description of conidial and telial stages, a list of all examined specimens in Ukraine and data on global distribution of this species are provided below. Original illustrations are followed by information on its morphology, phenology and general distribution.

Basidiomycota
Agaricomycotina
Bartheletiomycetes
Bartheletiales
Bartheletiaceae

Bartheletia paradoxa G. Arnaud ex Scheuer, R. Bauer, M. Lutz, Stabenth., Melnik & Grube, *Mycological Research* **112**: 1269–1270 (2008). – *Bartheletia paradoxa* G. Arnaud, *Bull. Trimestriel Soc. Mycol. France* **69**: 300 (1954) nom. inval.

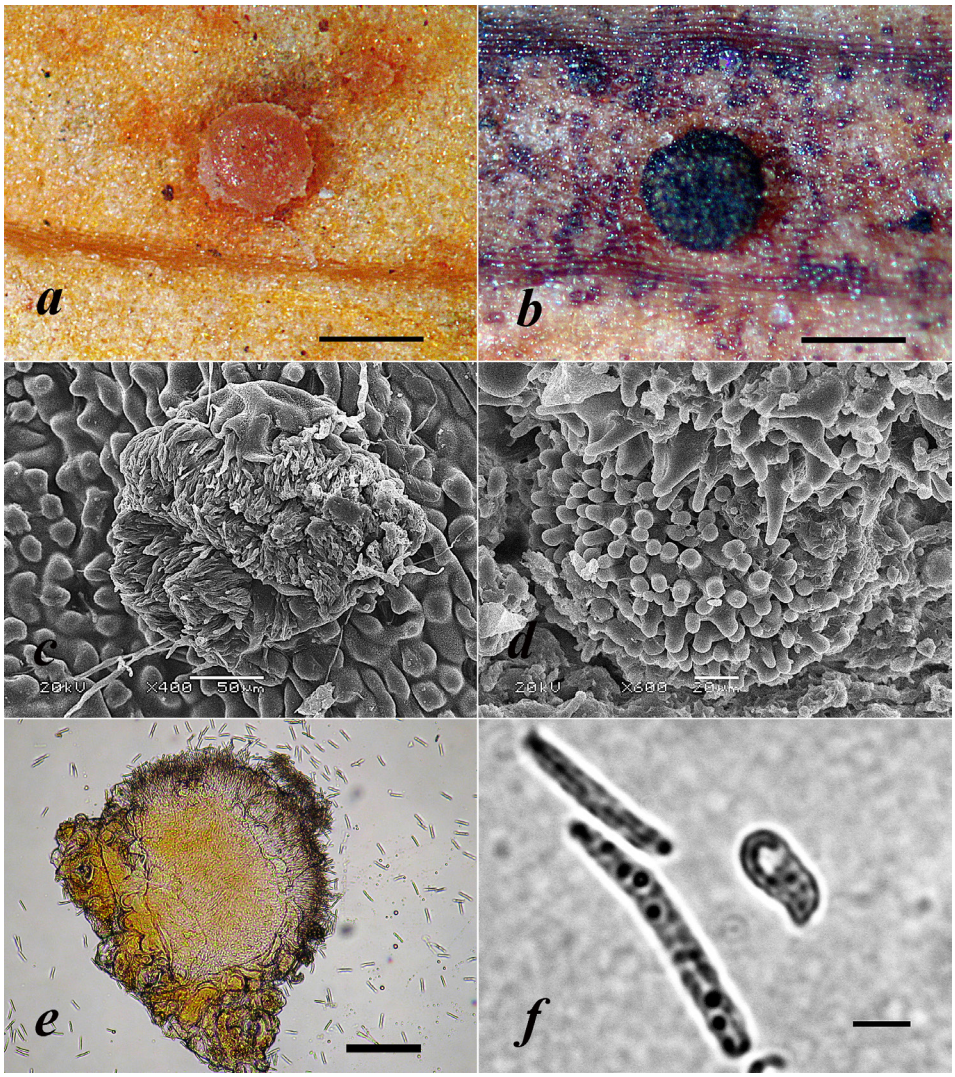
Foliicolous fungus, growing on fallen leaves. Conidial sori on freshly fallen leaves of the current year, slimy, ca 100–400 μm in diam. when dry (Fig., *a*, *c*, *e*). Conidiophores branched. Conidiogenous cells thin, holoblastic, terminal, or intercalary with one or two conidiogenous branches, unilocal with percurrent proliferation. Conidia hyaline, one-celled, straight, cylindrical-bacilliform or sometimes slightly broader below the middle, (15–)17–25(–28) × (2.5–)3(–3.5) μm (Fig., *f*), with a short attenuate base and minutely truncate scar, often with minute guttules. Conidia occasionally produce secondary conidia, superficially resembling basidiospores of agaricoid fungi, ovoid, up to 12 μm long and 6 μm wide, formed on a stalk of subterminal to submedial position, up to 10 μm high (Fig., *f*). Teliospores either single, immersed in the leaf tissues and more or less evenly dispersed (most conspicuous in the epidermis), or conglutinated in compact, erumpent and finally superficial telia (Fig., *b*). Telia single or arranged in circular groups, nearly always surrounded by a halo of solitary intraepidermal teliospores, similar to those of rust fungi, often developing from conidial sori, hemispherical or cushion-like to more or less spherical, the largest ones often more irregular and with a conspicuous depression in the centre, single or gregarious to confluent, 150–850(–1200) μm in diam. Solitary intramatrical teliospores in the epidermal cells or deeper in the leaf tissue, dispersed or somewhat agglomerated, spherical or broadly ellipsoidal to somewhat irregular in shape, brown, 25–40 μm in diam. Conglutinated teliospores in the telia thick-walled, dark brown to blackish brown, (35–)50–125(–140) × 12–30 μm, often with a bifid base, and usually with one protruding, conical to cylindrical cap-like wall thickening up to 25(–30) μm high at the apex (Fig., *d*), sometimes also with two thickenings.

