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# Arthropod-pathogenic Entomophthorales from Switzerland. IV. Second addition

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A re-examination of the author's collection revealed data of 21 entomophthoralean fungi. Most of the data sets are incomplete but should inspire entomologists and insect mycologists to further investigations. A new species, *Erynia thurgoviensis*, from an unidentified Psychodidae is described. Four further sets allowed to identify *Pandora bibionis* Li *et al.*, *P. delphacis* (Hori) Humber, *Zoophthora forficulae* (Giard) Batko and *Z. obtusa* Bałazy as new Swiss records. Seven data sets allowed a provisional attribution to a known species and a further seven sets didn't allow any conclusions. Hitherto unknown data are given for *Batkoa apiculata* and *Erynia ovispora*. It may be assumed that some new species of Entomophthoraceae are among the material described here. The new combination *Zoophthora aphrophorae* (Rostrup) S. Keller is validated.

Key words: Entomopathogenic fungi, Entomophthorales, *Erynia thurgoviensis* sp. nov., new records, catalogue, fungal diversity.

## INTRODUCTION

During many years the author collected arthropods infected with Entomophthorales (Fungi, Entomophthoromycotina) in Switzerland. From this collection 88 species were attributed to existing taxa or described as new species (Keller 2008). However, a lot of material, usually consisting of only a very low number of infected hosts remained unidentified. The fungi were only mounted, the structures measured and the nuclei counted whenever possible. Only recently the material and the data were subjected to a re-examination. The results are presented in this paper.

## MATERIAL AND METHODS

Dead insects with and without external signs of fungus diseases were collected. A small part of the collection was immediately placed in 70 % ethanol. Most of the collection was transported to the laboratory and placed in small Petri dishes on wet filter paper or on the surface of water to induce sporulation. The actively projected conidia were collected with a slide or picked up from the water surface. Conidia and cadavers dissected in small pieces were mounted in lactophenol-aceto-orcein (LPAO), exceptionally in lactophenol-anilin blue (LPAB). Details on preparation, staining and mounting techniques are given elsewhere (Keller 1987, 1991). The length/diameter ratio of the conidia is abbreviated with «Q» for quotient.

The record list starts with the new species, followed by the new Swiss records, new data on old records, records of species with uncertain identity but with similarities with known species and records of incompletely known fungi. Within these groups the fungi are listed in alphabetical order. The names of the cantons, where the finding sites are located, are given with the official abbreviations: TG stands for Thurgau, SG for St. Gallen, SH for Schaffhausen and ZH for Zurich.

RESULTS

*New species*

### *Erynia thurgoviensis* S. Keller sp. nov.

Plate 1, Figs. 1–7

*Rhizoidea monohyphalia, diametro 7–31 µm hapteronibus inflatibus vel sine specialis structuris. Corpora hyphalia irregularia subellipsoidea vel subovoidea. Conidiophora digitata ramosa. Conidia primaria 22–30 x 10–12 µm, mononucleata, bitunicata, elongata, ellipsoidea con papilla angusta. Cystidia distincta atenuata vel inflata subterminala. Sporae perdurantes absunt.*

*In specie nematocerum incognita (Dipteribus, Psychodidae) (hospite typico).*

*Holotypus*: ZT Myc 24147, Helvetia (Fischingen TG), coll. et leg. S. Keller, 17. July 2006, no. DP06-10, paratypus ZT Myc 24148.

*Host*: Unidentified Psychodidae (Diptera).

*Symptoms*: Dead hosts fixed to wet moss with rhizoids, bands of conidiophores white to greyish, especially well developed between head and thorax.

Rhizoids monohyphal with a diameter of 7–31 µm, endings with a few root-like holdfasts, enlarged or without specialised structures (Plate 1, fig. 2). Hyphal bodies irregularly rounded, subellipsoidal to subovoidal. Conidiophores branched, diameter basal of the branching (8–) 9 (–10) µm (1 series, n =25) (Plate 1, fig. 1). Primary conidia develop through a narrow neck at the end of the conidiophores (Plate 1, fig. 6) Primary conidia (22–) 26.5–27.0 (–30) x (10–) 10.6–10.7 (–12) µm, Q = 2.49–2.54 (2 series, n = 25), elongate, ellipsoid, slightly asymmetric, largest diameter in the central part; papilla narrow, 3–4 µm wide, conical, rounded (Plate 1, fig. 7). Cystidia powerful, tapering, many of them with a terminal or subterminal enlargement, basal diameter 14–38 µm (n = 17), terminal diameter 6–22 µm (n = 21) (plate 1, figs. 3–4). A single isolated cystidium was 430 µm long (plate 1, fig. 5). Resting spores absent.

*Etymology*: The name refers to the canton where the species was found.

*Distribution*: Fischingen (TG).

*Distinguishing characters*: The new species has similarities with *Erynia fluvialis*, *E. ovispora* and *E. variabilis*. It differs from *E. fluvialis* mainly by the larger conidia and by the shape of the cystidia. The primary conidia of *E. ovispora* have the same length but are broader and consequently they have a distinctly smaller length/diameter ratio. *Erynia thurgoviensis* differs from *E. variabilis* by the shape of the primary conidia and by the shape of the cystidia. Further, it differs from all three species by the narrower papilla.

*Remarks*: The fungus was found on two host specimens on July 17, 2006. The hosts were fixed to moss covering a steep slope through which permanently dripped water from a source. The holotype material was mounted in LPAO, the paratype material in LPAB.

