Turczaninowia 27, 4: 122–129 (2024)
DOI: 10.14258/turczaninowia.27.4.14
http://turczaninowia.asu.ru

ISSN 1560–7259 (print edition)
TURCZANINOWIA
ISSN 1560–7267 (online edition)

УДК 582.293.24:581.95(571)

Is *Leptotrema lithophila* (Graphidaceae, lichenized Ascomycota) still an endemic species of Sikhote-Alin' Range?

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Keywords: Alkhanai National Park, biodiversity, Khabarovsk Territory, new records, rare species, Red Data Book, relic species, Primorye Territory, South Siberia, temperate East Asia, Transbaikal Territory.

Summary. *Leptotrema lithophila*, the rare species being recognized as endemic for Sikhote-Alin' Mountain (Russian Far East), has been discovered for the South Siberia from the Transbaikal Territory. The species was found in a single locality – in the Alkhanai National Park, on isolated cliff named Dimchig Sume Mt. within the lower forest belt in rock's cleft in wet and shade micro condition. All known localities of *Leptotrema lithophila* are given including the first locality of the species from Khabarovsk Territory. The species is excluded from the lichen flora of the Kamchatka Territory. A comparison of the material from the main and peripheric parts of its distribution area, as well as ecology and illustrations for the species are given. In addition, the red-listed species *Coccocarpia erythroxyli* and *C. palmicola* are reported for the first time for Alkhanai National Park. Those species, as well as *Leptotrema lithophila*, are treated as relics of Paleogene-Neogene thermophilic mesogydrophilic flora. Taking into account the relict status of this rare species, *Leptotrema lithophila* is recommended for inclusion in the Red Data Book of Russia.

Является ли *Leptotrema lithophila* (Graphidaceae, лихенизированные Ascomycota) эндемиком хребта Сихоте-Алинь?

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Ключевые слова: биоразнообразие, Забайкальский край, Красная книга, национальный парк «Алханай», Приморский край, редкий вид, реликтовый вид, умеренная Восточная Азия, флористические находки, Хабаровский край, Южная Сибирь.

Аннотация. *Leptotrema lithophila*, редкий вид, описанный как эндемик гор Сихотэ-Алинь (Дальний Восток России), обнаружен в Южной Сибири в Забайкальском крае. Вид был найден в единственном местообитании – в национальном парке «Алханай», на изолированной скале Димчиг Суме в нижней части лесного пояса, в расщелине скалы, во влажных и затенённых микроусловиях. Приведены все известные местонахождения *Leptotrema lithophila*, включая первое местонахождение вида в Хабаровском крае. Вид исключён из флоры лишайников Камчатского края. Приводится сравнение материала из основной и периферийной частей ареала, а также распространение и экология; даются фотографии. Кроме того, для национального парка «Алханай» впервые приводятся краснокнижные виды *Coccocarpia erythroxyli* и *C. palmicola*, которые наряду с *Leptotrema lithophila*, являются реликтами палеоген-неогеновой термофильной мезогидрофильной флоры. Учитывая реликтовый статус этого редкого вида, *Leptotrema lithophila* рекомендован к включению в Красную книгу России.

Поступило в редакцию 08.11.2024
Принято к публикации 05.12.2024

Submitted 08.11.2024
Accepted 05.12.2024

Introduction

Leptotrema lithophila Oxner was described as endemic species of Sikhote-Alin' Range (southern part of the Russian Far East) based on two specimens collected on Tumannaya Mt. (Lazovsky Nature Reserve) and Kedrovaya Pad' Nature Reserve presently deposited in KW (Oxner, 1960). The species was also reported by Knyazheva (1973) from the southern part of the Primorye Territory. Tchabanenko (1990) cited *Leptotrema lithophila* from Lazovsky Nature Reserve based on holotype specimen data. Subsequently, the species was included to checklists for the southern part the Russian Far East by Tchabanenko (2002) and Urbanavichus (2010). The second collection of *Leptotrema lithophila* was made 50 years after its original description ca. 50 km to the NW from the *locus classicus* (Cherdantseva et al., 2013). Yakovchenko and Davydov found the species for the first time on the seacoast within middle Sikhote-Alin' Range in the Primorye Territory (Davydov et al., 2021a).

The species was recorded in the Kamchatka Territory by Mikulin (1988) and then was included in the Handbook of the lichens of Kamchatka (Mikulin, 1990). Basing on this record the species was subsequently listed in Urbanavichus (2010) for the northern part of the Russian Far East. The discovery of *Leptotrema lithophila* in Kamchatka had called into questions its status as the endemic species of Sikhote-Alin' Range. At the same time, the growth of the lichen from such tropical genus so much to the north caused some doubts since, firstly, Mikulin (1990) used the following characteristic for *Leptorema lithophila* as "the thallus is attached by the hyphae of medulla" whereas the thallus of *L. lithophila* soon partly flake away from the rocky substrate and has numerous thick branched root-like outgrowths on the lower cortex. In addition, this remarkable species was not found during over 15-years comprehensive study of lichens of Kamchatka (Himelbrant et al., 2009, 2019, 2021, 2023; Davydov et al., 2011, 2024a, b; Himelbrant, Stepanchikova, 2011; Stepanchikova, Himelbrant, 2011; Kotkova et al., 2023; Stepanchikova et al., 2023).

