Asexual morphs of powdery mildew species (*Erysiphaceae*) – new and supplementary morphological descriptions and illustrations (part 2)

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Abstract: Schmidt, A. & Braun, U. 2024: Asexual morphs of powdery mildew species (*Erysiphaceae*) – new and supplementary morphological descriptions and illustrations (part 2). Schlechtendalia **41**: 43–59.

The second contribution to descriptions of asexual morphs of powdery mildew species is provided, with a particular focus on characteristics of the conidial germination patterns. The concept followed the first contribution published in 2020. Descriptions and illustrations are based on collections made by the first author during long-term examinations of species of the *Erysiphaceae*. Voucher specimens are deposited at herbarium KR (Natural Science Museum, Karlsruhe, Germany). The conidial germination patterns of several powdery mildew species have been examined in detail for the first time, including *Erysiphe lycopsidis*, *Euoidium pseudolongipes*, *Golovinomyces bolayi*, *G. macrocarpus*, *Podosphaera euphorbiae* (on its type host *Euphorbia peplus*), *P. macrospora*, *P. mors-uvae*, *P. phtheirospermi*, and *Sawadaea tulasnei*. *Salix* ×*multinervis* and *S.* ×*smithiana* are new host records from *Erysiphe capreae*.

Zusammenfassung: Schmidt, A. & Braun, U. 2024: Asexuelle Morphen von Mehltauarten (*Erysiphaceae*) – neue und ergänzende morphologische Beschreibungen und Abbildungen (Teil 2). Schlechtendalia **41**: 43–59.

Der zweite Beitrag mit Beschreibungen asexueller Morphen von Mehltau-Arten wird zur Verfügung gestellt, mit einem besonderen Schwerpunkt auf Merkmale der Keimungsmuster der Konidien. Das Konzept folgt dem ersten Teil, der 2020 publiziert wurde. Beschreibungen und Abbildungen basieren auf Kollektionen der Erstautorin, die sie im Rahmen langjähriger Untersuchungen von Arten der *Erysiphaceae* gefunden hat. Belegexemplare sind im Herbarium KR (Naturkundemuseum Karlsruhe, Germany) deponiert. Die Keimungsmuster einiger Mehltauarten wurden erstmalig im Detail untersucht, darunter *Erysiphe lycopsidis*, *Euoidium pseudolongipes*, *Golovinomyces bolayi*, *G. macrocarpus*, *Podosphaera euphorbiae* (on its type host *Euphorbia peplus*), *P. macrospora*, *P. mors-uvae*, *P. phtheirospermi* und *Sawadaea tulasnei*. *Salix* ×*multinervis* und *S.* ×*smithiana* sind neue Wirtsangaben für *Erysiphe capreae*.

Key words: *Helotiales* (*Erysiphales*), anamorphs, traits, conidial germination.

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Introduction

Powdery mildews (*Helotiales*, *Erysiphaceae*) are a large family of plant pathogenic ascomycetes (Salmon 1900, Braun 1987, Braun & Cook 2012), encompassing numerous phytopathologically relevant plant diseases worldwide. Patterns of the conidial germination represent taxonomically significant traits on genus as well as species rank. First conidial germination experiments go back to Neger (1902), later followed by more comprehensive examinations performed by Hirata (1942, 1955) and Zaracovitis (1966), who tried to generalize the germination patterns. Much later, Cook & Braun (2009) proposed a more generalized classification of conidial germination patterns by combining them with anamorph types of individual powdery mildew genera. The new classification was later accepted and applied in Braun & Cook (2012).

The first author has carried out comprehensive germination studies with powdery mildew conidia over a long time. Some descriptions and illustrations have already been published in previous taxonomic treatments, such as Schmidt (1999), Schmidt & Scholler (2002, 2006, 2011, 2012), and Scholler et al. (2016). Schmidt & Braun (2020) published a first contribution to the conidial germination patterns of powdery mildew species aiming at providing supplementary descriptions for species with unknown or insufficiently known details of the germination of their conidia. The present publication represents the second part of this series.

Materials and methods

The germination experiments described in the present work were performed as follows: Fresh conidia were dusted on glass slides and deposited in Petri dishes with moist cellulose tissue . The closed Petri dishes were kept at room temperature behind a north-sided window for about 24 hrs with a natural change between day light and darkness. Measurements were usually based on about 25 conidia and made in tap water. Voucher specimens were deposited in the mycological collection of the herbarium KR (Natural History Museum, Karlsruhe, Germany).

Results

Descriptions and illustrations of asexual morphs of several powdery mildew species with special emphasis on the conidial germination

[The descriptive terminology used in this work is based on Braun & Cook (2012), including special terms used for types and patterns of the conidial germination, such as "perihilar" (subapical in conidia with a terminal hilum, i.e., around the hilum rim in catenescent conidia or in secondary conidia with truncated apex when formed singly).]

Erysiphe

Erysiphe aquilegiae DC. Fig. 1

Material examined: Germany, Schleswig Holstein, Herzogtum Lauenburg, Groß Grönau, An der Gärtnerei 1, cultivated, on *Thalictrum aquilegiifolium*, 11 Sep. 2020, A. Schmidt, KM 372 (KR-M-0042986).

Fig. 1: *Erysiphe aquilegiae* on *Thalictrum aquilegiifolium*. A: Conidiophores; B: Conidia; C: Conidium with long germ tube (longitubus pattern); D–E: Conidia with germ tubes. Scale bars = 10 µm.

The characteristics of the conidiophores agree well with previous descriptions (Paulech 1995: 115; Shin 2000: 33–34; Braun & Cook 2012: 362; Schmidt & Braun 2020: 34–36). The conidia are ellipsoid, sometimes cylindrical, 30–40 × 16–20.5 µm, length/width ratio 1.6–2.2, on average 1.9. Conidial germ tubes formed in a moist chamber are short to long (longitubus pattern), perihilar, 1–2 per conidium, aseptate or with 1–2 septa, single septum at or near the base or up to the middle of the germ tube, second septum up to the upper half of the germ tube, terminal appressorium lobate to multilobate in short germ tubes, lacking or swollen (club-shaped) in long germ tubes. Germination rate high (c. 30–50 %).

Erysiphe capreae DC. ex Duby Fig. 2 A, B

= *Erysiphe pseudoregularis* U. Braun

Material examined: Germany, Schleswig-Holstein, Lübeck, St. Gertrud, Lauerholz, Deepenmoor, on *Salix* ×*multinervis* (*aurita* × *cinerea*), 26 Aug. 2022, A. Schmidt, KM 402 (KR-M-0050999), anamorph; ibid., on *Salix* ×*multinervis* (*aurita* × *cinerea*), 14 Oct. 2022, A. Schmidt (KR-M-0051035), teleomorph. Germany, Schleswig-Holstein, Ostholstein, Scharbeutz,

Kurpark, on *Salix* ×*smithiana* (*carprea* × *viminalis*), 20 Aug. 2022, A. Schmidt, KM 401 (KR-M-0051204), anamorph; ibid., 21 Oct. 2022, *Salix* ×*smithiana*, A. Schmidt (KR-M-0051215), holomorph.

Conidiophores agreeing with previous descriptions (Braun & Cook 2012, Darsaraei et al. (2021); conidia ellipsoid-cylindrical, 29–46 × 16–24 µm, length/width ratio 1.6–2.4 [Ø 1.9] (on *Salix* ×*multinervis*), 32.5–45 × 18.5–26 µm, length/width ratio 1.5–2.0 [Ø 1.8] (on *Salix* ×*smithiana*), germ tubes perihilar, occasionally short, but mostly long to very long, mostly aseptate, occasionally with a single septum, terminal appressoria lobate in short to moderately long germ tubes, lacking to club-shaped in long to very long germ tubes. *Salix* ×*multinervis* and *S.* ×*smithiana* are additional hosts for *E. capreae*.