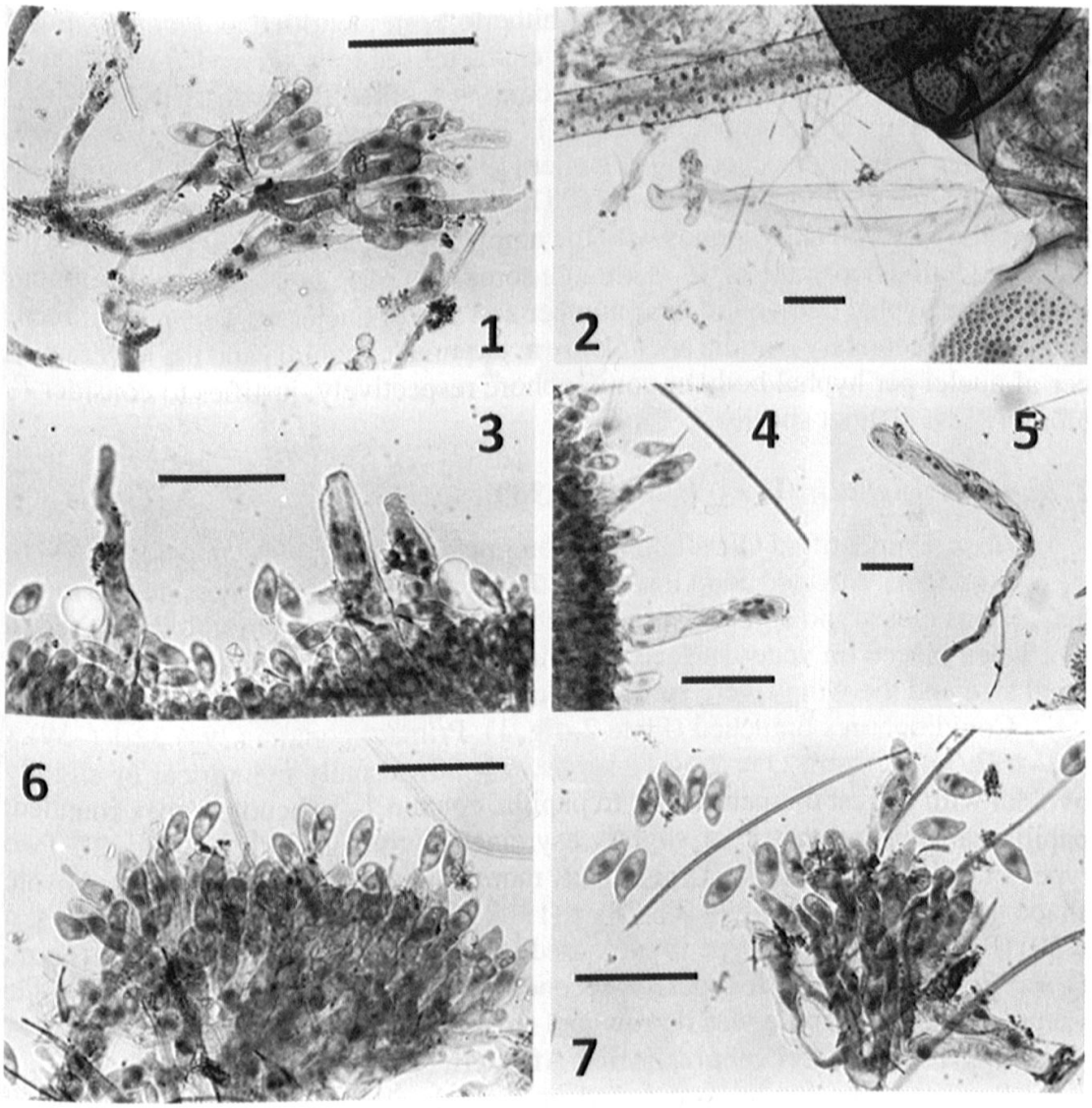


Plate 1: *Erynia thurgoviensis*. Fig. 1. Conidiophore; 2. Rhizoids; 3-4. Cystidia; 5. Isolated cystidium; 6. Formation of primary conidia; 7. Conidiophore and primary conidia. All mounted in LPAO. Bars represent 50 $\mu$m.

*New Swiss records*

**1. *Pandora bibionis* Li, Huang & Fan (1997)**

*Host*: Unidentified species of Nematocera (Diptera).

*Symptoms*: Dead insects fixed with rhizoids to the underside of leaves

Rhizoids monohyphal. Conidiophores branched with 6–12 nuclei (n = 14). Primary conidia (12–) 14.1–17.0 (–19) x (7–) 8.4–10.3 (–12) $\mu$m, Q = 1.65–1.72 (4 series, n = 25), ovoid, slightly asymmetric, bitunicate, papilla broad. Cystidia slender.

*Distribution*: Rheinau (ZH) and Rüdlingen (ZH).

*Remarks*: The species was collected in June and in October on several sciarid-like midges fixed on the underside of leaves of trees standing on the shore of the river Rhine. The data exactly match those of the original description (Li *et al.*

1997). It is possible that the species has hitherto been identified as *Pandora dipterigena* (Thaxter) Humber. This species is characterised by a very wide variation of the dimension of the primary conidia. According to the original description (Thaxter 1888) they measure on average 22 x 11 µm, with a maximum of 30 x 15 µm. The average dimension according to Keller (1991) is 15.4–26.6 x 8.7–15.9 µm with a length/diameter quotient of 1.55–2.16. This author gives the number of nuclei per hyphal body (which corresponds with the number of nuclei per conidiophores) with 9–28 and with an average of 16. Although some data of *P. bibionis*, like the dimensions of the hyphal bodies and their number and size of nuclei, as well as the dimensions of the secondary conidia are unknown, the smaller conidia and the lower number of nuclei per hyphal body or conidiophore respectively, justifies to consider *P. bibionis* as a distinct species.

**2. *Pandora delphacis* (Hori) Humber (1989)**

*Host*: Unidentified Cicadellidae (Homoptera)

*Symptoms*: Infected adult insect fixed with rhizoids to the underside of a maize leaf, wings closed, no signs of infection visible. The cadaver strongly increased in size when placed on water surface, reaching about 2–3-times the length of the original size and the wings were spread laterally.

Conidiophores branched (Plate 2, fig. 1). Primary conidia (29–) 32.1 (–39) x (12–) 12.6 (–15) µm, Q = 2.54 (1 series, n = 50), usually cylindrical or slightly ovoidal with largest diameter close to papilla, contain 1–3 vacuoles, apex rounded; papilla narrow, symmetric or slightly asymmetric, rounded (Plate 2, fig. 2). Two types of secondary conidia. Type Ia was more abundant, had an ellipsoid-obovate shape and measured (22–) 24.2 (–28) x (13–) 14.5 (–16) µm, Q = 1.66 (1 series, n = 50) (Plate 2, figs. 3–4); type Ib measured (18–) 19.2 (–21) x (13–) 14.1 (–16) µm, Q = 1.36 (n = 14). Both types of secondary conidia usually contained a single vacuole and their papilla was narrow and stretched out.

*Distribution*: Reckenholz, Zürich-Affoltern (ZH).

*Remarks*: The fungus was found on a single cicadellid collected on August 11. The species was identified mainly based on the data given by Bałazy (1993) and by the drawings of the original description, which is written in Japanese and does not contain dimensions.

**3. *Zoophthora forficulae* (Giard) Batko (1964).**

*Host*: *Forficula auricularia* L.

*Symptoms*: Infected host enclosed in a folded leaf of *Enonymus europaeus* L.

