Golovinomyces orontii and other powdery mildews on *Rosmarinus officinalis*

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Euoidium violae, the anamorph of *Golovinomyces orontii* has been recently found in Germany on *Rosmarinus officinalis*, an important medical ornamental as well as spice plant. This is the first record from Germany and the second worldwide. All records of powdery mildew on this host refer to anamorphs. The species concerned are discussed and keyed out.

Key words – Erysiphales – *Golovinomyces* – *Leveillula* – *Neoërysiphe* – rosemary

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Introduction

Rosmarinus officinalis L. (*Lamiaceae*), known as rosemary, is an old cultivated plant of Mediterranean origin. Nowadays rosemary is grown in different parts of the world and used as an ornamental and fragrance plant, as a herbal remedy with a wide range of medical benefits (regulating blood pressure, stimulating the circulation, boosting the health of the heart, as antidepressant, tonic for the nerves, diuretic, treatment of migraines as well as antiseptic and antimycotic agent), and for culinary purposes, above all in the Mediterranean cuisine (Rodway 1980, Hänsel et al. 1994, http://en.wikipedia.org/Wiki/Rosemary).

Powdery mildew diseases are a threat to cultivated rosemary worldwide, although major outbreaks have been reported only sporadically (Blumer 1967, Gorter & Eicker 1984, Amano 1986, Braun 1987, 1995, Karis 1995, Tanda & Hirose 2003, Piątek 2004, Gadgil 2005, Brandenburger & Hagedorn 2006, Park et al. 2009, Voytyuk et al. 2009, Jage et al. 2010, Braun & Cook 2012). Recent infections of *Rosmarinus officinalis* in Germany proved to be caused by a species of *Golovinomyces* (U. Braun) Heluta, i.e. not by *Neoërysiphe galeopsidis* (DC.) U. Braun, the only powdery mildew hitherto known from Germany on this host (Brandenburger & Hagedorn 2006, Jage et al. 2010). Because the differentiation of anamorphs of *Golovinomyces* (= *Euoidium* Y.L. Paul & J.N. Kapoor) is not easy, the reliability of previous records on rosemary is often doubtful. As far as known, only conidial states of powdery mildews have been found on this

host. Therefore, powdery mildews occurring on *Rosmarinus officinalis* are discussed and the species concerned are keyed out.

Methods

The powdery mildew on rosemary recently found in Germany was removed from the leaf surface using a razor blade, placed in a drop of lactic acid, gently heated, stained with methyl (cotton) blue and examined by standard light microscopy using oil immersion (bright field and phase contrast). Thirty measurements (× 1000 magnification) of conidia and other structures were made, with the extremes given in parentheses. A Leica DFC290 digital camera was used to take micrographs of conidia and conidiophores. Standard methods were used to isolate genomic DNA from mycelium of powdery mildew colonies, for PCR amplification and to obtain a rDNA ITS sequence (for details see Weber 2011).

Results and discussion

Blumer (1967) referred collections of powdery mildew on *R. officinalis* from Germany and Portugal to *Oidium* sp. without any further differentiation. Amano (1986) listed *Erysiphe galeopsidis*, *Leveillula taurica* (Lév.) Arnaud and *Oidium* sp. as causal agents of powdery mildew diseases of *R. officinalis* in North Africa, Asia, Australia and New Zealand, as well as Europe. Records of *Sphaerotheca* sp. on *R. officinalis* in North America (Holcomb 1992, Westervelt 2003) are doubtful. The exclusive presence of conidial states on rosemary suggests an accidental nature of infections on this host. The following powdery mildew species are known on rosemary:

(1) ***Golovinomyces biocellatus*** (Ehrenb.) Heluta (≡ *Erysiphe biocellata* Ehrenb.).

This species has a wide host range among genera and species of the *Lamiaceae*, but its occurrence on *Rosmarinus officinalis* is unclear and unproven. Gorter & Eicker (1984) and Crous et al. (2000) recorded it on this host from South Africa and Park et al. (2009) from South Korea. The latter authors supported the identification of the Korean collection by means of an analysis of ITS sequences. However, the Korean sequence shows a 100% identity to our ITS sequence from Germany (see below). Pennycook (1989) listed *Erysiphe cichoracearum* DC. as a powdery mildew on rosemary from New Zealand. However, this record is also unclear because *E. cichoracearum* s. lat. previously encompassed most nowadays recognized species of *Golovinomyces*, including *G. biocellatus* as well as *G. orontii*. Therefore, it remains doubtful whether the true *G. biocellatus* is able to infect rosemary.

(2) ***Golovinomyces orontii*** (Castagne) Heluta (≡ *Erysiphe orontii* Castagne; *Euoidium violae* (Pass.) U. Braun & R.T.A. Cook, anamorph). Gadgil (2005) recorded this species on rosemary from New Zealand. Collections recently found in Germany proved to pertain to *G. orontii* based on morphology.

Fig. 1 – *Golovinomyces orontii* on *Rosmarinus officinalis*. Micrograph of conidiophores and conidia. Bar: 10 µm.

