

The first report of *Chaenothecopsis perforata* from North America

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ABSTRACT. – *Chaenothecopsis perforata* is reported as new to North America from Canada (Ontario and Québec) and the United States (Iowa, Michigan, Minnesota, Nebraska, Pennsylvania, Texas, and Wisconsin). The species occurs on the exudate of *Rhus* and this is the first documented occurrence on angiosperm exudate for any calicioid fungus in North America.

KEYWORDS. – Biogeography, Mycocaliciaceae, calicioid, *Rhus glabra*, *R. typhina*, *R. lanceolata*, *R. virens*, resinicolous.

INTRODUCTION

Resiniculous members of the calicioid fungus order Mycocaliciales have been well studied in recent decades (Rikkinen 1999, 2003; Selva 2013; Selva & Tuovila 2016; Titov & Tibell 1993, 1999; Tuovila et al. 2014). Historically, calicioids that grow on angiosperm exudate were poorly understood and little studied, presumably because of the unusual substrates on which they grow. However, seven species of *Chaenothecopsis* Vain. and *Mycocalicium* Vain. are now known globally from this substrate (Samuels & Buchanan 1983; Tewari & Pant 1966; Tibell & Titov 1995; Titov & Tibell 1999; Tuovila et al. 2011, 2014). Two additional species are known from the viscin of *Tristerix* Mart. species (Funk & Kujt 1982, Messuti et al. 2012). Previously, all the known records of calicioids on angiosperm exudate have come from Africa (Ghana), Australasia (New Zealand), Eurasia (China, Germany, India, Russia), and South America (Argentina, Ecuador, Peru). Here, we report one of these species, *Chaenothecopsis perforata* Rikkinen and Tuovila, for the first time from North America.

Chaenothecopsis perforata was described by Tuovila et al. (2014) from specimens collected in China on the hardened exudate of *Rhus chinensis* Mill. Intrigued by this, the first author began searching populations of *Rhus* L. for resin flows which could sustain a population of calicioids. Almost immediately, a population of *C. perforata* was discovered at a site close to his house. Targeted searches of every patch of *Rhus* encountered followed, which revealed that *C. perforata* was present in most large populations of *R. typhina* L., particularly in stands with mature and gnarled individuals. The calicioid species was subsequently found at both heavily urbanized localities and in rural or agrarian landscapes. Further search efforts in Iowa, Nebraska, and western Minnesota lead to the discovery of the species on mature *R. glabra* L. Likewise, search efforts in Texas revealed that the species was also present on *R. lanceolata* (A. Gray) Britton and *R. virens* Lindh. ex A. Gray.

MATERIALS AND METHODS

Most specimens were collected by the authors with additional specimens provided by John Thayer and Jacob Walden. All specimens are deposited in the herbarium of the James Ford Bell Museum of

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Natural History (MIN), Canadian Museum of Nature (CANL), University of Maine, Fort Kent (UMFK) or New York Botanical Garden (NY). External characteristics of specimens were examined under a Leica S6E stereo-zoom dissecting microscope. A Leica CME compound microscope was used to examine anatomy and to view chemical reactions. Chemical spot tests were performed using 10% potassium hydroxide (K) following Selva (2013) and Lugol's solution (IKI) after pre-treatment with K. Measurements of ascospore and ascus dimensions were made, using an ocular micrometer, of squash preparations of apothecia in water. Measurements of apothecium height, capitulum and stalk diameters, and length and width of asci are given as a–b, where a and b represent the extremes of numerous measurements (>50). Length and width of ascospores are presented as: the arithmetic mean (\bar{x}) +/- one standard deviation (SD), bounded by the smallest and largest observed values (i.e., (smallest observed) \bar{x} -1SD – \bar{x} – \bar{x} +1SD (largest observed)).