The Alkhanai National Park is located on the southern slope of the Mogoitui Ridge (Transbaikal Territory) with the highest point Alkhanai Mt. (elev. 1662 m). The territory is characterized by a distinct vertical zonality. The subalpine belt (above 1500 m a. s. l.) is confined to the top of Alkhanai Mt. *Pinus pumila* (Pall.) Regel and *Larix gmelinii* (Rupr.) Rupr. sparse growth are common within the belt. In the upper forest belt (1400–1500 m a. s. l.) the forests of *Pinus sibirica* Du Tour and *Larix gmelinii* with large-block boulders are common. *Picea obovata* Ledeb. is distributed along streams, springs and tributaries of the Ilya and Ureya Rivers. The bushes of *Betula* spp. and *Salix* spp. are abundant here. The forests of the lower forest belt (1000–1400 m a. s. l.) are formed by *Larix gmelinii*, *Betula platyphylla* Sukaczev, *Pinus sylvesrtis* L. and *Populus tremula* L. Within the forest-steppe zone (850–1000 m a. s. l.) the *Larix gmelinii* – *Betula platiphylla* forests are clearly confined to the slopes of the northern expositions, and the Dahurian prairies (Kamelin, 1987; Belikovich, Galanin, 2005) – to the slopes of the southern expositions. The checklist of lichens of the Alkhanai National Park includes 132 taxa from 60 genera (Yakovchenko, Galanina, 2009).

As a result of identification of herbarium material collected in 2009 from Alkhanai National Park, *Leptotrema lithophila* has been found in South Siberia where it is collected in a single locality on an isolated cliff within the lower forest belt in rock's cleft in wet and shaded micro conditions. The accompanying species, *Coccocarpia erythroxyli* (Spreng.) Swinscow et Krog and *C. palmicola* (Spreng.) Arv. et D. J. Galloway listed in the Red Data Book of Transbaikal Territory (Makryi, 2017) are reported here for the first time for Alkhanai National Park. The species is reported here for the first time for Khabarovsk Territory from the left bank of the Amur River. In addition, all known localities are given including full locality label data of the specimen reported by Cherdantseva et al. (2013) which regarded as closest locality to the *locus classicus*.

Materials and methods

The material for the study comprises four specimens collected by the author in 2009, 2011, 2012, and 2014 from Transbaikal, Khabarovsk and Primorye Territories and deposited in the Herbarium of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far Eastern Branch, Russian Academy of Sciences (VLA), the Herbarium of the Altai State University (ALTB) and the personal collection of the author. The review of the natural conditions of the Russian Far East and lichenological studies of the region is given in Davydov et al. (2021b). The specimens were examined using a stereomicroscope (Zeiss Stemi 2000-C) and a compound microscope (Zeiss Axio Lab.A1). Cross-sections of apothecia

and thalli were made by hand with razor blade and observed after mounting in water. Measurements of ascospores and apothecia are presented as: (extreme minimum)minimum–maximum(extreme maximum). Measurements of other parameters are given as maximum value observed. The measurements of anatomical structures were made to the nearest 0.5 μm. Number of measurements is given for ascospores and apothecia in brackets [*n*]. Terminology is given followed by Frisch et al. (2006) and Rivas Plata et al. (2010). Lichen substances were studied using spot tests with potassium hydroxide solution (K), sodium hypochlorite solution (C) and 1,4-p-phenylendiamine (PD), and by high performance thin-layer chromatography (TLC) with solvent systems A (toluene: 1,4-dioxane: acetic acid, 180 : 45 : 5), B′ (hexane: methyl tert-butyl ether: formic acid, 140 : 72 : 18) and C (toluene: acetic acid = 170 : 30) following Orange et al. (2001). Distance between locations measured using Google Earth (www.earth.google.com).