Primary conidia (17–) 20.2 (–23) x (7–) 8.6 (–10) µm, Q = 2.36 (1 series, n = 50). Capilliconidia (18–) 20.9 (–24) x (6–) 6.3 (–7) µm, Q = 3.29 (1 series, n = 50) produced on slender conidiophores with a length of (42–) 54 (–70) µm (1 series, n = 50).

*Distribution*: Neunkirch (SH)

*Remarks*: Bałazy (1993) gives the dimension of the primary conidia with 21–27 x 6.5–8 µm, that of the capilliconidia with 18.5–23.8 x 5–5.5 µm. Although the dimensions given for the Swiss record do not exactly match Bałazy's data, I attributed the species to *Z. forficulae*. The species was collected on July 23, near Neunkirch SH.

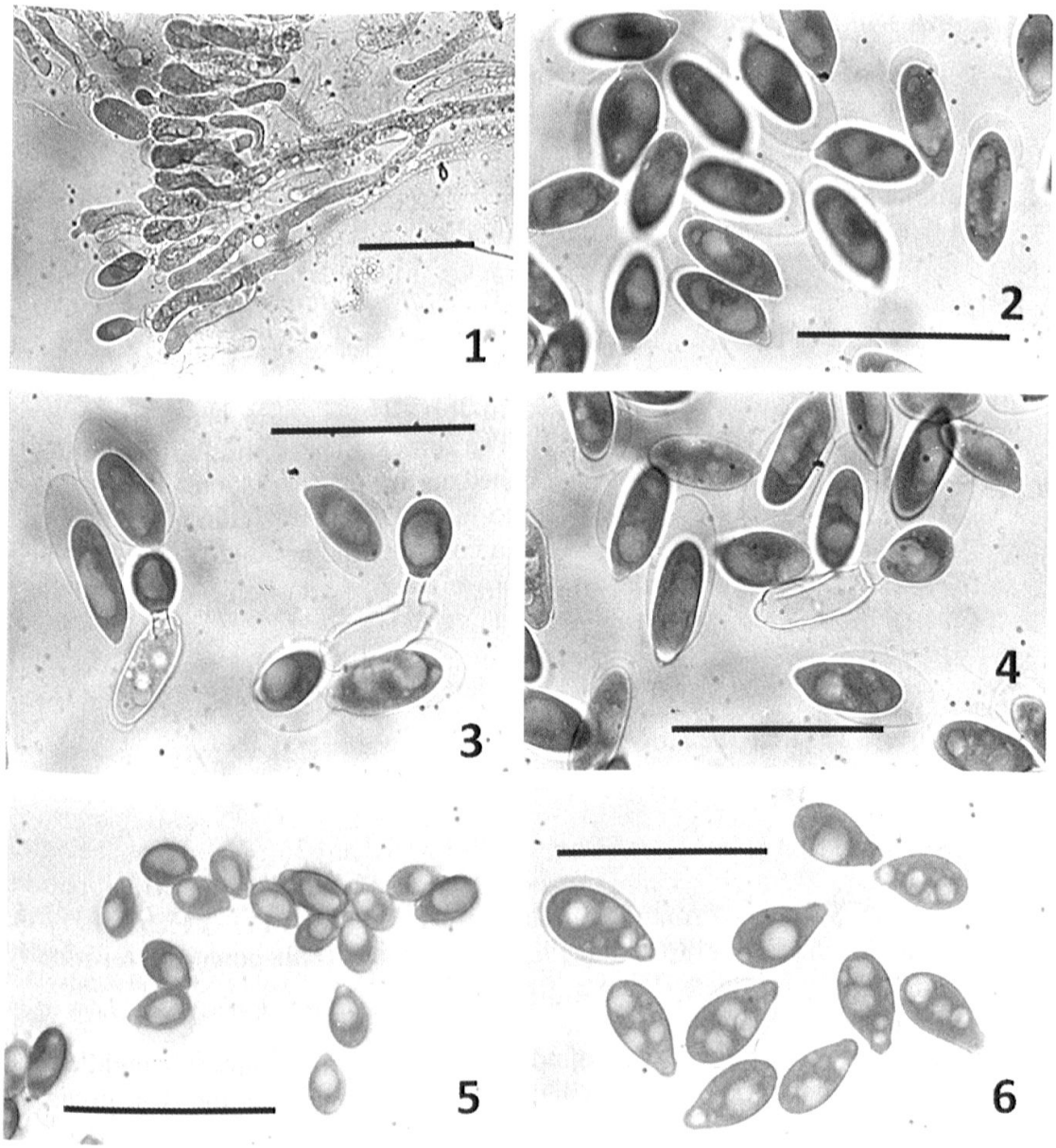


Plate 2: Figs. 1-4: *Pandora delphacis*. 1. Conidiophore; 2. Primary conidia ; 3-4: Primary conidia and formation of secondary conidia (all mounted in LPCB). Figs. 5-6 Comparison of the primary conidia between *Erynia* cf. *plecopteri* (LPAB) (Fig. 5) and *Erynia plecopteri* (LPAB) (Fig. 6). Bars represent 50 $\mu$m.

### 4. *Zoophthora obtusa* Bałazy (1993).

*Host*: Unidentified Diptera.

Primary conidia (22–) 23.8 (–27) x (6–) 7.3 (–8) $\mu$m, Q = 3.25 (1 series, n = 25). Capilliconidia (17–) 18.3 (–21) x (5–) 5.7 (–6) $\mu$m, Q = 3.21 (1 series, n = 25). Projected secondary conidia 16–19 x 7–8 $\mu$m (n = 5).

*Distribution*: Rheinau (ZH)

*Remarks*: The species was collected on a single fly on June 10, 2003. The primary conidia are slightly larger than given in the original description (18–25 x 6–7 $\mu$m, Q = 3.4; Bałazy 1993) while the secondary ones match the description. That's why I attributed the species to *Z. obtusa*, although with some hesitation.

*Old records with additional data*

**1. *Batkoa apiculata* (Thaxter) Humber (1989).**

*Host*: *Hilara* sp. (Diptera, Empididae) and unidentified flies.

*Symptoms*: Infected hosts fixed to the underside of leaves of trees.

Unbranched conidiophores with (15–) 19.5 (–27) nuclei with a diameter of (3.5–) 4.0 (–5) µm (n = 50). Primary conidia (28–) 32.0–32.2 (–36) x (23–) 26.4–26.5 (–30) µm, Q = 1.21–1.22 (3 series, n = 50), ovoid, with (15–) 19.4 (–23) nuclei) (n = 15) with a diameter of (3–) 3.4 (–4) µm, papilla rounded or pointed. Primary conidia germinate with up to 5 germ tubes.