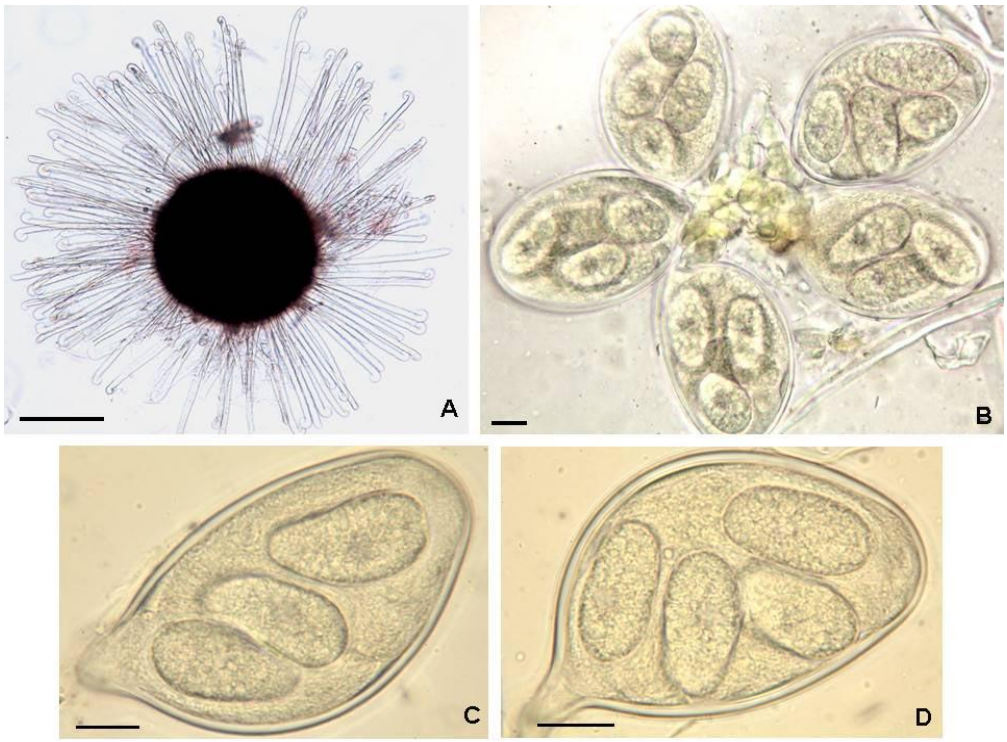

Fig. 2 A: *Erysiphe capreae* on *Salix* ×*multinervis*. A: Chasmothecium; B–D: Asci. Scale bars, A = 100 µm; B–D = 10 µm.

Fig. 2 B: *Erysiphe capreae* on *Salix* ×*multinervis*. A: Conidiophore; B: Conidia; C–E: Conidia with common germ tubes (longitubus type). Scale bars = 10 µm.

Erysiphe convolvuli DC. Fig. 3

Material examined: Germany, Schleswig-Holstein, Lübeck, St. Gertrud, Israelsdorf, Hasselbruchweg, on *Convolvulus arvensis*, 24 June 2021, A. Schmidt, KM 377 (KR-M-0047507).

The conidiophores agree well with previous descriptions and illustrations (Braun & Cook 2012). The foot-cells are straight to curved-sinuous. Fresh conidia were ellipsoid-cylindrical, 36–58 × 15–21 µm, germination rate in a moist chamber high, > 50 %, germ tubes short to very long (longitubus pattern), occasionally aseptate, but usually with a single septum, near the base or up to about the middle of the germ tube, terminal appressorium lobate to multilobate in short to moderately long germ tubes, lacking to club-shaped in long germ tubes.

Fig. 3: *Erysiphe convolvuli* on *Convolvulus arvensis*. A: Conidia; B–D: Conidia with germ tubes. Scale bars = 10 µm.

Erysiphe divaricata (Magnus) U. Braun & S. Takam. Fig. 4

Material examined: Germany, Schleswig-Holstein, Lübeck, St. Gertrud, Lauerholz, Deepenmoor, on *Frangula alnus*, 28 May 2023, A. Schmidt, KM 406 (KR-M-0053051). Germany, Schleswig-Holstein, Lübeck, Lauerholz, Wesloer Moor, on *Frangula alnus*, 10 June 2023, A. Schmidt, KM 407 (KR-M-0053052).

The conidiophores agree well with previous descriptions (Braun & Cook 2012). The germination rate of the conidia was high; conidia ellipsoid, sometimes cylindrical, 26–42 × 15–20 µm, length/width ratio 1.4–2.4 (Ø 1.9), germ tubes perihilar, short to long (longitubus pattern), aseptate or with a single septum at the base, occasionally with two septa, second septum in the upper half, terminal appressorium lobate to multilobate, club-shaped or lacking in long germ tubes.

Erysiphe heraclei DC. Fig. 5

Material examined: Germany, Schleswig-Holstein, Herzogtum Lauenburg, Groß Grönau, An der Gärtnerei 1, cultivated, on *Foeniculum vulgare*, 26 Aug. 2020, A. Schmidt, KM 371 (KR-M-0042993).

The conidiophores and conidia (cylindrical, 31–50 × 14–18 µm, length/width ratio 2.1–3.2, Ø 2.6) agree well with previous descriptions, as for example in Braun & Cook (2012: 384). The germination rate of the conidia was high (20–30 %): Conidia with a single perihilar germ tube, short and moderately long, aseptate, with a single septum near the base, occasionally with two septa, second septum elevated, up to about the middle, short germ tubes subcylindrical to slightly clavate, with a terminal appressorium, mostly multilobate, longer germ tubes without appressorium or with swollen apex, clavate.

