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## First record of the bryophilous fungus *Paruephaedria heimerlii* (Dactylosporaceae, Ascomycota) for Mexico

### Primer registro del hongo briófilo *Paruephaedria heimerlii* (Dactylosporaceae, Ascomycota) para México

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#### Abstract:

**Background and Aims:** The briofilous fungi are a diverse and polyphyletic group of symbiotic mushrooms associated specifically with few bryophyte species, genera or families. *Paruephaedria heimerlii* stands out as a species with a bryophilous habit in Jungermanniales; it is known from Alaska, Europe, Japan and Tasmania. Therefore, the objective of this work is to present the first record of this species in Mexico, its first known tropical locality. **Methods:** The studied specimens were collected in the vegetation of pine-oak forest and tropical cloud forest in the state of Veracruz, Mexico. The material was herborized and decontaminated by cooling, followed by determination from histological sections of the ascomas and observed with an optical microscope. Finally, the material was deposited in the fungal collections of the herbaria ENCB of the Instituto Politécnico Nacional and XALU of the Facultad de Biología of the Universidad Veracruzana.

**Key results:** Using morphological characteristics and measures of sexual structures like spores, asci and hymenial structures, the studied material was determined as *Paruephaedria heimerlii*, representing the first record of this species both in Mexico and for the tropics.

**Conclusions:** According to our observations and comparisons with reports in literature, it is probable that the presence of *P. heimerlii* is not conditioned to the temperature or altitude of the habitat in which it is found, but to the availability of hosts.

**Key words:** bryoparasitic fungi, Lecanoromycetes, tropical cloud forest, Veracruz.

#### Resumen:

**Antecedentes y Objetivos:** Los hongos briófilos son un grupo diverso y polifilético de hongos simbióticos asociados específicamente con algunas especies, géneros o familias de briofitos. *Paruephaedria heimerlii* destaca como una especie con hábito briófilo en Jungermanniales; se conoce de Alaska, Europa, Japón y Tasmania. Es por ello que el objetivo de este trabajo es presentar el primer registro de la especie para México, siendo esta la primera localidad tropical.

**Métodos:** Los ejemplares estudiados fueron colectados en la vegetación de bosque de pino-encino y en bosque de niebla en el estado de Veracruz, México. El material fue herborizado y descontaminado por enfriamiento, posteriormente determinado a partir de cortes histológicos de los ascomas y observado bajo el microscopio óptico. Finalmente, los ejemplares fueron depositados en la colección de hongos de los herbarios ENCB del Instituto Politécnico Nacional y XALU de la Facultad de Biología de la Universidad Veracruzana.

**Resultados clave:** Usando características morfológicas y mediciones de estructuras sexuales como esporas, ascas y estructuras himeniales, el material estudiado se determinó como *Paruephaedria heimerlii*, lo cual representa el primer registro de esta especie tanto para México como para el trópico.

**Conclusiones:** De acuerdo con nuestras observaciones y comparaciones con lo reportado en la literatura, es probable que la presencia de *P. heimerlii* no esté condicionada a la temperatura o altitud del hábitat en el cual se encuentra, pero sí a la disponibilidad de hospederos.

**Palabras clave:** bosque nuboso tropical, hongo brioparásito, Lecanoromycetes, Veracruz.

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## Introduction

The associations between fungi and Bryophyte species can be as pathogens, parasites, saprobes, or commensals (Dav-ey and Currah, 2006); however, these are poorly documented or understood (Döbbeler and Hertel, 2013; Kowal et al., 2018). In the case of endophytic bryophyte fungi, it is known that these can help them resist certain stressors such as extreme pH levels and promote protonema growth (During and Van Tooren, 1990). Of these symbioses between bryophytes and fungi, the best known and most documented in the world correspond to parasitic fungi (Döbbeler, 1997; Döbbeler and Hertel, 2013). The ecological niche that bryophytes provide for parasitic fungi is quite restricted to a few taxa, mainly Ascomycota genera that are phylogenetically not related (Döbbeler and Hertel, 2013).