*Distribution*: Rheinau (ZH) and Fischingen (TG).

*Remarks*: The fungi were collected in July. The species has already been reported from Switzerland (Keller 1987). The dimensions of the primary conidia given above are slightly below those published earlier but correspond with the data given by Bałazy (1993). The main reason to list *B. apiculata* again is the fact that *Hilara* is a new host genus and that the data confirms the number of 16–20 nuclei in conidiophores and primary conidia given for the first time by Mendez Sanchez *et al.* (2010).

**2. *Erynia ovispora* (Nowakowski) Remaudière & Hennebert (1980).**

*Host*: Unidentified Tipulidae (Diptera, Nematocera).

*Symptoms*: Infected insect laying on the water surface of a rain puddle on a forest path.

Rhizoids monohyphal with branched endings (Plate 3, fig 2). Hyphal bodies subspherical to ellipsoidal with 11 –15 nuclei (n = 3) (Plate 3, fig. 1). Conidiophores branched (Plate 3, fig. 3). Primary conidia (22–) 25.0 (–28) x (11–) 12.5 (–15) µm, Q = 2.0 (1 series, n = 50), ellipsoidal (Plate 3, fig. 7). Cystidia powerful, terminally enlarged or slightly bifurcate (Plate 3, figs. 4–6).

*Distribution*: Siblingen (SH).

The sporulating cadaver was found on the surface of a rainwater puddle on a forest path. The data match the original description as well as the data given by Bałazy (1993), especially concerning the cystidia. However, there are differences concerning the shape of the hyphal bodies. *Erynia ovispora* was originally described from the brachycerous fly *Lonchaea vaginalis* Fallen (Nowakowski 1877). According to Bałazy (1993) the species is oligophagous, attacking hosts of the dipteran families Lonchaeidae, Syrphidae, Sarcophagidae, Calliphoridae, Tipulidae and Psychodidae. All Swiss records so far are from Psychodidae; Tipulidae represent a new host family for Switzerland.

*Species with uncertain identity*

**1. *Entomophaga* cf. *tipulae* (Fres.) Humber (1989).**

*Host*: Unidentified species of Tipulidae or Limoniidae (Diptera, Nematocera).

*Symptoms*: Infected insect was fixed with the legs to a piece of wood about 10 cm above the water level.

Hyphal bodies spherical, subspherical to pyriform, (25–) 31.5 (–41) x (24–) 28.1 (–34) µm, Q = 1.12 (1 series) with (11–) 17.7 (–23) nuclei with a diameter of

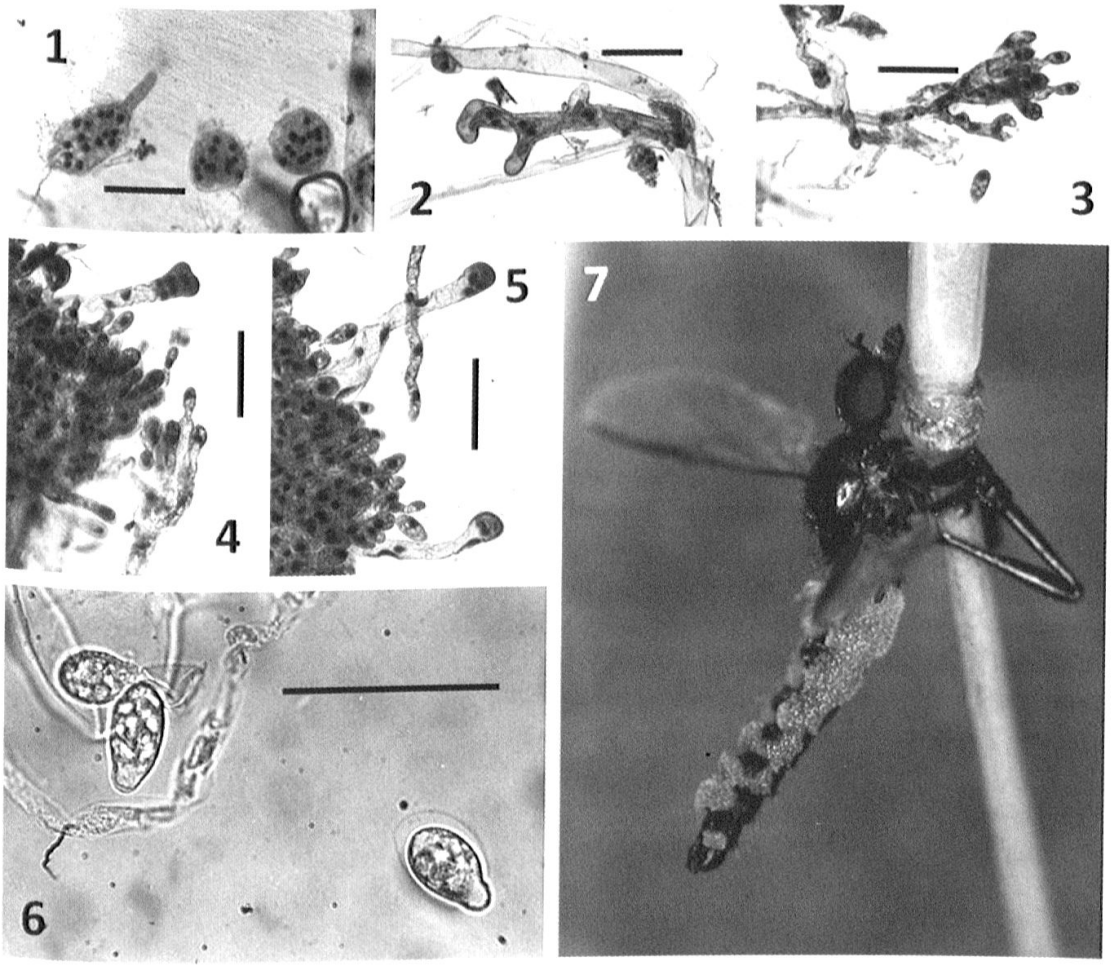


Plate 3. Figs 1-6: *Erynia ovispora* from Tipulidae. 1. Hyphal bodies; 2. Rhizoid; 3. Conidiophore; 4-5. Cystidia. 6. Primary conidia (all mounted in LPCB). Bars represent 50 $\mu$m. Fig. 7. *Entomophthora* sp. 3, sporulating cadaver of *Bibio marci* fixed with legs to a pod of oilseed rape.