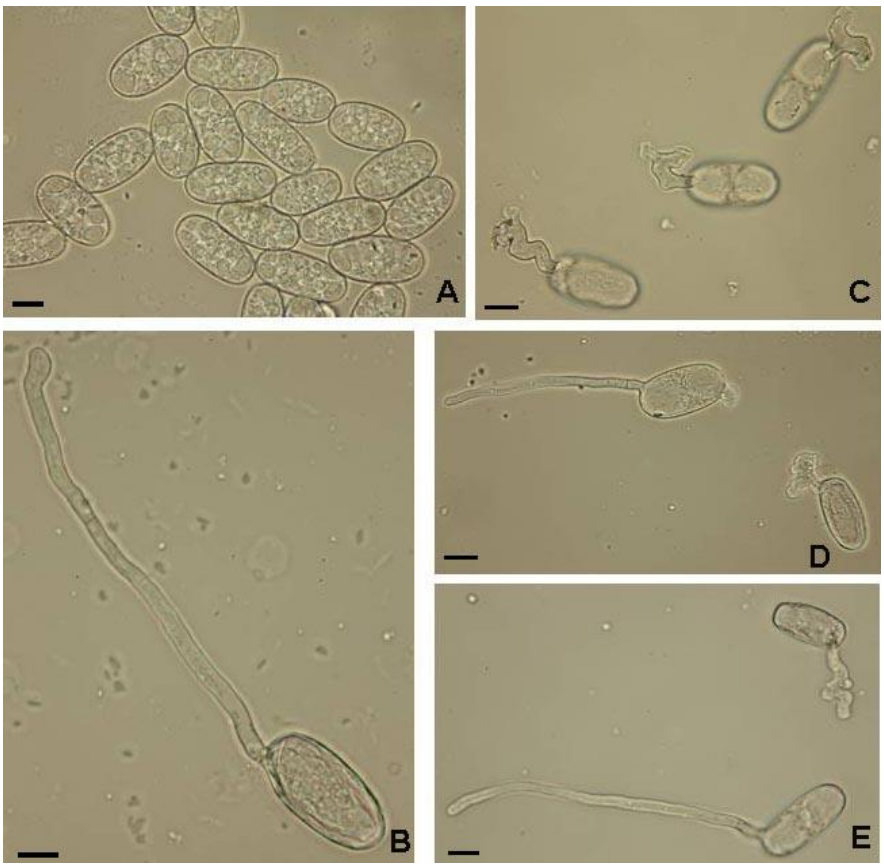

Fig. 4: *Erysiphe divaricata* on *Frangula alnus*. A: Conidia; B: Conidium with germ tube (longitubus pattern); C–E: Conidia with germ tubes (D and E with short and long germ tubes). Scale bars = 10 µm.

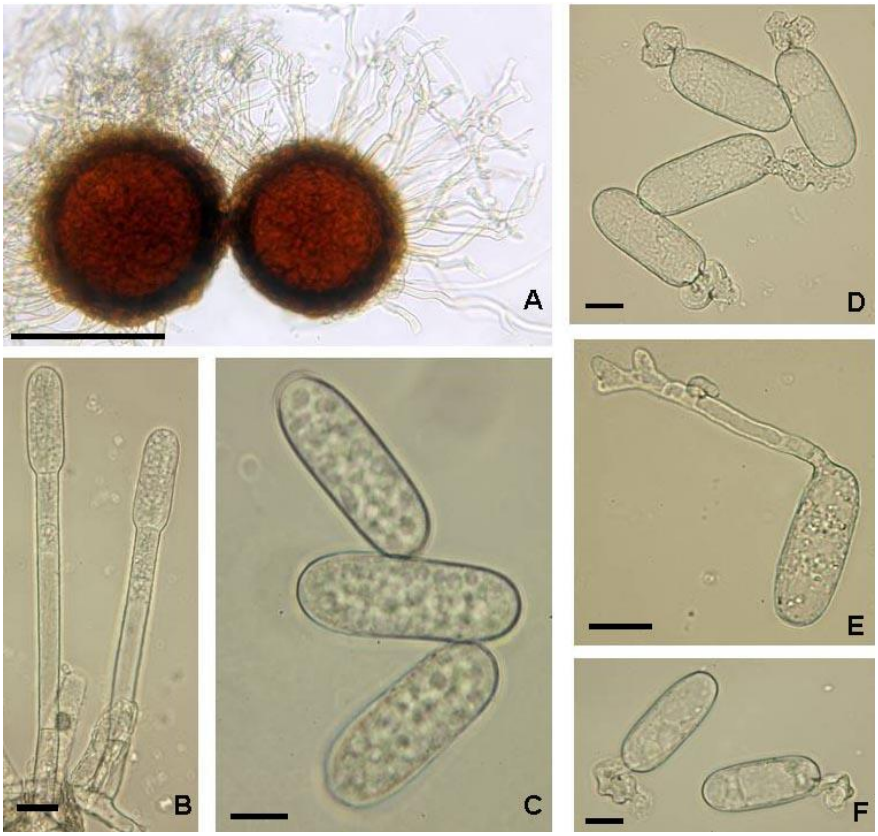

Fig. 5: *Erysiphe heraclei* on *Foeniculum vulgare*. A: Chasmothecia; B: Conidiophores; C: Conidia; D–F: Conidia with germ tubes. Scale bars, A = 100 µm, B–F = 10 µm.

Erysiphe lycopsidis R.Y. Zheng & G.Q. Chen Fig. 6

= *Erysiphe asperifoliorum* var. *anchusae* U. Braun.

≡ *Erysiphe cynoglossi* var. *anchusae* (U. Braun) U. Braun.

Material examined: Germany, Niedersachsen, Landkreis Lüneburg, Nahrendorf (Göhrde), on *Anchusa arvensis*, 21 Oct. 2018, A. Schmidt, KM 351 (KR-M-0006642), holomorph.

Chasmothecia are developed, 110–130 µm diam., with few short appendages, brown; asci with 3–4(–5) ascospores, falling within the morphological range of this species. Mycelium with lobate hyphal appressoria. The conidia are formed singly, ellipsoid-doliiform, sometimes cylindrical, 30–48.5 × 18–24.5 µm, length/width ratio 1.4–2.4, on average 1.9; germination rate high in a moist chamber (30–50 %); with a single perihilar germ tube, usually short (typical longitubus pattern not developed), short cylindrical to clavate, germ tubes without septum or with a single septum at or near the base, terminal appressorium swollen (club-shaped) to usually slightly lobate to multilobate.

So far, a detailed description of the conidial germination of *Erysiphe lycopsidis* has not yet been available. Braun & Cook (2012: 393, fig. 448) only depicted a single conium with a germ tube formed in vivo.