The family Dactylosporaceae is characterized by superficial blackish apothecia, excipulum of texture angularis to globose cells, hymenium consisting of a thick gelatinous matrix, paraphyses with swollen and pigmented apices, cylindrical to clavate amyloid octosporic asci with I- tholus covered by a I+ blue external gelatinous cap; subglobose to ellipsoid ascospores, and one to several transverse septa (Hafellner, 1979; Bellemère and Hafellner, 1982; Döbbeler and Buck, 2017; Ekanaya et al., 2019). This family presents species with variable ecological habits; among the main ones are saprobes on bark and wood, parasites, or lichenized taxa (Wijayawardene et al., 2018; Ekanayaka et al., 2019). In this family, only the genus *Dactylospora* Körb has been reported with species with a briophilous habit. However, the phylogenetic reconstruction of the genus using the molecular markers nrLSU and mtSSU has resulted in the transfer of numerous species to the genus *Sclerococcum* Fr. (Diederich et al., 2013, 2018; Pang et al., 2014). In Mexico only *Dactylospora stygia* var. *stygia* (Berk. and M.A. Curtis) Hafellner and *D. stygia* var. *tenuispora* (Dennis) Hafellner are registered as saprophytic species in tropical forest and tropical cloud forest in the states of Tabasco and Veracruz (Chacón and Tapia, 2016). In contrast, most of the species of the family have been indicated as lichenicolous; *Sclerococcum montagnei* Hafellner and *S. pleiospermum* (Triebel) Ertz & Diederich on *Lecanora* Ach. and *Pertusaria* DC.; *S. athallinum* (Müll. Arg.) Ertz & Diederich on *Baeomyces* Pers., *S. parasiticum* (Flörke) Ertz & Diederich on *Pertusaria*

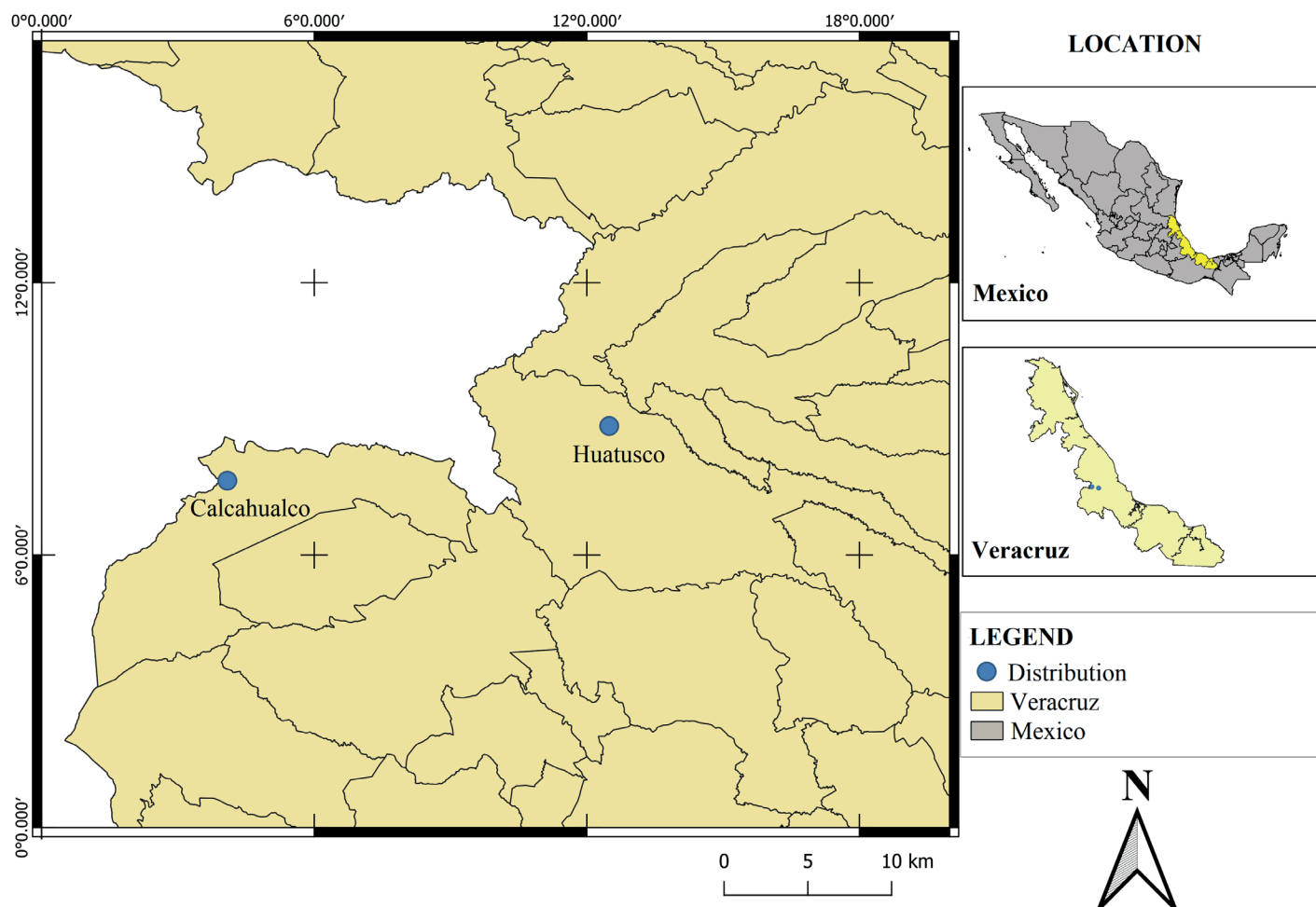
DC. and *Ochrolechia* A. Massal., and *Sclerococcum saxatile* (Schaer.) Ertz & Diederich on *Pertusaria* DC. (Diederich, 2004; Hafellner, 2004), all for the Sonoran Desert region in northern Mexico.