Images of the apothecia were captured with a Leica DVM6 digital microscope (Fig. 1A and 1E). Images of ascospores in water mounts, were captured using a Leica DMR compound microscope under oil immersion at 1000x magnification (Fig. 1B). A FEI Apreo scanning electron microscope (SEM), was used to capture additional images of ascospores at a 5 mm beam distance using the T1(A) detector (Fig. 1C). Specimens were prepared for the SEM using a stereomicroscope to remove ascomata which were mounted onto an aluminum stub using double-sided carbon tape. The stub was then placed in a Denton Vacuum Desk II sputter coater for 15 seconds, which deposited a thin mixture of gold and palladium onto the stub before imaging. The map was produced with SimpleMappr (Fig. 1D; Shorthouse 2010).

RESULTS AND DISCUSSION

It is remarkable that *Chaenothecopsis perforata* apparently has avoided notice in North America for so long. Presumably, the substrate has not been examined by lichenologists, particularly those interested in calicioids. However, *Rhus typhina* is the only known host for *Phaeocalicium curtisii* (Tuck.) Tibell, another calicioid, which has been widely documented throughout North America (Harris 1976; Harris & Lendemer, 2005; McMullin & Lendemer 2016; Selva 1988, 2014; Thomson 2003; Tibell & Ryan 2004; Wetmore 2005) suggesting that *C. perforata* simply has been overlooked. In fact, one of us (RTM) has returned to sites where he previously collected *P. curtisii* and found *C. perforata* on trunks adjacent to where *P. curtisii* occurs.

Phaeocalicium curtisii resembles *C. perforata* and is currently the only other species of calicioid fungus known from *Rhus* in North America. Usually, it is easy to differentiate between the two species solely based on substrate, with *C. perforata* restricted to resin and *P. curtisii* to the bark, but additional examination is required when sap flows have enveloped populations of *P. curtisii* giving it a resinicolous appearance. The two species are readily separated by examining the ascospores, as those of *P. curtisii* are 1-septate and those of *C. perforata* are simple. Additionally, the two species differ in their capitulum shape: *P. curtisii* is cupulate whereas *C. perforata* is obovoid to hemispherical

Many species of calicioids are host specific, particularly species occurring on angiosperm exudate (Tuovila 2013). It is intriguing that *C. perforata* has been recorded from the hardened exudate of multiple species of *Rhus*, including *R. chinensis* (in China) and *R. glabra*, *R. lanceolata*, *R. typhina*, and *R. virens* (in Canada and the U.S.A.). It is worth noting that *C. perforata* has now been recorded from both traditionally recognized subgenera of *Rhus*, with *R. virens* in *Rhus* subg. *Lobadium* (Raf.) A. Gray and all of the other species (including *R. chinensis*) in *Rhus* subg. *Rhus* (Yi et al. 2007). Thus, it is likely that it occurs on the exudate of additional species in the genus *Rhus*, and possibly other members of the Anacardiaceae. It should be noted that over the past two years the first author has searched many patches of *R. aromatica* Aiton in Kansas, Michigan, North Dakota, and Texas, but apparently that species does not wound regularly, and hence resin flows are rare. Additionally, a handful of populations of *R. copallinum* L. in Texas and Kansas have been examined but no wounds were located during these searches. Both *R. aromatica* and *R. copallinum* produce resin but no suitable “flows” have been located.

The discovery of *C. perforata* in North America suggests that other resinicolous calicioids on angiosperm exudate may await discovery in the region. Tuovila (2013) hypothesized that the high level of host specificity in resinicolous calicioids that occur on angiosperm exudate renders discovery of additional calicioid species likely. We hope that our discovery will encourage others to search their local resin-producing plants for undocumented calicioids. One group of vascular plants with a high potential for hosting additional species in North America is the Anacardiaceae. Many members in this family are known for resin production (Langenheim 2003) including *Mangifera indica* L. whose resin is the only known substrate for *Mycocalicium chaudhari* Tewari & Pant, a species currently known only from India (Tewari