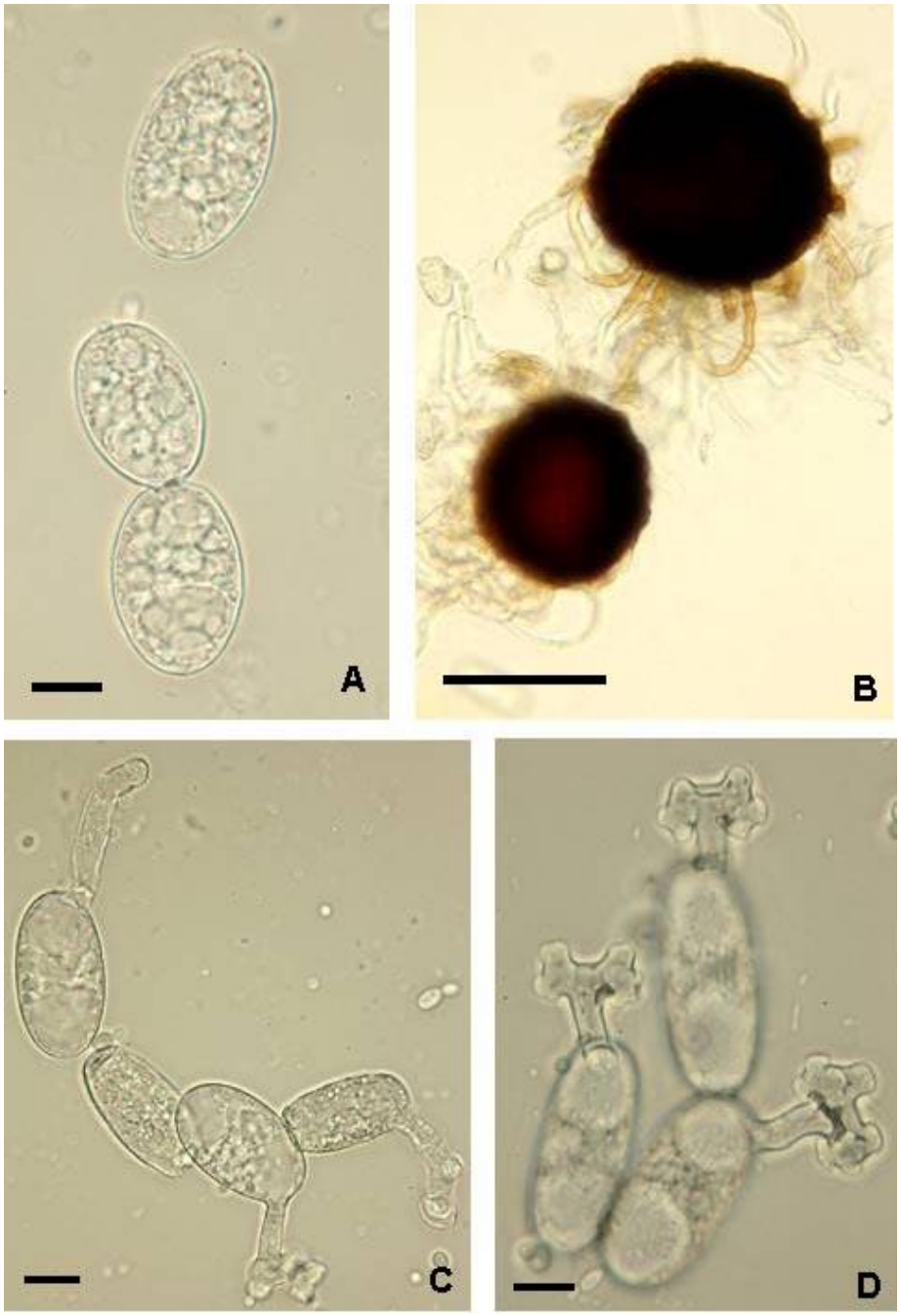

Fig. 6: *Erysiphe lycopsidis*. A: Conidia; B: Chasmothecia; C–D: Conidia with germ tubes. Scale bars = 10 µm (A,C,D), = 100µm (B).

Erysiphe radulescui Docea Fig. 7

Material examined: Germany, Schleswig-Holstein, Herzogtum Lauenburg, Groß Grönau, An der Gärtnerei 1, cultivated, on *Eutrema japonica*, 1 Aug. 2020, A. Schmidt, KM 367 (KR-M-0042984), anamorph; ibid., on *Eutrema japonica*, 20 Aug. 2020, A. Schmidt, KM 367 (KR-M-0042994), with teleomorph.

The conidiophores, conidia and conidial germination agree well with the description recently given in Bradshaw et al. (2024). In the latter work, *Erysiphe cruciferarum* has been split into three species, viz., *E. cruciferarum* s. str., *E. radulescui*, and *E. alliariicola*. Sequence data retrieved from powdery mildew on wasabi were available and confirmed that it pertains to *E. radulescui*. The conidia on wasabi are ellipsoid to usually cylindrical, 32–48 × 14–18 µm, length/width ratio 1.8–3.2, (Ø 2.5), germ tubes perihilar, short to moderately long, aseptate or with a single septum near the base, occasionally with two septa, second septum in the upper half, terminal appressorium club-shaped, lobate to multilobate. Chasmothecia 110–140 µm diam., peridium cells 10–24 µm diam., appendages numerous, 0.3–2.9 times as long as the chasmothecial diam., mycelioid, septate, thin-walled, brown below, hyaline towards the apex, only with a few fully developed 3–5-spored asci.

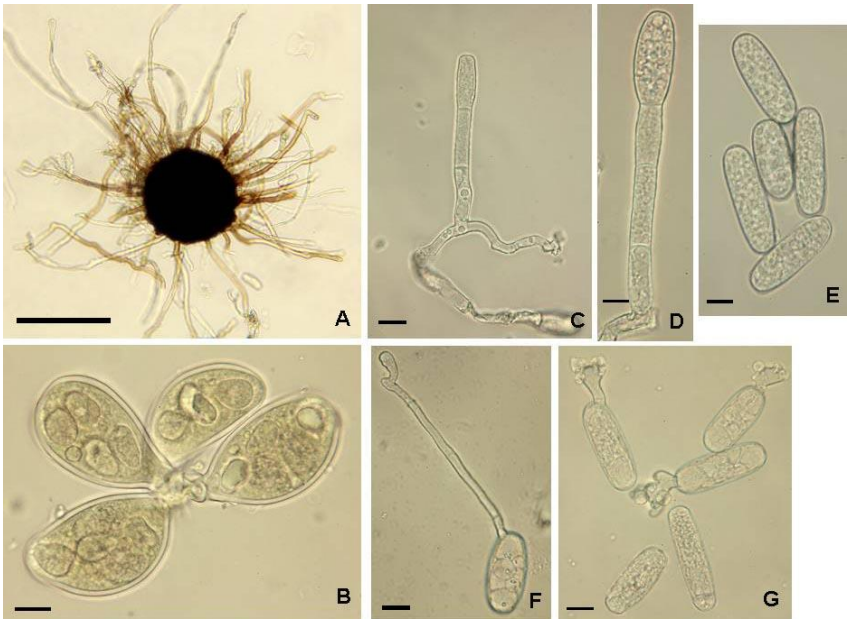

Fig. 7: *Erysiphe radulescui* on *Eutrema japonica*. A: Chasmothecium; B: Asci; C, D: Conidiophores; E: Conidia; F: Conidium with long germ tube (longitubus pattern); G: Conidia with germ tubes. Scale bars, A = 100 µm, B–G = 10 µm.

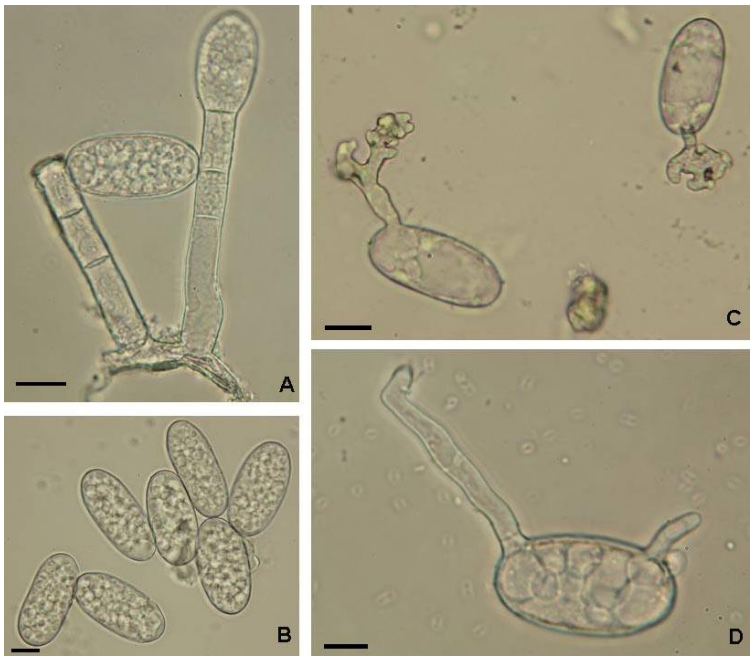

Fig. 8: *Erysiphe sedi* on *Hylotelephium telephium*. A: Conidiophores; B: Conidia; C, D: Conidia with germ tubes. Scale bars = 10 µm.

Erysiphe sedi U. Braun Fig. 8

Material examined: Germany, Schleswig-Holstein, Herzogtum Lauenburg, Groß Grönau, An der Gärtnerei 1, cultivated, on *Hylotelephium telephium*, 13 Aug. 2021, A. Schmidt, KM 384 (KR-M-0047503).