According to Index Fungorum (2021), there are two species included in *Paruephaedria* Zukai, another genus in this family. *Paruephaedria heimerlii* Zukai is a species with a bryoparasitic habit, traditionally classified within the genus *Dactylospora* (Döbbeler and Triebel, 1985). We consider here the name *P. heimerlii*, originally proposed by Zukai (1891), due to the lack of available sequences of the species that will allow to clarify its phylogenetic position and its relationship with other genera with similar characteristics such as *Sclerococcum* or *Dactylospora*. The latter is concerning, since it has recently been pointed out by various authors that it is not a monophyletic genus (Pang et al., 2014; Diederich et al., 2018; Xian-Dong et al., 2018). Another briophilous species in Dactylosporaceae is *Dactylospora inopina* Döbbeler and W.R. Buck, differing from *P. heimerlii* by its polysporous asci and four-celled spores (Döbbeler and Buck, 2017). Consequently, the objective of this work is to present with pictures and description the first record of the species *P. heimerlii* both in Mexico and the tropics.

## Materials and Methods

The specimens studied were collected in the pine-oak forest in the town of Atotonilco in the municipality Calchualco (19°08'40.0"N, 97°11'38.8"W, 2180 m a.s.l.) and in the tropical cloud forest in the municipality Huatusco (19°10'34.4"N, 96°58'40.6"W, 1340 m a.s.l.), in the state of Veracruz, Mexico (Fig. 1). The material was herborized and decontaminated by cooling (-10° C), and it was deposited in the fungal collections of the herbaria ENCB of the Instituto Politécnico Nacional and XALU (acronyms according to Thiers, 2021+) of the Facultad de Biología, Universidad Veracruzana. Ascomata histological sections were made freehand with a stereoscopic microscope (Carl Zeiss model Stemi Dv4, Jena, Germany), and mounted in water. The determination of the briophilous fungus was following the key proposed by Marsh et al. (2010). Their structures were measured in water with an optical microscope (Carl Zeiss Primo Star HAL / LED model, Jena, Germany) at the Environmental Quality Laboratory of the Facultad de Biología of





**Figure 1:** Sampled localities of *Paruephaedria heimerlii* Zukai reported in Veracruz, Mexico.

the Universidad Veracruzana, Xalapa, Mexico. The reaction of amyloid compounds in the hymenium was tested with Lugol's solution (IKI). The photographs were taken with an iPhone SE 2020 cell phone (Zhengzhou, China).