Distribution in Ukraine. On freshly fallen and rotting leaves of *Ginkgo biloba*: Kyiv, M.M. Gryshko National Botanical Garden, 50° 24′ N, 30° 33′ E, 10.11.2016 (telia), V.P. Hayova (*KW-M* 70870), 9.11.2017 (conidiomata & telia), V.P. Hayova (*KW-M* 70872); O.V. Fomin Botanical Garden, 50° 26′ N, 30° 30′ E, 3.11. 2017 (conidiomata & telia), V.P. Hayova (*KW-M* 70871); Feofania suburb, 50° 20′ N, 30° 29′ E, 21.11. 2017, V.P. Heluta (*KW-M* 70880) (telia).

General distribution. Europe: Austria, Czech Republic, Denmark, France, Germany, Russia, Sweden, The Netherlands, Ukraine (current report), United Kingdom; Asia: Japan, Korea (Scheuer et al., 2008; Braun, 2009; Lotz-Winter et al., 2011; Kirschner, Okuda, 2013; Koukol, Lotz-Winter, 2016).

Bartheletia paradoxa appears to be a saprobe, rather than endophyte, although highly specific to its substrate. Its biology is still unclear but the fungus is assumed by Kirschner & Okuda (2013) as a pioneer colonizer of *Ginkgo* leaves at the initial stage of leaf litter decomposition.

Recently a new phenotypic phenomenon, formation of secondary conidia in *B. paradoxa*, was discovered (Koukol, Lotz-Winter, 2016). In our two specimens containing conidial sori, we also observed secondary conidia although they were not as numerous as reported for the specimens from the Czech Republic and Germany. Mature and detached secondary conidia resemble basidiospores of *Agaricomycetes* and, most probably, their prompt formation is to provide rapid colonization of freshly fallen leaves. Moreover, secondary conidia are formed apically on rather long stalks which



Bartheletia paradoxa: ***a*** – fragment of ginkgo leaf showing erumpent conidial sorus (scale bar = 0,2 mm); ***b*** – habit of single erumpent telium and numerous scattered intraepidermal teliospores (scale bar = 0,5 mm); ***c*** – scanning electron microscopy of conidial sorus showing conglutinated conidia (scale bar = 50 µm); ***d*** – scanning electron microscopy of two neighbouring telia showing teliospores with apical cap-like wall thickenings of various height, note the highest thickenings in the upper one (scale bar = 20 µm); ***e*** – light microscopy of conidial sorus (scale bar = 100 µm); ***f*** – light microscopy of two primary and one secondary conidia (scale bar = 5 µm).

may also contribute to dispersal over greater distances by rain-splash or air current. Secondary conidia enhance reproductive potential in the conditions of very short period of asexual reproduction.