Erysiphe sedi pertains to the *E. aquilegiae* complex (Bradshaw et al. 2023). The conidiophores agree well with previous descriptions, including Braun & Cook (2012: 408). The conidial germination rate was high (c. 30 %). The conidia are ellipsoid-cylindrical, 34–50 × 16.5–22 µm, length/width ratio 1.6–2.9 (Ø 2.1); usually with a single germ tube, rarely two, perihilar, occasionally arising from the apex, short to moderately long (typical longitubus pattern not developed), cylindrical to clavate, with a single septum at or near the base, conidial appressoria swollen or usually slightly to multilobate.

Euoidium

Euoidium pseudolongipes (U. Braun & Gabler) U. Braun & R.T.A. Cook Fig. 9

≡ *Oidium pseudolongipes* U. Braun & Gabler.

Material examined: Germany, Schleswig-Holstein, Herzogtum Lauenburg, Groß Grönau, An der Gärtnerei 1, cultivated, on *Exacum trinervium*, 15 Jul. 2023, A. Schmidt, KM 410 (KR-M-0053055).

The characteristics of the hyphal appressoria and very long conidiophores with elevated basal septum agree very well with the previous description published by Braun & Cook (2012: 336–337). The catenescent conidia are ellipsoid, doliiform, and limoniform, 24–34.5 × 14–22, length/width ratio 1.3–2.1 (Ø 1.7). The germination pattern of *E. pseudolongipes* has so far not been described in detail. In a moist chamber a single moderately long to very long perihilar to occasionally lateral germ tube is formed per conidium, straight and cylindrical to curved-sinuous, longer ones filiform, septum lacking or with a single septum near the base, occasionally with two septa in rather long germ tubes, second septum in the upper half, terminal appressoria lacking or almost so or with swollen apex (clavate appressorium).

Fig. 9: *Euoidium pseudolongipes* on *Exacum trinervium*. A: Conidiophore. B: Conidia; C, E, F: Conidia with germ tubes; D: Conidial chain. Scale bars = 10 µm.

Golovinomyces

Golovinomyces artemisiae (Grev.) Heluta Fig. 10

Material examined: Germany, Schleswig-Holstein, Lübeck, Karlshof, Glashüttenweg, on *Alchemilla millefolium*, 22 Jul. 2023, A. Schmidt, KM 409 (KR-M-0053054).

The characteristics of the conidiophores agree well with previous descriptions, including Braun & Cook (2012: 301). The catenescent conidia are broad ellipsoid, ovoid, doliiform to limoniform, 29–38(–43) × 20–26(–26.5) µm, length/width ratio 1.3–1.8 (Ø 1.5), in a moist chamber a single perihilar germ tube is formed, short to very long (longitubus pattern), cylindrical to filiform, straight to curved-sinuous, often aseptate, sometimes with a single septum up to the middle, apex undifferentiated or swollen, i.e., with a clavate appressorium.

Fig. 10: *Golovinomyces artemisiae* on *Alchemilla millefolium*. A: Conidia; B–F: Conidia with germ tubes. Scale bars = 10 µm.

Golovinomyces bolayi S. Takam., Lebeda & M. Götz Fig. 11

Material examined: Germany, Schleswig-Holstein, Lübeck, St. Gertrud, Israelsdorf, Hasselbruchweg, on *Cichorium intybus*, 18 June 2020, A. Schmidt, KM 365 (KR-M-0042989).

The characteristics of the conidiophores agree well with the recent description of *G. bolayi* published in Braun et al. (2019). However, a detailed description of the conidial germination has not been given in the latter publication. The catenescent conidia are ellipsoid-cylindrical to doliiform, 26–36 × 16–21 µm, length/width ratio 1.4–2.1 (Ø 1.8), germination rate in a moist chamber high (20–30 %), usually with a single perihilar germ tube, occasionally with two germ tubes, short, usually not longer than the conidial length, subcylindrical to clavate, aseptate or mostly with a single septum near the base, occasionally with two septa, second septum up to the upper half, apex undifferentiated to usually swollen, i.e., with the club-shaped, occasionally sublobate appressorium.

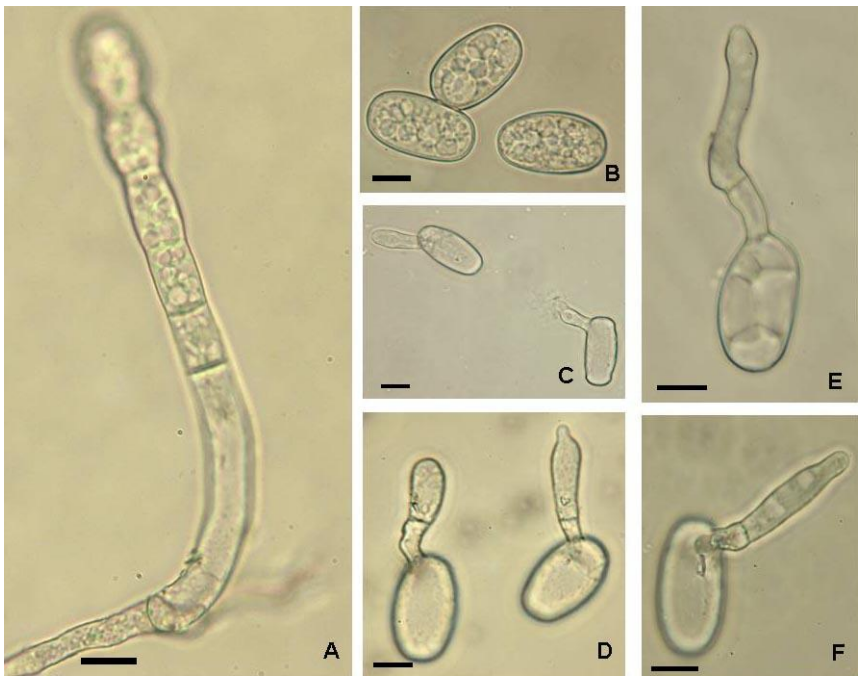

Fig. 11: *Golovinomyces bolayi* on *Cichorium intybus*. A: Conidiophores; B: Conidia; C−F: Conidia with germ tubes. Scale bars = 10 µm.

Golovinomyces macrocarpus (Speer) U. Braun Fig. 12

Material examined: Germany, Schleswig-Holstein, Lübeck, Kücknitz (Herrenwyk), on *Tanacetum vulgare*, 25 Sep. 2021, A. Schmidt, KM 385 (KR-M-0047513).

The characteristics of the conidiophores agree well with previous descriptions, including Braun & Cook (2012: 319). However, the conidial germination was not described in detail in the latter publication. The germination rate of *G. macrocarpus* in a moist chamber was low (< 5%). The catenescent conidia were ellipsoid-doliiform, 24–40 × 18–21 µm, length/width ratio 1.3–2.2 (Ø 1.6), with a single perihilar germ tube, short, moderately long to long, subcylindrical, clavate, filiform, aseptate or with a single elevated septum, up to the middle, sometimes even up to the upper half, apex undifferentiated or swollen, i.e., with a club-shaped appressorium.

Fig. 12: *Golovinomyces macrocarpus* on *Tanacetum vulgare*. A: Conidia; B−E: Conidia with germ tubes. Scale bars = 10 µm.

Podosphaera

Podosphaera euphorbiae (Castagne) U. Braun & S. Takam. Fig. 13

Material examined: Germany, Schleswig-Holstein, Lübeck, St. Gertrud, Israeldorf, Buchenweg, on *Euphorbia peplus*, 28 Aug. 2022, A. Schmidt, KM 403 (KR-M-0050991); Schleswig-Holstein, Lübeck, St. Gertrud, Israeldorf, Buchenweg, on *Euphorbia peplus*, 22 Sep. 2022, A. Schmidt, KM 404 (KR-M-0050992); Baden-Württemberg, Karlsruhe, centre of the city, on *Euphorbia peplus*, 20 June 2022, M. Scholler, KM 389 (KR-M-0050994), with chasmothecia.