Results and Discussion

The diagnostic features of *Leptotrema lithophila* based on the South Siberian material are summarized by 1) crustose pale grey (brownish in herbarium), continuous, irregular thallus up to 5 cm long and 0.3–0.8 mm thick, soon partly flaking away from the substrate (Fig. 1), 2) presence of numerous inclusions of calcium oxalate crystals in the thallus, 3) *Trentepohlia* algae as photobiont, 4) beige to brownish lower surface with numerous root-like heavy-branched outgrowths, 5) sunken, rounded to irregular, pruinose myriotremoid- to lepadinoid-type apothecia, (0.1–)0.3–0.5(–0.6) mm in diam. [*n* = 15], 6) 8-spored asci with brown, ±ellipsoid submuriform to muriform ascospores, (20.5–)22.0–24.5(–26.5) × (9.5–)12.5–14.5 μm [*n* = 25], 7) lacking secondary metabolites detected by TLC, 8) growing on siliceous rocks in shaded situations, and 9) occurrence at elevation up to 1162 m a. s. l. within the lower forest belt.

Morphological features of the South Siberian specimen of *Leptotrema lithophila* agree well with the protologue (Oxner, 1960) and available description of the species (Piterans, 1975) as well as herbarium specimens of the species (Yakovchenko 1174, VLA!) collected by the author ca. 50 km NW from the *locus classicus* (Cherdantseva et al., 2013), however, apothecia and thallus thickness in South Siberian material are smaller – maximum value corresponds to the average value in material from the Russian Far East. In the region the species is morphologically resemble to some representatives of *Diploschistes* Norman (Graphidaceae) but not closely related and phenotypically differing mainly by the photobiont – trebouxioid in *Diploschistes* and trentepohlioid in *Leptotrema*.

In South Siberia *Leptorema lithophila* is known from the single locality where it occurs on siliceous rock massif Dimchig Sume Mt. (Alkhanai National Park) growing on rock and partly on mosses and humus at elevation 1162 m (Fig. 2). The species required the special microclimate conditions – wet hidey cleft in solitary rocks within forest belt on low elevation. The lower forest belt is characterized by wetter and warmer conditions in contrast to upper forest belt and steppe belt. The distribution and ecology of *Leptotrema lithophila* suggest its relic status in South Siberia – it is located in a very limited area strongly separated from the main population by large disjunction and grows in wet micro conditions on isolated rocks within forest belt on low elevation which can be considered as a refugium of the paleogen-neogen thermophilic mesohydrophilic flora. Other rare relic lichens, *Coccocarpia erythroxyli* and *C. palmicola* listed in the Red Book of Trans-Baikal Territory (Makryi, 2017), were found in Dimchig Sume Mt. These species also grow in wet micro conditions with mosses but occur in more exposed habitats on the silicate rock surface. These species are reported here for the first time for the Alkhanai National Park (Fig. 3).

We provide here the label data of the specimen collected by the author and reported by Cherdantseva et al. (2013) which is the closest collection of the species to the *locus classicus*. In addition, the species is reported here for the first time for the Khabarovsk Territory where it was found on rocks in wet rock crevice of cliffs. This locality is situated on the left bank of Amur River and does not belong to Sikhote Alin' Range strictly although is located very close. The distance between the most remote localities within southern part of the Russian Far East exceeds ca. 1000 km. The South Siberian locality is equidistant from the southernmost locality in the Primorye Territory and the locality in the Khabarovsk Territory and is ca. 1700 km. The locality from the Khabarovsk Territory is the northernmost since the record of the species in Kamchatka Territory (Mikulin, 1988, 1990) was not confirmed: three specimens from Kamchatka collected and identified as *Leptorema lithophila* by A. G. Mikulin deposited in VLA belong to genus *Diploschistes*.

Fig. 1. *Leptorema lithophila* habit in South Siberia: a – pale grey thallus of *Leptorema lithophila* growing on wet hidey rock cleft on Dimchig Sume Mt., Alkhanai National Park (field photo); b – brownish thallus of *Leptorema lithophila* after 15-years keeping in herbarium. Scale = 1 cm

Thus, *Leptotrema lithophila* is not considered as an endemic species of the Sikhote-Alin' Range, as it has been found in South Siberia, but the centre of its area is devoted to the Sikhote-Alin' Range (Fig. 4). The species occurs on elevation 25 to 1162 m a. s. l. from the coastal to inland regions, occurring on siliceous rock surfaces in wet rock crevice of isolated cliffs or gravelly barrens in wet and shaded situations. The species is doubtfully reported to the Kamchatka Territory (Mikulin, 1988, 1990) and for the northern part of the Russian Far East (Urbanavichus, 2010) and should be excluded from the list of the territory.

Fig. 2. The wet hidey cleft in isolated siliceous cliff in the forest belt at low elevation is a required habit for *Leptorema lithophila* in South Siberia (Dimchig Sume Mt., Alkhanai National Park).

Fig. 3. Accompany to *Leptorema lithophila* red listed, relic species, *Coccocarpia palmicola*, newly recorded for Alkhanai National Park.