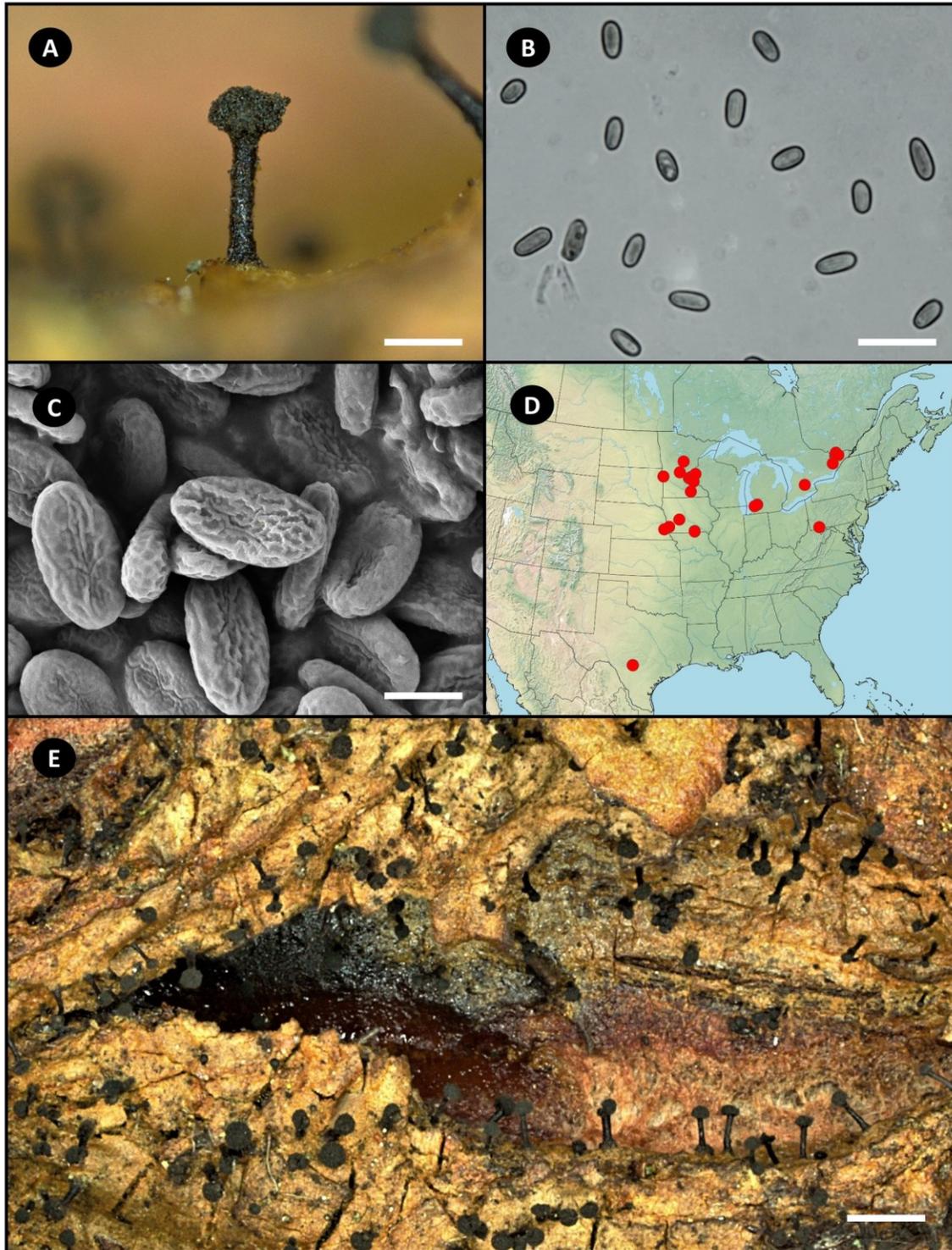


Figure 1. Morphology, habit and geographic distribution of *Chaenothecopsis perforata* (micrographs all from *Gockman 5487*, UMFK). **A**, apothecium (scale = 0.15 mm). **B**, ascospores in a water mount under a compound microscope at 1000 \times (scale = 12.0 μ m). **C**, ascospores under a scanning electron microscope (scale 2.0 μ m). **D**, North American distribution. **E**, apothecia as they appear in a colony on the substrate (scale = 0.8 mm).