Additional specimens examined (only morphology, i.e., without conidial germination): Germany, Thüringen, Landkreis Sonneberg, east of Schalkau, on *Euphorbia cyparissias*, 1 Oct. 2017, A. Schmidt, KM 342 (KR-M-0049603); Hessen, Werra-Meißner-Kreis, Bad Sooden-Allendorf, northern slope of Spitzenberg and Heiligenberg, on *Euphorbia helioscopia*, 2 Oct. 2019, A. Schmidt, KM 361 (KR-M-0013224); Sachsen-Anhalt, Burgenlandkreis, Naumburg, OT Bad Kösen, bus stop in front of the church, on *Euphorbia myrsinites* (cult.), 26 Nov. 2019, W. Henschel, KM 363 (KR-M-0013221).

Euphorbia peplus is the type host of *Podosphaera euphorbiae*. The conidia and conidial germination on this host is characterised as follows: The catenescent ellipsoid-cylindrical conidia are 24–34 × 12–16 µm, length/width ratio 1.9–2.6 (Ø 2.2), with fibrosin bodies; conidia with a single, occasionally two germ tubes, perihilar to lateral, short and cylindrical to clavate or moderately long, straight to curved or somewhat sinuous, aseptate or with a single septum at or near the base, occasionally somewhat elevated, apex undifferentiated to swollen (club-shaped).

The additional morphologically examined specimens on *Euphorbia cyparissias*, *E. helioscopia*, and *E. myrsinitis* are in full agreement with the anamorphic characteristics of *Po. euphorbiae*. The conidia are characteristically short and narrow, and usually cylindrical [on *E. cyparissias* 20–29 × 9.5–12 µm, length/width ratio 1.8–2.8 (Ø 2.4), from dried material, on *E. helioscopia* 23–32.5 × 11,5–17µm, length/width ratio 1.6–2.3 (Ø 2.0), (fresh), on *E. myrsinitis* 26–34 × 12–15.5 µm, length/width ratio 1.7–2.8 (Ø 2.2) (fresh)]. The identity of *Oidium cyparissiae* (≡ *Fibroidium cyparissiae*) and its relation to *Po. euphorbiae* is questionable und unresolved. Sydow (1897) described *O. cyparissiae* with rather long cylindrical conidia, 35–45 × 10–15 µm, which is much longer than in *Po. euphorbiae*. Therefore, Braun & Cook (2012) maintained this species as *Fibroidium cyparissiae*. It is necessary to re-examine type material of *O. cyparissiae* to prove the correctness of Sydow's measurements.

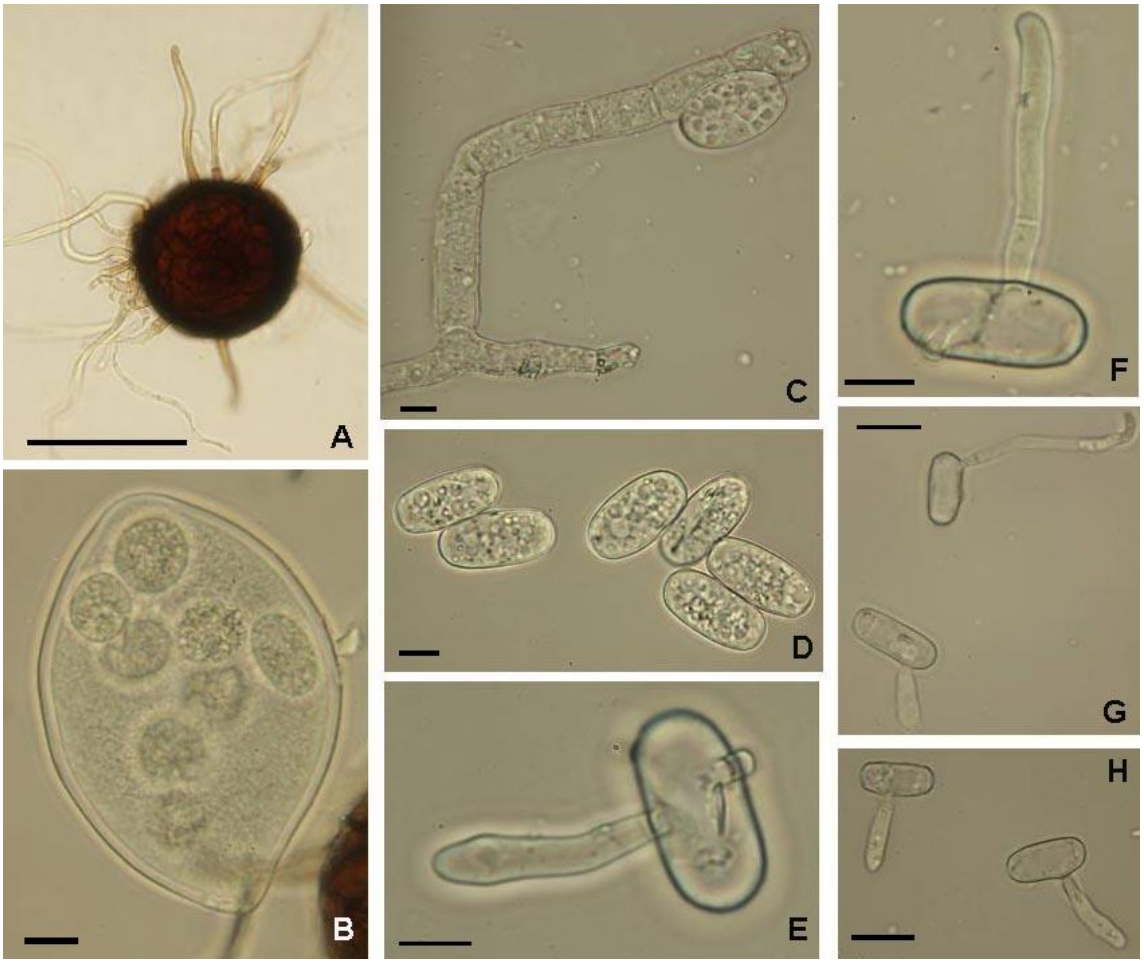

Fig. 13: *Podosphaera euphorbiae* on *Euphorbia peplus*. A: Chasmothecium; B: Ascus; C: Conidiophore; D: Conidia; E–H: Conidia with germ tubes. Scale bars, A = 100 µm, B–F = 10 µm, G, H = 30 µm.

Podosphaera leucotricha (Ellis & Everh.) E.S. Salmon Fig. 14

Material examined: Germany, Schleswig-Holstein, Herzogtum Lauenburg, Groß Grönau, An der Gärtnerei 1, cultivated, on *Photinia ×fraseri*, 30 June 2023, A. Schmidt, KM 408 (KR-M-0053053).

The catenescent conidia were ellipsoid, 22–30 × 13–18 µm, length/width ratio 1.5–2.0 (Ø 1.8), with fibrosin bodies; germination rate high, conidia with a single germ tube, perihilar to somewhat lateral, short to moderately long, cylindrical to clavate, aseptate or with a single septum at the base or somewhat elevated, apex undifferentiated or swollen, club-shaped. These characteristics agree well with the description given in Braun & Cook (2012: 106).