## Results

### Taxonomy

Lecanoromycetes

Lecanorales

Dactylosporaceae

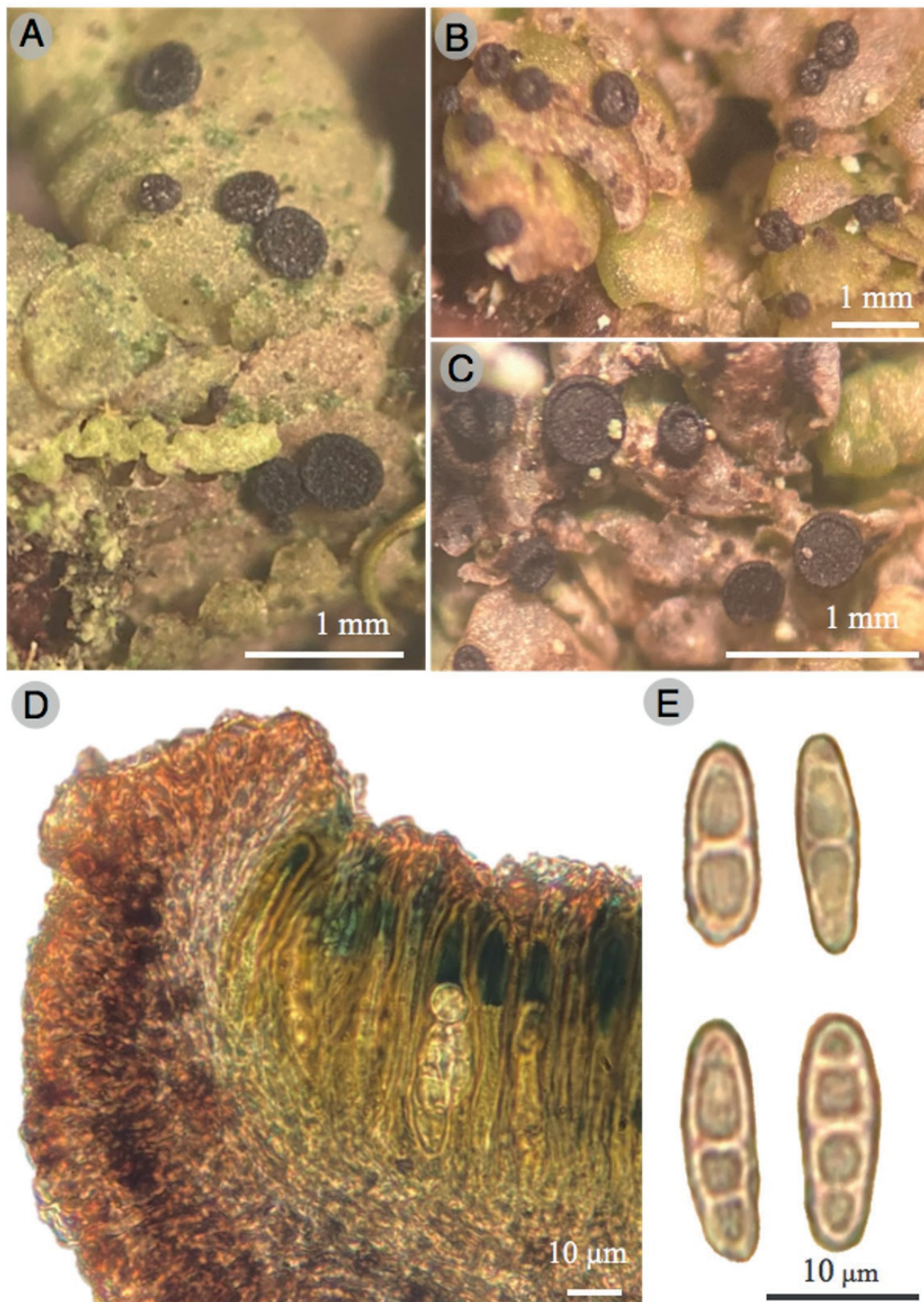
*Paruephaedria heimerlii* Zukai, Flora, Regensburg 74: 98. 1891. Fig. 2.

TYPE: GERMANY. Bayern. Hochland, Lahn bei der Jachenau, *Sendtner s.n.* (neotype: M-M0041422).

= *Dactylospora heimerlii* (Zukai) Döbbele and Triebel Bot. J. 107(1-4): 509. 1985.