& Pant 1966; Tibell & Titov 1995). Even though new species of resinicolous calicioids on angiosperm exudate likely remain undiscovered on the North American continent, the hosts of two other described species have naturalized here: *Mangifera indica*, host for *Mycocalicium chaudhari*, has been introduced in southern Florida and *Ailanthus altissima* (Mill.) Swingle, host for *Chaenothecopsis pallida* Rikkinen & Tuovila (Tuovila et al. 2014), is widely naturalized throughout the continental U.S.A. and southeastern Canada. Many additional angiosperm families occurring in North America produce resins that could provide suitable substrates for calicioids. Those wishing to search for additional species may find the work of Langenheim (2003) useful as it provides a list of families and genera that are known for resin production as well as basic information about distribution.

TAXONOMIC SECTION

Chaenothecopsis perforata Rikkinen & Tuovila, Mycologia 106(5): 992-994. 2014. **TYPE: CHINA.** Hunan Province. Xinning County. Shunhuangshan National Forest Park. Zheng Jiang Valley. Heavily grazed plantation forest with young *Cunninghamia lanceolata* and *Trachycarpus fortunei* mixed with naturally regenerated evergreen trees, 26u249350N, 110u599200E, ca. 950 m. On branches of *Rhus chinensis*, 24.ix.2001, J.K. Rikkinen 010540 (H[n.v.], holotype).

FIGURE 1.

DESCRIPTION. – **Thallus:** absent. **Apothecia:** on exudate of *Rhus* species, medium in size, 0.30–1mm tall; *capitulum* obovoid to hemispherical, black, shiny, 0.15–0.75 mm across; *stalk* black to dark- or light brown to grayish or greenish-gray, 0.06–0.13 mm in diameter, shiny when young, typically straight and unbranched, composed of periclinally-arranged hyphae, light greyish-brown to hyaline in section; *exciple* pale grayish-brown, composed of periclinally-arranged hyphae; *epithecium* grayish-brown, formed as a continuation of the excipulum across the top of the asci; *hypothecium* hyaline. **Asci:** cylindrical, 35–44 × 3.0–4.0 µm, apex thickened and penetrated by a short canal, with ascospores uniseriately arranged. **Ascospores:** simple, ellipsoidal to broadly cylindrical, ranging from pale grayish- to yellowish-brown to brown, (5.0)–5.2–5.9–6.5–(8.0) × (2.0)–2.7–2.9–3.2–(4.0) µm, with smooth walls.

CHEMISTRY. – No substances detected. Spot tests: apothecia and stalk K-, C-, KC-, P-, HNO₃-, IKI+ violet-red (in fungal hyphae).

ECOLOGY AND DISTRIBUTION. – *Chaenothecopsis perforata* has only been collected from the hardened exudate of *Rhus* species. Eastern records (Michigan, Ontario, Pennsylvania, Quebec, Wisconsin, and most of those from Minnesota) were collected from *R. typhina* and most western records (Iowa, Nebraska, and some of those from Minnesota) were from *R. glabra*. The Texas specimens were collected from *R. lanceolata* and *R. virens*. In many patches of *Rhus*, *C. perforata* appeared to be common, having been located in most localities subjected to targeted searches. This suggests that it previously was overlooked, likely due to its occurrence on angiosperm exudate, a seldom collected substrate that appears devoid of life to the casual observer.