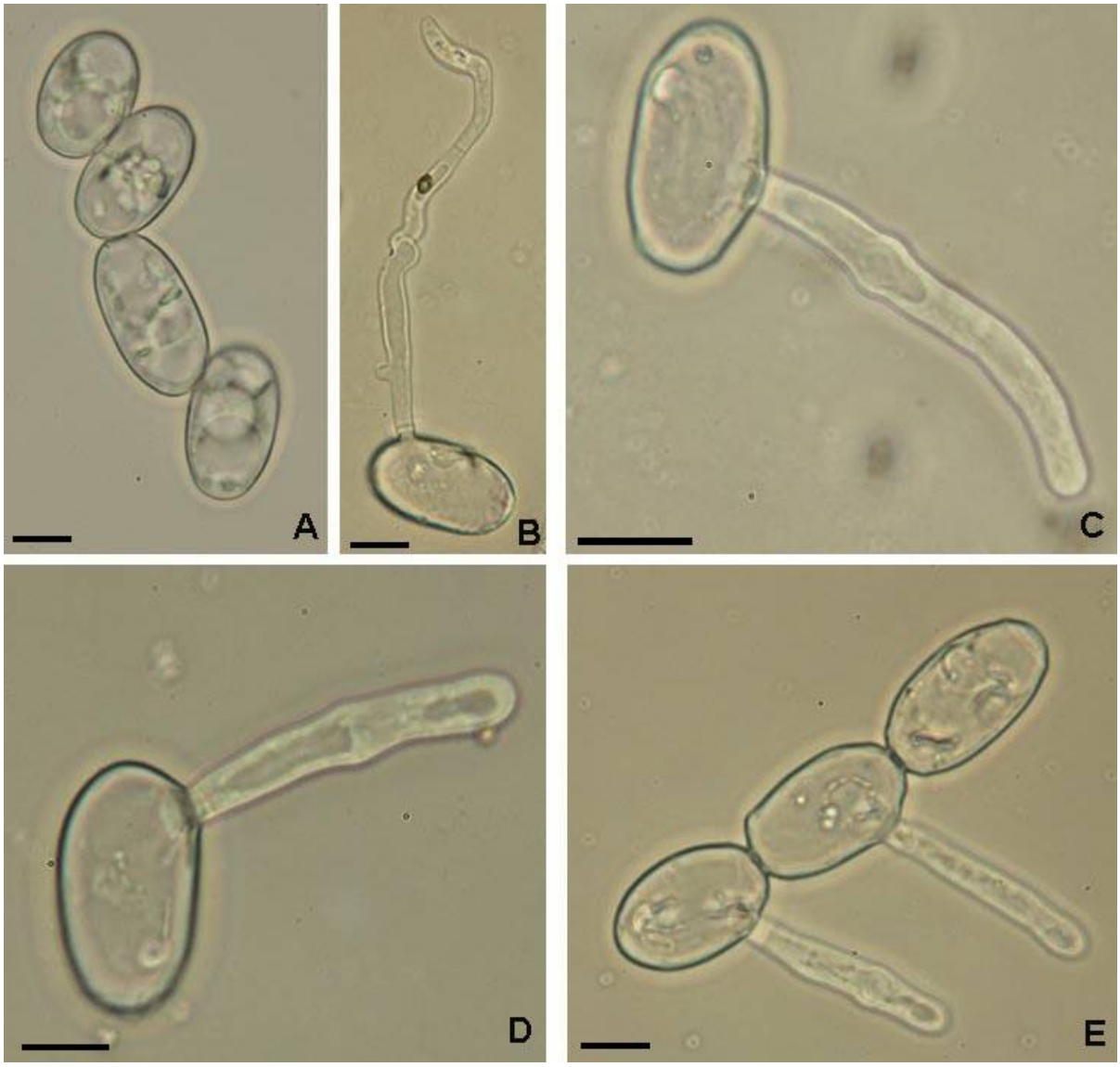

Fig. 14: *Podosphaera leucotricha* (on *Photinia ×fraseri*). A: Conidia; B–E: Conidia with germ tubes. Scale bars = 10 µm.

Podosphaera macrospora (U. Braun) U. Braun & V. Kumm. Figs. 15

Material examined: Germany, Schleswig-Holstein, Herzogtum Lauenburg, Groß Grönau, An der Gärtnerei 1, cultivated, on *Heuchera ×brizoides* ('*Heuchera* × *hybrida*'), 1 Aug. 2022, A. Schmidt, KM 399 (KR-M-0050989).

The catenescent conidia with fibrosin bodies are ellipsoid-ovoid to doliiform, relatively large, 32–44 × 16–22 µm, length/width ratio 1.5–2.5 (Ø 1.9), germination rate moderate, germ tubes perihilar to usually lateral, common Brevitubus subtype of the *Fibroidium* type (Braun & Cook 2012: 22), short cylindrical to clavate, occasionally shallowly forked, two-armed, aseptate, occasionally with a single basal septum, apex undifferentiated to club-shaped.

Notes: This is the first description of the conidial germination of *Podosphaera macrospora*. The germination pattern agrees well with most species of *Podosphaera* with large peridium cells and mycelioid chasmothecial appendages (subsect. *Magnicellulatae*).

Fig. 15: *Podosphaera macrospora* on *Heuchera ×brizoides*. A: Conidia; B: Conidium with conspicuous fibrosin bodies; C−F: Conidia with germ tubes. Scale bars = 10 µm.

Podosphaera mors-uvae (Schwein.) U. Braun & S. Takam. Fig. 16

Material examined: Germany, Schleswig-Holstein, Herzogtum Lauenburg, Groß Grönau, An der Gärtnerei 1, cultivated, on *Ribes rubrum*, 11 June 2020, A. Schmidt, KM 364 (KR-M-0042983).

The catenescent conidia with mostly conspicuous fibrosin bodies are ellipsoid-doliiform, 23–31 × 16–20.5 µm, length/width ratio 1.2–1.6 (Ø 1.4). The germination rate of the conidia is high (20 to 30 %), conidia with a single, rarely two germ tubes, terminal, perihilar or lateral, short cylindrical to clavate or moderately long, aseptate, with a single septum at the base or in the upper half, occasionally with two septa, one at the base and the other one in the upper half, germ tubes simple or branched, forked at the apex or with short lateral outgrowths, apex undifferentiated to club-shaped.

Notes: The conidial size of the examined specimens agrees well with the specification given in Braun & Cook (2012). However, a detailed description of the conidial germination is not given in the latter publication.

Fig. 16: *Podosphaera mors-uvae* on *Ribes rubrum*. A: Conidiophores; B: Conidia; C−E: Conidia with germ tubes. Scale bars = 10 µm

Podosphaera phtheirospermi (Henn. & Shirai) U. Braun & T.Z. Liu Fig. 17

Material examined: Germany, Schleswig-Holstein, Lübeck, Herrenwyk, on *Odontites vulgaris*, 23 June 2004, A. Schmidt, KM 381 (KR-M-0047505), with chasmothecia.

The catenescent conidia are ellipsoid-doliiform, 23–33 × 14.5–20 µm, length/width ratio 1.3–2.1 (Ø 1.7), with conspicuous fibrosin bodies. The germination rate was high (c. 20 %), germination pattern belonging to the Brevitubus subtype of the *Fibroidium* type (Braun & Cook 2012: 22), germ tubes perihilar to lateral, characteristically short and aseptate, cylindrical to clavate, but mostly shallowly forked, two-armed, sessile, subsessile, or only with a very short supporting stalk.