(4–) 4.6 (–5.5) $\mu$m (1 series). Conidiophores unbranched with (17–) 23.1 (–30) nuclei. Primary conidia pyriform (38–) 42.3 (–48) x (24–) 29.1 (–36) $\mu$m, Q = 1.45 (1 series), usually with single prominent vacuole. Rhizoids absent.

*Culture*: Good growth on *Entomophthora* complete medium developed by Ben-Ze'ev (pers. comm.). After four weeks the colonies had a diameter of 8 cm. Aerial mycelium white to dirty white, around the inoculation point dense, otherwise loose and felt-like. Primary conidia (34–) 46.3 (–67) x (24–) 36.7 (–54) $\mu$m, Q = 1.26 (1 series).

*Distribution*: Wattwil (SG) in the brook «Feldbach» at an altitude of 870 m.

*Remarks*: A single host specimen was collected in mid-August. It is noteworthy that the fungus grew on artificial, egg yolk based media, which is rather uncommon with species of *Entomophaga*.

A similar fungus with the following data was collected on July 14 on a similar host at Fischingen fixed with the legs to the underside of a leaf of a bush about 150 cm above a small river: Empty (germinated) hyphal bodies were spherical and measured (22–) 25.5 (–29) $\mu$m (1 series). The unbranched conidiophores contained

(18–) 23.3 (–29) nuclei (n = 25). The primary conidia were pyriform and measured (36–) 40.5 (–45) x (23–) 26.0 (–30) µm, Q = 1.56 (n = 25), usually they contained a single prominent vacuole. Rhizoids were absent.

**2. *Erynia* cf. *plecopteri* Descals & Webster (1984).**

*Host*: Unidentified species of Nemouridae (Plecoptera).

*Symptoms*: Dead insect fixed on the shady side of a stone immediately above the water level, wings slightly spread.

Rhizoids monohyphal with a diameter of 10–16 µm. Primary conidia (16–) 18.7 (–21) x (8–) 9.1 (–10) µm, Q = 2.06 (1 series, n = 25), mononucleate, bitunicate, elongate ellipsoid, largest diameter in the centre or slightly in the apical part, usually one prominent vacuole, sometimes two, papilla rounded (Plate 2, fig. 5). Type Ia secondary conidia (13–) 14.3 (–16) x (8–) 9.1 (–10) µm, Q = 1.58 (1 series, n = 25). Cystidia narrow and slightly tapering, resting spores absent.

*Distribution*: Fischingen (TG), on stones in the river Murg at an altitude of 670 m.

The species was found on a single individual, collected on July 3, in the same environment and at the same time as *E. plecopteri* (Keller 2007). It differs from this species by the distinctly smaller conidia (Plate 2, figs. 5–6).

**3. *Erynia* cf. *sepulchralis* (Thaxter) Remaudière & Hennebert (1980).**

*Host*: Unidentified Diptera.

*Symptoms*: Infected fly fixed to wet moss with rhizoids.

Rhizoids monohyphal, powerful, diameter ranging from 18–41 µm, endings simple or branched, without specialised holdfast. Primary conidia (27–) 29.4 (–32) x (12–) 13.9 (–16) µm, Q = 2.11 (1 series, n = 25), ellipsoidal, 1–2 vacuoles, papilla prominent, about 6 µm long and 6–7 µm wide.

*Distribution*: Fischingen (TG).

*Remarks*: The fungus was found on a single host specimen on June 6. The cadaver was fixed to moss covering a steep slope through which permanently dripped water from a source. The dimensions of the primary conidia correspond with those of *E. sepulchralis* given by Bałazy (1993) with 27–35 x 10–15 µm. Thaxter (1888) however, described the primary conidia as longer (35–48 x 10–15 µm).

**4. *Furia* cf. *neopyralidarum* (Ben-Ze'ev) Humber (1989).**

*Host*: Unidentified larva of Lepidoptera.

*Symptoms*: Dead caterpillar fixed with rhizoids to grass.

Rhizoids monohyphal. Hyphal bodies rod-shaped, straight, slightly bent or ondulated, measuring (56–) 85 (–133) µm (n = 50) (Plate 4, fig. 1). They contain (5–) 9.8 (–16) nuclei with a diameter of 5.4 (5–6.5) µm (n = 50). Conidiophores branched (Plate 4, fig. 4), contain nuclei with a diameter of 5.8 (5–6.5) µm (n = 50). Primary conidia (18–) 21.9 (–25) x (12–) 13.9 (–18) µm, Q = 1.58 (n = 50), short ovoid, bitunicate, usually with a single prominent vacuole, papilla short, blunt (Plate 4, fig. 2). Secondary conidia similar to primary ones (Plate 4, fig. 3).

*Distribution*: Watt-Regensdorf (ZH).

*Remarks*: The fungus was collected on September 9, 1994 on a single caterpillar.