Many exudate flows on which *C. perforata* occurs, appear to originate from “frost cracks” or ruptures in the bark, possibly caused by unknown pathogens. Others appear to originate from damaged bark caused by insects, birds, or mechanical damage. One collection of *C. perforata* was made from bud scars on older branches of *R. typhina*, which may be a regular niche for the species. *Chaenothecopsis perforata* occurs on the shiny black resin that forms in chambers under damaged portions of bark as well as on dull/matte brown to tan, or white in *R. virens*, resin that accumulates on the outside of the bark. Often the species can form extensive colonies where suitable habitat abounds.

Specimens examined. – **CANADA. ONTARIO.** LANARK CO.: corner of Clear Lake 11 Line and Armstrong Line, ca. 3.5 km S of Hwy 7, mature stand of *R. typhina*, 11.iii.2018, resinicolous on *R. typhina*, R.T. McMullin et al. 19166 (CANL). NATIONAL CAPITAL REGION: City of Ottawa, Fletcher Wildlife Garden, along Bill Holland Trail, ca. 300 m S of the trail head, stand of *R. typhina*, 22.xi.2018, resinicolous on *R. typhina*, R.T. McMullin 20104 & L. Elias (CANL). City of Ottawa, Carp Hills, along Thomas A. Dolan Parkway, north side of the road, ca. 1.3 km NE of Carp Rd., stand of *R. typhina*, 15.xii.2018, resinicolous on *R. typhina*, R.T. McMullin 19164 (CANL). WELLINGTON CO.: City of Guelph,

University of Guelph, The Arboretum, ca. 40 m S of the jct. of Ivey Trail and the J.C. Taylor Nature Centre, mature stand of *R. typhina*, 5.xi.2018, resinicolous on *R. typhina*, *R.T. McMullin 20103* (CANL).

QUEBEC. OUTAOUAIS REGION: Municipality La Pêche, Wakefield, 15 Hall Rd., on the N side of the driveway, 30.viii.2018, resinicolous on an exposed and mature *R. typhina*, *R.T. McMullin 19167 & M. Graham* (CANL); Gatineau Park, Luskville Falls Trail trailhead, adjacent to the parking lot, large stand of mature *R. typhina*, 2.iv.2018, resinicolous on *R. typhina*, *R.T. McMullin 19165 & L. Elias* (CANL).

U.S.A. IOWA. APPANOOSE CO.: Numa, 109 m E of 160th Ave., ca. 1.2 km S of the intersection with 524th St., small stand of *R. glabra* in an abandoned farm, 21.ii.2018, resinicolous on the trunks and branches of *R. glabra*, *O. Gockman 5560 & R. Cress* (MIN); ca. 250 m N of 160th Ave., ca. 996 m W of its intersection with 170th Ave., small stand of young *R. glabra* in clearing in mesic forest, 22.ii.2018, resinicolous on the trunks of *R. glabra*, *O. Gockman 5561 & R. Cress* (MIN).

GUTHRIE CO.: Guthrie Center, along Grand Ave. c. 598 m N of the intersection with 220th St., small roadside stand of *R. glabra*, 22.iii.2018, resinicolous on the trunks and branches of *R. glabra*, *O. Gockman 5578 & J. Thayer* (MIN).

MILLS CO.: Glenwood, across Elrod Rd. from West Liberty Cemetery, small stand of *R. glabra* between road and plowed field, 22.iii.2018, resinicolous on the trunks and branches of *R. glabra*, *O. Gockman 5577 & J. Thayer* (MIN).

MICHIGAN. ALLEGAN CO.: Allegan, along Fallbrook Trail ca. 175 m N of Valley Vista Dr., small stand of *R. typhina* over pipeline corridor, 27.ii.2018, resinicolous on the trunks of *R. typhina*, *O. Gockman 5563 & S. Milburn* (MIN).

VAN BUREN CO.: Geneva Township, along 64th St., ca. 816 m S of the intersection with Phoenix St., scattered *R. typhina* at edge of agricultural field, 26.ii.2018, resinicolous on the trunks of *R. typhina*, *O. Gockman 5746 & S. Milburn* (MIN).