Notes: The shape and size of the conidia of the examined specimen agree very well with the description given in Braun & Cook (2012). However, the conidia germination was not described in the latter work.

Fig. 17: *Podosphaera phtheirospermi* on *Odontites vulgaris*. A: Conidiophore; B: Conidia; C−E: Conidia with germ tubes. Scale bars = 10 µm

Sawadaea

Sawadaea bicornis (Wallr.) Homma Fig. 18

Material examined: Germany, Schleswig-Holstein, Lübeck, centre, on *Acer campestre*, 9 Jul. 2021, A. Schmidt, KM 379 (KR-M-0047508).

Braun & Cook (2012: 16, fig. 7 I; 174) described and illustrated the conidial germination pattern of *Sawadaea bicornis* and assigned it to the Orthotubus subtype of the *Fibroidium* type. The conidial germination performed with conidia formed on *Acer campestre* agrees well with the description and illustration in Braun & Cook (2012). The macro-conidia were broad ellipsoid-doliiform, short cylindrical to angular, 27–38.5 × 15–21 µm, length/width ratio 1.3–2.4 (Ø 1.8), fibrosin bodies conspicuous, with a single perihilar to lateral germ tube, subcylindrical to clavate, short (about as long as the conidial length) to moderate long (to about three times the conidial length), aseptate or with a single septum near the base, but always somewhat elevated, apex undifferentiated to usually swollen, club-shaped.

Fig. 18: *Sawadaea bicornis*. A: Conidiophore; B: Conidia; C, D: Conidia with germ tubes. Scale bars = 10 µm.

Fig. 19: *Sawadaea tulasnei*. A: Conidiophore; B: Conidia; C−E: Conidia with germ tubes. Scale bars = 10 µm.

Sawadaea tulasnei (Fuckel) Homma Fig. 19

Material examined: Germany, Schleswig-Holstein, Lübeck, Israeldorf, Holunderweg, on *Acer platanoides*, 4 Aug. 2021, A. Schmidt, KM 383 (KR-M-0047511); Schleswig-Holstein, Lübeck, St. Gertrud, Park Street, on *Acer platanoides*, 19 Jul. 2022, A. Schmidt, KM 397 (KR-M-0051083); Schleswig-Holstein, Ostholstein, Scharbeutz, Kurpark, on *Acer platanoides*, 24 Jul. 2022, A. Schmidt, KM 398 (KR-M-0050988).

The conidiophores in the examined specimens agree well with the description given in Braun & Cook (2012). The germination rate was relatively low (c. 10–15 %), above all in KM 397. The description of the conidial germination is based on KM 383 and KM 398. Macro- and microconidia developed, micro-conidia do not germinate. Macro-conidia broad ellipsoid-doliiform, 20–28 × 14–20 µm, length/width ratio 1.1–1.7 (Ø 1.4), with conspicuous fibrosin bodies, conidia with a single germ tube, perihilar to lateral, short to rather long, subcylindrical, clavate, stout to somewhat irregularly shaped, aseptate, with a single septum near the base or elevated up to the upper half, occasionally with two elevated septa, apex undifferentiated to usually swollen, club-shaped.
Notes: Braun & Cook (2012: 16, fig. 7 I) assigned the conidial germination pattern of *Sawadaea* to the Orthotubus subtype of the *Fibroidium* type and provided an illustration of this type in *S. bicornis*. However, the conidial germination of *S. tulasnei* was not described. The conidial germination of *S. tulasnei* agrees well with the orthotubus subtype.

Corrigenda to Schmidt & Braun (2020)

Schmidt & Braun (2020: 40, Fig. 14 C): This figure refers to a germinated conidium of *Erysiphe howeana* (not *E. buhrii*).

Schmidt & Braun (2020: 53, *Erysiphe trifoliorum* (Wallr.) U. Braun s. lat. on *Lathyrus* spp.): The identity of *Lathyrus* 'cf. *heterophyllus*' (unknown from norther Germany) has been corrected to *Lathyrus* cf. *latifolius* (by V. Kummer und M. Ristow). *Erysiphe pseudogegularis* U. Braun, treated in Schmidt & Braun (2020), turned out to be a synonym of *E. capreae* (Darsaraei et al. 2021).

Discussion

Schmidt & Braun (2020) discussed in detail the history of the exploration of the conidial germination patters of powdery mildews and emphasized the significance for the taxonomy of this fungal group and for diagnostic purposes (Neger 1902, Hirata 1955, Braun 1977, Zaracovitis 1965, Braun et al. 2002). Braun & Cook (2012: 15–22) outlined a comprehensive and detailed new system of conidial germination types, subtypes, and patterns, reflecting basic types linked with powdery mildew genera and sections, but also specific variations characteristic for individual species. There is still a considerable lack of information on the specific traits of conidial germinations for numerous powdery mildew species, even for common, widespread species. There are only few publications, such as Shin (2000), with comprehensive, detailed descriptions and illustrations of conidial germinations. The present series aims at filling this gap.

The present contribution provides first descriptions of conidial germination details for *Erysiphe lycopsidis*, *Euoidium pseudolongipes*, *Golovinomyces bolayi*, *G. macrocarpus*, *Podosphaera euphorbiae* (on its type host *Euphorbia peplus*), *P. macrospora*, *P. mors-uvae*, *P. phtheirospermi* and *Sawadaea tulasnei*. The results of our examinations are not surprising. The different conidial germination types correlate with powdery mildew genera, sections, and subsections. The germination pattern of all examined *Erysiphe* species, including *E. lycopsidis*, coincides with the *Pseudoidium* type, which is characteristic for *Erysiphe* (Braun & Cook 2012: 351), except for *E. capreae*, which differs in having predominantly very long germ tubes. Germ tubes belonging to the longitubus pattern of the *Pseudoidium* type have been found in most *Erysiphe* spp., including *E. aquilegiae*, *E. convolvuli*, *E. divaricata*, and *E. radulescui*, but this pattern was lacking or less evident in *E. lycopsidis* and *E. sedi*. *Euoidium pseudolongipes* possesses a conidial germination type that is in line with the longitubus pattern within the *Euoidium* type, characteristic for *Golovinomyces* sect. *Depressi* (Braun & Cook 2012: 294). The germination types of all examined *Golovinomyces* spp. have also been as expected. *G. artemisiae*, a species of sect. *Depressi*, exhibits a typical longitubus pattern within the *Euoidium* type. The germinated conidia of *E. bolayi* pertain to the common *Euoidium* type, and *G. macrocarpus* is characterised by a mixture of common *Euoidium* type and longitubus pattern. Within the observed conidial germination types of examined *Podosphaera* species, there were no surprises as well. *P. euphorbiae* and *P. mors-uvae* are two species of sect. *Sphaerotheca* subsect. *Sphaerotheca*. The characteristics of the conidia germination agree with the Orthotubus subtype of the *Fibroidium* type, as in other species of this subsection. All species pertaining to subsection *Magnicellulatae* exhibit the common brevitubus subtype of the *Fibroidium* type (Braun & Cook 2012: 22). A first detailed description of the conidia germination is given for *Sawadaea tulasnei*. It coincides with the general traits of *Sawadaea* species and belongs to the Orthotubus subtype of the *Fibroidium* type (Braun & Cook 2012: 22). In contrast to species of most other powdery mildew genera, the germination rate of the conidia in *Sawadaea* species is very low, which might be a general

characteristic for species of this genus. However, for general conclusions, additional, above all Asian *Sawadaea* species must be examined in this respect.

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