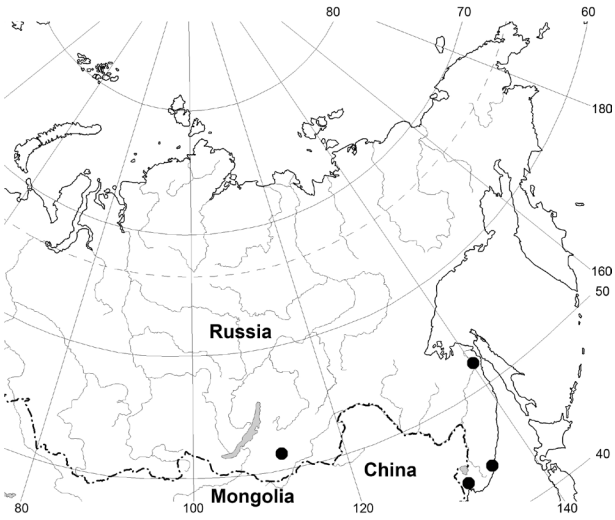

Fig. 4. Location map of *Leptotrema lithophila.*

The distribution of *Leptotrema lithophila* is probably wider as the species can be found in suitable habitats of nemoral refugia of South Siberia and southern part of the Russian Far East as well as temperate East Asia. Taking into account the relict status of *Leptotrema lithophila*, the species is recommended for inclusion in the Red Book of Russia.

Specimens *Leptotrema lithophila* examined: "Russia, Transbaikal Territory, Alkhanai National Park, Mogoytuyskiy Range, left bank of Uzbogoe River, Dimchig-Sume Massif, N exposition, 50°50'03.6"N, 113°23'25.4"E, 1162 m a. s. l., on rocks in wet rock crevice. 22 IX 2009. L. Yakovchenko. 1205" (ALTB); "Khabarovsk Territory, left bank of Amur River, Komsomol'skiy District, at 60 km NE from Boktor Settlement, Gorin River basin, Poludenniy Stream valley in lower part, cliffs on overgrowing talus slope, 51°24'18"N, 137°53'45"E, 885 m a. s. l., on rocks in wet rock crevice. 26 VIII 2011. L. Yakovchenko. 1257" (VLA, dupl. ALTB); "Primorye Territory, Dal'negorskiy District, at 1.5 km SW from the Lidovka Settlement, Japan Sea coast, foothills of Sikhote-Alin' Range, gravelly barrens covered by shrubs, 44°24'22"N, 135°52'25"E, 25 m a. s. l., on siliceous rocks. 17 VIII 2014. L. Yakovchenko, E. A. Davydov. 12304" (ALTB); "Shkotovskiy District, at 7.8 km SSW from Anisimovka Settelment, southern Sikhote-Alin' Range, upper stream of Berezoviy Stream, north slope of Litovka (Falasa) Mt., gravelly barrens field, 43°06'18.2"N, 132°47'15.4"E, 990 m a. s. l., on shady rocks. 26 VI 2012. L. Yakovchenko. 1174" (VLA, dupl. ALTB); "Litovka (Falasa) Mt.,

gravelly barrens field in *Abies-Picea* forest, on rocks in shade. 19 VIII 1967. L. A. Knyazheva" (VLA, L-4302); "Vorobei Mt., gravelly barrens field in *Abies-Picea* forest, on rocks in shade. 23 VIII 1967. L. A. Knyazheva" (VLA, L-4479).

Specimens of *Diploschistes* incorrectly identified as *Leptotrema lithophila*: "Russia, Kamchatka Territory, Elizovsky District, Kronotsky Nature Reserve, Central Semyachik Volcano System, south east slope of Baran'ya Mt. (1426,2 m a. s. l.), at 1 km NW toward to lower termal field, gravelly barrens field, 1000 m a. s. l., on rocks. 31 VII 1982. A. G. Mikulin" (VLA, L-3353); "the mouth of Big Chazhma River, coastal rocks at 1 km SE, 10 m a. s. l., on soil. 23 VI 1981. A. G. Mikulin" (VLA, L-3354); "Valaginsky Range, mountain peak at 1 km SE from Lysaya Mt. (1222 m a. s. l.), mountain tundra, 1300 m a. s. l., on rocks. 24 VI 1984. A. G. Mikulin" (VLA, L-3352).

Acknowledgements

I appreciate Dr. Irina Galanina and Dr. Irina Stepanchikova for their valuable help with the searching of the Mikulin's specimens identified as *Leptorema lithophila* in VLA as well as literature references on lichens of Kamchatka. Many thanks to Dr. Evgeny A. Davydov for pleasant company during collecting *Leptorema lithophila* in Far East field excursion in 2014 and for valuable comments during the preparation of this MS. The research was carried out within the state assignment of Ministry of Science and Higher Education of the Russian Federation of the Federal Scientific Center of East Asian Terrestrial Biodiversity FEB RAS (theme No 124012400285-7).

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