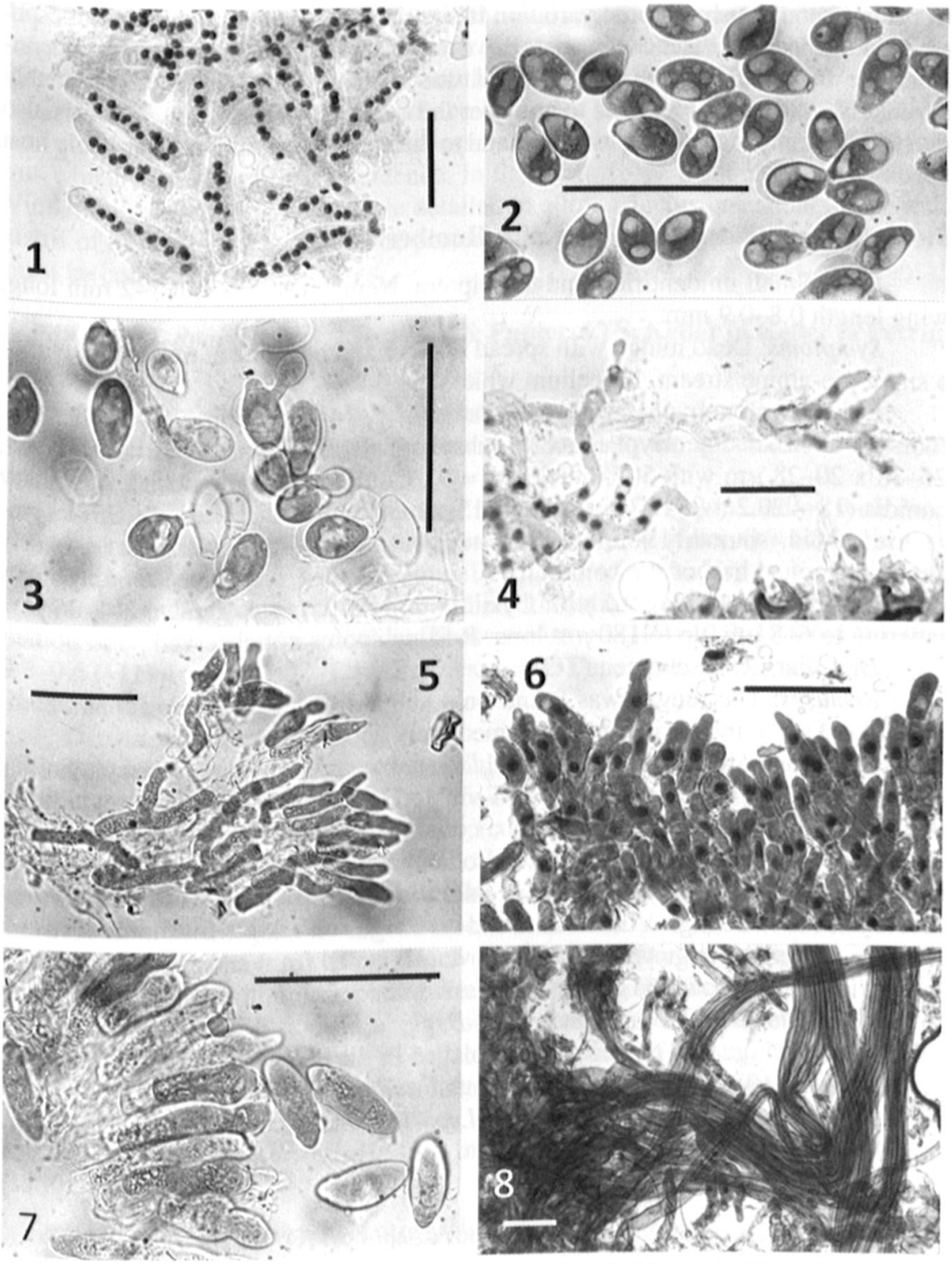


Plate 4. Figs. 1-4: *Furia* cf. *neopyralidarum*. 1. Hyphal bodies; 2. Primary conidia; 3. Formation of secondary conidia; 4. Conidiophore (all mounted in LPAO). Figs. 5-8: *Zoophthora* cf. *aphidis*. 5-6. Conidiophores; 7. Endings of conidiophores and primary conidia; 8. Compound rhizoids (all mounted in LPAO). Bars represent 50 $\mu$m.

Ben-Ze'ev (1982) described the species based on dried material collected by Petch on adult moths in Ceylon, now Sri Lanka. According to Ben-Ze'ev the primary conidia measure (14–) 18.4 (–28) x (9–) 12.1 (–17) $\mu$m, Q = 1.52. They contain a single nucleus, the spherical nuclei had a mean diameter of 6.9 $\mu$m. The photos

of primary conidia show some variation in the shape of the conidial body but especially in the papilla. The Swiss material nearly matches these data when we consider the fact that Ben-Ze'ev's material was dried and therefore very probably shrunk. Nevertheless, I hesitate to consider the two species as identical. This is also due to different geographical locations and to different host stages and probably host species.

**5. *Pandora* cf. *glaeospora* (Vuillemin) Humber (1989).**

*Host*: Small unidentified midge (Diptera, Nematocera), about 1–2 mm long, wing length 0.8–0.9 mm.

*Symptoms*: Dead midge with spread wings fixed on stone at the water level of a small pre-alpine stream. Mycelium white.

Rhizoids monohyphal with a diameter of 7–14 $\mu$m, ending enlarged, short root-like or sucker-like. Hyphal bodies subspherical, ellipsoidal to short rod-shaped, 26–38 x 20–28 $\mu$m with 5–15 nuclei (n = 9). Conidiophores branched. – Primary conidia (18–) 20.2 (–23) x (12–) 12.9 (–15) $\mu$m, Q = 1.57 (1 series, n = 25), asymmetric, ovoid, smoothly joining elongate, conical papilla; nucleus large, nearly filling the apical half of the conidium. A single rounded, secondary conidium was observed measuring 12 x 9.5 $\mu$m. Cystidia powerful, basal diameter 14–26 $\mu$m, tapering to 6–8 $\mu$m, up to 180 $\mu$m long. Resting spores not observed.

*Distribution*: Fischingen (TG).

*Remarks*: The fungus was found on a single infected midge on June 28, attached to a stone in the river Murg immediately above the water level.

Vuillemin (1886) described *E. glaeospora* only by the primary conidia. According to him they measure 20 x 14 $\mu$m and are ovoid with a strong papilla not demarcated from the conidial body by a collar. The data given above can be considered identical with the original description but are insufficient to draw any conclusions about the identity. Further, the ecological circumstances also are against an identity of the two fungi. Vuillemin found his fungus on midges in a mushroom cultivation, while the fungus mentioned above originated from an aquatic habitat.

At this place I would like to emphasize that Vuillemin described the fungus as *Entomophthora glaeospora* and not as *E. gloeospora* as it is written in nearly all recent papers (Fig. 1). The species was placed in the genus *Erynia* by Remaudière & Hennebert (1980) and later in the genus *Pandora* by Humber (1989). Miller & Keil (1990) redescribed the species from *Lycoriella mali* (Diptera, Sciaridae) giving

**Entomophthora glæospora**, sp. nov. (Pl. I, fig. 1-16.)

Dans le courant de juin, une épidémie fit périr en grand nombre les moucherons qui vivaient dans nos cultures de Champignons inférieurs. L'agent de la maladie était un parasite végétal, nouvelle espèce d'Entomophthorée que nous appellerons *Entomophthora glæospora*. Cette espèce se développe à la façon de

Fig. 1. Original description of *Entomophthora glaeospora* showing the correct spelling of the epithet «*glaeospora*» taken from Vuillemin (1886).

18.7 x 9.5 µm as average dimension of the primary conidia. In comparison to the original description there is a significant difference in the diameter of the conidia. Therefore, there are some doubts about the identity of the two fungi.

Although the fungus described above is very probably a species of *Erynia* it was provisionally attributed to *P. glaeospora* since this is the valid name of the fungus which shows the best coincidence. In this context we must also be aware that Vuillemin's description is too little detailed to allow conclusions about the generic status of his fungus. Therefore, the placement of the species in the genus *Pandora* must be considered as arbitrary.