Phenology of *B. paradoxa* is very distinctive. *Bartheletia* infects only freshly fallen leaves of the current year so that infection may happen just after the leaves have dropped. Up to now, no signs of any symptoms were found on living leaves still attached to the tree. It is suggested that spores may be transferred from the remnants of rotten leaves of the preceding year lying on the ground. Once infection does happen, the growth of *Bartheletia* is extremely rapid. The developing conidial sori erupt through the leaf surface, producing copious conidia and secondary conidia, and very soon they are gradually replaced by teliospores and telia originated from the same basal cushions. The erumpent and finally superficial telia are surrounded by scattered solitary thick-wall teliospores, submerged below the cuticle. The entire cycle from teliospore germination to teliospore maturity can be over in as little as two weeks. The teliospores remain dormant the following winter through summer and eventually germinate to produce basidia in autumn shortly before the leaves are shed.

In our first observations made in very early November, only a small part of freshly fallen leaves exhibited some symptoms of colonization while in a few days conidial sori were abundant. Our specimens collected in the first decade of November 2017 contain both conidiomata and telia; those collected in late November – only telia. Interestingly, in our collections of early November 2016 we do not observe any conidiomata as they have already been totally replaced by telia. Thus, development of both stages varies annually depending on climate conditions during the growing season, and more specifically, on the time when a tree sheds its leaves. During November, the fungus was found under each ginkgo tree we observed as they all had accumulated leaf litter of the preceding year.

According to currently known records, *Bartheletia paradoxa* has very uneven global distribution, although *Ginkgo biloba* is widely cultivated across the world. Described from outside of the ancient distribution area of the host plant in 1932, the fungus was subsequently recorded only in the 21st century in ten European countries as well as in Korea and Japan in East Asia. However, the species has not yet been reported within the presumptive native range of *Ginkgo* in China. Moreover, despite wide cultivation of *G. biloba* globally, *B. paradoxa* has not yet been recorded in some mycologically rather well studied regions, like North America or New Zealand. Since the species does not really belong to inconspicuous fungi, particularly due to its long lasting telial stage, it remains unclear why it remained undescribed until the mid-20th century and is still overlooked despite its widespread nature.

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Повідомляється про перші в Україні знахідки *Bartheletia paradoxa* на опалих листках *Ginkgo biloba* в трьох локалітетах у межах Києва в листопаді 2016 і 2017 рр. Знайдено конідіальну і теліальну стадії гриба. Наводяться морфологічні особливості конідіом, конідій, вторинних конідій, теліїв і теліоспор. На сьогодні цей вид відомий з декількох країн Європи та Східної Азії (Кореї та Японії). Незважаючи на широке культивування *Ginkgo biloba* у світі, *B. paradoxa* поки що не була відмічена ні в межах гаданого природного ареалу цієї рослини в Китаї, ні в таких мікологічно добре вивчених регіонах, як Північна Америка чи Нова Зеландія. Стаття ілюстрована оригінальними мікрофотографіями.

Ключові слова: *Ginkgo biloba*, базидіоміцет, поширення, морфологія, фенологія

Гаевая В.П., Тихоненко Ю.Я. **Первые находки *Bartheletia paradoxa* (*Bartheletiomycetes, Agaricomycotina*) в Украине**. Укр. бот. журн., 2017, 74(6): 578–581.

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Сообщается о находках *Bartheletia paradoxa* на опавших листьях *Ginkgo biloba* в трех локалитетах в Киеве в ноябре 2016 и 2017 гг. Найдены конидиальная и телиальная стадии гриба. Приводятся морфологические особенности конидиом, конидий, вторичных конидий, телиев и телиоспор. На сегодняшний день этот вид известен из нескольких стран Европы и Восточной Азии (Кореи и Японии). Несмотря на широкое культивирование *Ginkgo biloba* в мире, *B. paradoxa* пока не была отмечена ни в пределах вероятного природного ареала этого растения в Китае, ни в таких микологически хорошо изученных регионах, как Северная Америка или Новая Зеландия. Статья иллюстрирована оригинальными микрофотографиями.

Ключевые слова: *Ginkgo biloba*, базидиомицет, распространение, морфология, фенология