Apothecia 100-300 µm diameter, superficial, solitary or gregarious, sessile, pulvinate, black to pale brown in KOH, smooth or finely granulated surface; ectal excipulum 25-40 µm wide, angular to globular texture composed of polygonal cells, thin-walled, brown to dark brown; medullary excipulum 10-15 µm wide, intricate texture composed of hyaline intertwined hyphae, embedded in a gelatinous matrix; hymenium hyaline to brownish, enclosed in a thick gelatinous matrix; pseudoepithecium composed of hyaline to brown amorphous matter surrounding the paraphysis





**Figure 2:** *Paruephaedria heimerlii* Zuka; A-C. apothecia growing in a gametophyte of a leafy liverwort; D. hymenium in Lugol's solution; E. spores showing different septation.

tips; paraphyses 1.4–2 µm wide, filiform, septate, swollen, slightly branched and pigmented at the apex, extending beyond the asci and apices attached together to develop a pseudoepithecium; asci 45–50 × 17–20 µm, unitunicate, sessile, cylindric-clavate, rounded at the apex, inoperculate with an amyloid gelatinous cap, octosporic; ascospores 10–18 × 5–6 µm, spores ellipsoid when immature to fusoid when mature, with a transverse septum, hyaline to olivaceous, guttulate, smooth, thin-walled, multiseriate.

Habit and habitat: growing on phyllidia of a leafy liverwort.

Distribution: according to Döbbeler and Hertel (2013), *Paruephaedria heimerlii* is known from Alaska, Japan, Tasmania, and various localities in Europe, with an altitudinal range of 570 to 1250 m a.s.l. This is the first record for Mexico and for the tropics.

Material examined: MEXICO. Veracruz, municipality Calcahualco, Atotonilco, 2180 m a.s.l., 19°08'40.0"N, 97°11'38.8"W, 06.II.2021, *P. Sorcia-Navarrete* 405 (XALU), 406 (XALU), 407 (XALU). Municipality Huatusco, 1340 m a.s.l., 19°10'34.4"N, 96°58'40.6"W, 03.XII.2021, *J. Guzmán-Guillermo*, 2305 (XALU), 2306 (ENCB).

Taxonomic notes: this species grows exclusively on the phyllidia of leafy liverworts of the order Jungermanniales in forested regions with high humidity. Morphologically it is characterized by having a dark brown to black discoid apothecium, with asci that have a blue I + gelatin at the tip, spindle spores that vary in size and that can have one to three septa.

## Discussion

According to Döbbeler and Hertel (2013), the largest number of records of *P. heimerlii* have been made mainly in temperate forested regions of Europe, with some records in Alaska, Japan, and Tasmania. Such climate characteristics coincide with the pine-oak forest vegetation present in localities of the specimens *Sorcia-Navarrete* 405 (XALU), 406 (XALU) and 407 (XALU), although at an elevation of al-

most 1000 m higher than that registered in other sampled localities (Döbbeler and Hertel, 2013). However, the specimens Guzmán-Guillermo 2305 (XALU) and 2306 (XALU) were collected in a tropical cloud forest vegetation which is a confluence zone between tropical and temperate floristic elements. This suggests that the presence and reproduction of *P. heimerlii* are not conditioned to the temperature and other factors determined by altitude of the habitat in which it is found, but to the availability of hosts. However, it is necessary to carry out studies to affirm this. Regarding the host, all the specimens studied here were found parasitizing phyllidia of leafy liverworts, which coincides with the records previously made by other authors (Zukal, 1891; Marsh et al., 2010; Döbbeler and Hertel, 2013).

The collection of bryoparasitic fungi is commonly accidental and its scarce study is related to the lack of cooperation between bryologists and mycologists (Döbbeler, 1997), which has a high relevance if we consider the specificity of these fungi to a related species or genera of marchantiophytes (Döbbeler and Hertel, 2013). As has happened with this finding, the specimens analyzed here correspond to leafy liverworts that were accidentally collected among lichens.

Finally, it is highlighted that this new record for Mexico represents one more element to indicate the importance of continuing with field explorations that allow progress in the taxonomic knowledge of certain groups (Wilson, 2017). The discovery presented here is made in the state of Veracruz which has a long tradition of field studies. However, it is evident that there are biological groups like this one whose findings of new species or expansion of distribution ranges result in increasing diversity for this state, which agrees with the worldwide trend for this group since it is estimated that only 7% of the estimated diversity of fungi is known (Mora et al., 2011).

## Author contributions

JGG designed and directed the research, JGG and PLSN collected the specimens here studied, JGG, PLSN, TR and CICH wrote and reviewed the document, PLSN and TR illustrated the manuscript.





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