### 6. *Pandora* cf. *lipai* (Bałazy, Eilenberg & Papierok) S. Keller in Keller & Petrini (2005)

*Host*: Unidentified Cantharidae (Coleoptera).

*Symptoms*: Infected insects fixed with rhizoids to the underside of leaves of bushes along a brook.

Rhizoids abundant with a diameter ranging from 7–16 µm, ending with disc- to root-like holdfast. Primary conidia (16–) 17.6–19.0 (–21) µm, Q = 1.74 (2 series, n = 25), bitunicate, with 1–2 vacuoles. Two types of secondary conidia. Type Ia was rare probably due to the fact, that their formation lasted longer than the formation of type Ib secondary conidia. These measured (10–) 12.3–12.8 (–13) x (9–) 9.3–9.6 (–11) µm, Q = 1.32–1.33 (2 series, n = 25), apex pointed. Cystidia tapering. The material was mounted in LPAB.

*Distribution*: Fischingen (TG).

*Remarks*: The mean dimensions of the primary conidia are according to the original description (Bałazy 1993) 19.5–23 x 9–10.5 µm. According to Keller (2007) they measure on average 23.9–25.1 x 12.3–13.6 µm which is slightly above Bałazy's values. The dimensions given above for *Pandora* cf. *lipai* are slightly below Bałazy's values and could as well be identified as *P. lipai*. On the other hand there are distinct differences between the two collections from Switzerland. Considering the different hosts from which the fungus material originates, I cannot exclude that different fungus species are involved and that both Swiss collections are not identical with *P. lipai*. In his previous study Keller (2007) already pointed to the fact that the described fungus collection consisted of inhomogenous material. This is a further hint that *P. lipai* in a large sense is probably a complex of species.

### 7. *Zoophthora* cf. *aphidis* (Hoffmann in Fresenius) Remaudière & Hennebert (1980)

*Host*: *Cinara pilicornis* (Hartig) (Homoptera, Lachnidae).

*Symptoms*: Infected aphids fixed with rhizoids on branches of young fir trees (*Picea abies*).

Rhizoids compound (Plate 4, fig. 8). Conidiophores branched (Plate 4, figs. 5–6). Primary conidia (25–) 31.9–32.8 (–38) x (10–) 12.7 (–16) µm, Q = 2.51–2.89 (3 series, n = 50), cylindrical to subellipsoidal, apical part often tapering, often asymmetric, papilla rounded or pointed (Plate 4, fig. 7). A single capilliconidium was observed. It measured 31 x 12 µm and developed at the end of a capillary conidiophore with a length of 46 µm. A single secondary conidium of type I developed

laterally from a primary conidium and measured 18 x 14 µm. A special type of secondary conidia was observed. They developed at the end of a septate germ tube which developed apically in the axes of the primary conidium and measured 22–25 x 13–16 µm (n = 6).

*Distribution*: Watt-Regensdorf (ZH).

The fungus was collected on a few aphids in early July in dense colonies of *C. pilicornis*, which were heavily attacked by *Neozygites cinarae* (Keller 1997). It cannot be attributed with certainty to *Z. aphidis* due to the longer conidia and due to the host. *Zoophthora aphidis* is known as very specific, so far only recorded from *Anoecia corni* and occasionally from *Rhopalosiphum padi* (Keller 1991). All findings were done in autumn. Unfortunately, only a few secondary conidia were observed, those which formed on a septate germ tube are unusual. The germ tube looked the same as a mycelium forming germ tube.

*Incompletely known fungi*

**1. *Entomophaga* sp.**

*Host*. Unidentified species of Tipulidae or Limoniidae (Diptera, Nematocera).

*Symptoms*: A single host specimen was collected fixed with the legs to the underside of a leave of a bush about 150 cm above a brook.

Primary conidia short pyriform to ovoid (37–) 46.6 (–56) x (31–) 37.7 (–45) µm, Q = 1.24 (1 series, n= 25). Rhizoids absent.

*Distribution*: Fischingen (TG).

*Remarks*: This fungus differs from the members of the *E. tipulae*-group by the larger conidia and the lower length-diameter ratio. It was found on a single host specimen collected on July 17.

**2. *Entomophthora* sp. 1**

*Host*: *Hilara* sp. (Diptera, Empididae).

*Symptoms*: Infected hosts fixed to the underside of leaves of a tree.

Conidiophores unbranched with 13 (9–17) nuclei (n = 50). Primary conidia (19–) 21.9–23.0 (–25) x (16–) 17.3–17.9 (–21) µm, Q = 1.27–1.29 (2 series, n = 50), contain 12 (9–18) nuclei with a diameter of 3.5 (3.5–4.5) µm (n = 50). Secondary conidia (16–) 17.1 (–18) x (12–) 13.5 (–15) µm, Q = 1.27 (n = 50), apical point indistinct.

*Distribution*: Rheinau (ZH).

*Remarks*: The species was collected on July 17. Some more dead flies were present, but the cadavers were old and the fungus didn't sporulate any more. Considering the number of nuclei in conidiophores and primary conidia and the dimensions of the primary conidia, the fungus described here is between *E. muscae* and *E. ferdinandi*. The primary conidia of the former measures on average 26–31 x 20–24 µm (Q = 1.20–1.32) and contain on average 15–20 nuclei. The primary conidia of *E. ferdinandi* measure on average 23–27 x 18–24 µm (Q = 1.15–1.27) and contain on average 10–11 nuclei (Keller 2002).

### 3. *Entomophthora* sp. 2

*Host*: *Micropeza corrigiolata* L. (Diptera, Micropezidae).

*Symptoms*: Infected flies fixed with proboscis to the underside of leaves of lucerne. Several cadavers were found on the underside of maize leaves at the edge of a maize field bordering on a lucerne field.

Conidiophores unbranched. Rhizoids absent. Primary conidia 20–24 x 16–19 µm (n = 10).

*Distribution*: Neunkirch (SH), field site «Widen».

*Remarks*: Numerous infected Micropezidae were collected in August and September in a lucerne field and at the border of a maize field neighbouring on the lucerne field. Unfortunately, most of the cadavers were old and the fungus didn't sporulate any more. The microscopic preparations of some of the hosts contained very few fungal structures and just allowed to identify the fungus as a species of *Entomophthora*. A single slide contained conidiophores and a few primary conidia.

### 4. *Entomophthora* sp. 3

*Host*: *Bibio marci* L. (Diptera, Bibionidae).

*Symptoms*: Infected insect fixed with legs to a pod of oilseed rape (Plate 3, fig. 7).