MINNESOTA. ANOKA CO.: Blaine, ca. 127 m W of Lever St. NE, ca. 1.15 km N of the intersection with 125th Ave., large stand of mature *R. typhina* at edge of clearing, 28.ix.2017, resinicolous on the trunks of *R. typhina*, branches, and leaf scars of *R. typhina*, *O. Gockman et al. 5487* (MIN, UMFK).

BIG STONE CO.: Big Stone National Wildlife Refuge, ca. 345 m S of Hwy 75, adjacent to parking lot along Refuge Rd., small stand of mature *R. glabra*, 15.viii.2018, resinicolous on *R. glabra*, *O. Gockman 5745 & B. Grider* (MIN).

CROW WING CO.: Cuyuna Country State Recreation Area, on the S shore of June Lake, small stand of *R. typhina* along shore of lake, 19.vi.2018, resinicolous on the trunks of *R. typhina*, *O. Gockman 5747 & S. Milburn* (MIN).

HENNEPIN CO.: Maple Grove, 12320 87th Ave. N, small planting of *R. glabra* in back yard, 27.vii.2018, resinicolous on the trunks of *R. glabra*, *J. Walden 0001* (MIN).

RAMSEY CO.: Falcon Heights Community Park, ca. 270 m SE of the intersection of Larpentur Ave. and Roselawn Ave., small stand of *R. typhina* planted at the edge of soccer fields, 14.x.2017, resinicolous on the trunks of *R. typhina*, *O. Gockman et al. 5491* (MIN).

STEARNS CO.: Middle Spunk Rest Area, W end of truck parking area, small stand of *R. typhina* adjacent to parking lot, 26.vi.2018, resinicolous on the trunks of *R. typhina*, *O. Gockman 5749* (MIN).

STEELE CO.: South Creek Rest Stop, along off-ramp from Interstate 35, stand of *R. typhina* adjacent to roadway, 21.iii.2018, resinicolous on the trunks of *R. typhina*, *O. Gockman 5748 & J. Thayer* (MIN).

WASHINGTON CO.: Cottage Grove Ravine Park, 437 m SE of the intersection Ravine Parkway South and Innovation Rd., extensive stand of young *R. typhina* in a historical agricultural field, 12.x.2017, resinicolous on the trunks of *R. typhina*, *J. Thayer 33* (MIN).

NEBRASKA. CASS CO.: Wabash, 100 m SW of the intersection of Alvo Rd. and Hwy 1, small stand of *R. glabra* adjacent to road, 24.iv.2018, resinicolous on the trunks of *R. glabra*, *O. Gockman 5630* (MIN).

PENNSYLVANIA. FAYETTE CO.: Ohiopyle State Park, on the NE corner of the jct. of Mill Run Rd. and the Youghiogheny River, small stand of young *R. typhina*, 18.iv.2018, resinicolous on *R. typhina*, *R.T. McMullin 20002* (NY).

TEXAS. BANDERA CO.: Hill Country State Natural Area, adjacent to the Wilderness Trail just SW of the Twin Peaks, small stand of *R. lanceolata* in field, 19.i.2019, resinicolous on *R. lanceolata*, *O. Gockman 5761 & J. Walden* (MIN); Hill Country State Natural Area, adjacent to the unnamed road that leads to the group campsite just east of Twin Peaks, small stand of large *R. lanceolata* adjacent to roadway, 19.i.2019, resinicolous on *R. lanceolata*, *O. Gockman 5762 & J. Walden* (MIN).

MEDINA CO.: Hill Country State Natural Area, adjacent to the Medina Trail, scattered plants of *R. virens* along trail, 21.i.2019, resinicolous at the base of *R. virens*, *J. Walden 0021 & O. Gockman* (MIN).

WISCONSIN. POLK CO.: St. Croix Falls, across Hwy 87 from Lions Park, small stand of *R. typhina* adjacent to road, 11.v.2018, resinicolous on the trunks of *R. typhina*, *J. Thayer 42* (MIN).

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