Rhizoids absent. Hyphal bodies irregularly rounded. Conidiophores unbranched. Primary conidia 25–28 x 19–22 µm (n = 9), secondary conidia 20–21 x 15–16 µm (n = 2).

*Distribution*: Near Katzensee (Regensdorf, ZH).

*Remarks*: A single species was collected on June 6 hanging on the underside of a pod of oilseed rape (*Brassica napus* L.) on top of the plant.

### 5. *Erynia* sp. 1

*Host*: Small unidentified midge (Diptera, Nematocera), about 1–2 mm long, wing length 0.8–0.9 mm.

*Symptoms*: Dead midge with spread wings fixed on stone at the water level of a small pre-alpine stream. Mycelium white.

Rhizoids monohyphal with a diameter of 6–22 µm. Primary conidia elongate ovoid to pyriform, largest diameter in apical portion, (13–) 16.2 (–21) x (7–) 8.8 (–11) µm, Q = 1.84 (1 series, n = 25), usually with a single vacuole, papilla narrow and asymmetric.

*Distribution*: Fischingen (TG) on stones in the river Murg immediately above the water level.

*Remarks*: The fungus was found on a single midge on June 6. Although it has some similarities with *Erynia fluvialis* and *Erynia* cf. *glaeospora*, it is assumed to be a different species. Both fungi, *E.* cf. *glaeospora* and *Erynia* sp. 1, were collected in the same environment as *Erynia gracilis* and *E. fluvialis* (Keller 2007).

### 6. *Pandora* sp. 1

*Hosts*: Unidentified species of sciarid-like Nematocera (Diptera).

*Symptoms*: Infected insects fixed to the underside of leaves of bushes and trees.

Conidiophores branched with 6–12 nuclei. Primary conidia (12–) 14.1–17.0

(–19) x (7–) 8.4–10.3 (–12) µm, Q = 1.65–1.72 (4 series), ovoid, slightly asymmetrical; broad papilla. Rhizoids monohyphal with a diameter of 6–8 µm. Cystidia slender.

*Distribution*: On the shore of the river Rhine at Rheinau and Rüdlingen (ZH) on the underside of leaves of a lime-tree (*Tilia platyphyllos* Scop.). The material was collected in June.

### 7. *Zoophthora* sp.

*Host*: Unidentified species of Cantharidae (Coleoptera).

*Symptoms*: Infected insects fixed with rhizoids to the underside of leaves of bushes along a brook about a meter above ground.

Rhizoids compound with common disc-like holdfast, lateral parts sometimes splitting into thinner compound rhizoids which further divided into monohyphal holdfasts. Hyphal bodies hyphae-like, branched or unbranched with a diameter of (5–) 6.5 (–8) µm (n = 25). Conidiophores branched with a diameter of 5–6 µm. Primary conidia (13–) 15.6 (–17) x (5–) 5.9 (–6) µm, Q = 2.65 (n = 25), narrow fusiform to ellipsoidal, bitunicate; papilla blunt separated by an indistinct bulge from the body of the conidium. Cystidia slender, tapering, basal part faintly stained with a diameter of 5–6 µm, terminal parts slightly enlarged and darker stained. Secondary conidia and resting spores not present.

*Distribution*: Fischingen (TG).

*Remarks*: The fungus was found on two small cantharid beetles, probably *Malthodes* sp. collected on third July. The primary conidia resemble *Z. radicans*, but are distinctly smaller. A similar insect has been identified earlier as host of *Zoophthora crassitunicata* (Keller 1980). This species, however, differs clearly by the much larger conidia.

#### VALIDATION

The wrong citation of the year of publication (Keller 2007) makes it necessary to validate the new combination of *Zoophthora aphrophorae* as given below.

### *Zoophthora aphrophorae* (Rostrup) S. Keller comb. nov.

*Basionym*: *Entomophthora aphrophorae* Rostrup, Botanisk Tidsskrift 20, 128 (1896).

#### DISCUSSION

This fourth contribution to the knowlegde of arthropod-pathogenic Entomophthorales from Switzerland includes a new species and four new records. The identity of seven species is uncertain. They were provisionally attributed to known species. Further, seven data sets could not be attributed to any species. The incompletely known species and data sets were included in this list on one hand to demonstrate that still many species are not yet scientifically recorded, and on the other hand to stimulate entomomycologists for further investigations.

World-wide 239 species of arthropod-pathogenic Entomophthorales are described, most of them (171 species) belong to the family Entomophthoraceae, the form-genus *Tarichium* not included (Keller 2008, 2011, this paper). With these

new records the list of entomopathogenic Entomophthorales from Switzerland now comprises 93 species which represent 39 % of the species known world-wide. However, in Switzerland and elsewhere, only little efforts were made so far to explore the entomophthoralean fungi. It must be pointed out that the existing records are not the result of systematic explorations but were mainly gathered at localities where professional and private activities took place. There are still many habitats and arthropod populations which were not or only partially explored in respect to entomopathogenic fungi. It is the author's opinion that specific investigations would result in the detection of dozens if not hundreds of new species. Such projects are not only of academic interest. Since numerous pest species and vectors of human and animal diseases are among their hosts, such investigations could help to develop pest specific biocontrol methods.

ZUSAMMENFASSUNG

Bei der Überarbeitung der Entomophthoraceen-Sammlung des Autors fielen Daten von 21 Arten an. Die meisten Datensätze waren jedoch unvollständig und erlaubten keine oder nur eine unsichere Artbestimmung. Sie sollen jedoch Entomologen und Insektenmykologen zu weiteren Forschungen anspornen. Eine neue Art, *Erynia thurgoviensis*, von einer nicht identifizierten Psychodidae wurde beschrieben. Ebenso konnten vier für die Schweiz neue Arten bestimmt werden, nämlich *Pandora bibionis* Li *et al.*, *P. delphacis* (Hori) Humber, *Zoophthora forficulae* (Giard) Batko und *Z. obtusa* Bałazy. Sieben Datensätze ermöglichten eine provisorische Zuordnung zu beschriebenen Arten und weitere sieben Datensätze erlaubten nur eine Gattungsbestimmung. Es ist davon auszugehen, dass in diesem Material noch unbestimmte Arten von Entomophthoraceae enthalten sind. Bisher unbekannte Daten von *Batkoa apiculata* (Thaxter) Humber and *Erynia ovispora* (Nowakowski) Remaudière & Hennebert wurden aufgeführt. Die Neukombination *Zoophthora aphrophorae* (Rostrup) S. Keller wurde validiert.

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