A nuclear rDNA ITS sequence (GenBank JX898864) has been derived from the material examined (cited below), which shows 100% identity with three sequences

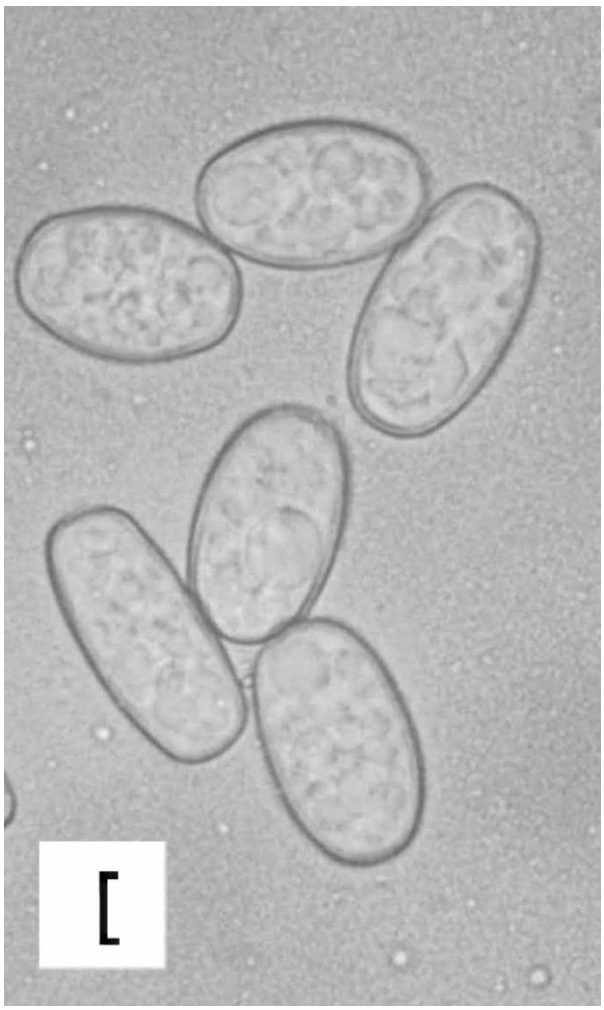

Fig. 2 – *Golovinomyces orontii* on *Rosmarinus officinalis*. Micrograph of conidia. Bar: 10 µm.

deposited as "*G. biocellatus*" [derived from *Rosmarinus officinalis*, USA, California, AB307672; *R. officinalis*, South Korea, FJ874774; and *Salvia officinalis*, USA, California, AB307674]. This result confirms that the powdery mildew anamorph on *Rosmarinus* has been correctly assigned to *Golovinomyces*. *G. biocellatus* and *G. orontii* are morphologically very similar and closely related (Braun & Cook 2012), forming an intricate assemblage in phylogenetic trees based on ITS rDNA sequences (Matsuda & Takamatsu 2003). In such groups of closely allied taxa, ITS data alone are often insufficient for the differentiation at species level (Groenewald et al. 2012). Furthermore, it must be taken into consideration that *G. orontii*, as currently perceived, represents a species complex comprising plurivorous as well as more specialized taxa. *G. orontii* is morphologically distinguished from *G. biocellatus*, also a compound species, by its anamorph which is characterized by conidiophores with curved-sinuous foot-cells and by producing less swollen spore units than in *G. biocellatus*.

The German collection represents the second record of *G. orontii* on rosemary worldwide. The occurrence of this species on *Rosmarinus* is not surprising since *Galeobdolon luteum* Huds. s. lat. and *Hyssopus officinalis* L., two other members of the *Lamiaceae*, are proven hosts of this species (Blumer 1952, 1967). The origin of these infections on rosemary is unclear, but *G. orontii* was also found on glasshouse cucumbers, which are an abundant crop in this region of Germany and may thus provide a source of inoculum (Kraul & Hau 2012).

The German material on rosemary is characterized as follows (Figs 1–3): **Mycelium** on leaves and stems amphigenous, forming thin patches or covers; **hyphae** branched, straight to strongly sinuous, 3–8 µm wide, septate, thin-walled, smooth; **hyphal appressoria** solitary, rather inconspicuous to nipple-shaped; **conidiophores** arising from the upper surface of mother cells or laterally, in the middle of the cell or towards a septum, erect, foot-cells cylindrical or subcylindrical (slightly increasing in width from base to top), straight to sinuous throughout or curved at the base (with up to 40% sinuous to curved foot-cells per microscope preparation), (30–)35–70 × (7–)9–12 µm, followed by 1–4 shorter cells, second cell rarely about as long as the foot-cell; **conidia** formed in chains (catenescent), ellipsoid, doliiform-limoniform, primary conidia obovoid-obpyriform, spore units not very swollen, 25–35 × 12–18 µm, ends truncate to rounded, germ tubes perihilar, short, cylindrical to somewhat club-shaped.

Material examined – **Germany**, Lower Saxony, Westoverledingen, Nursery Rogge, on *Rosmarinus officinalis*, 17 July 2012, A. Hildebrands & A. Wichura (HAL 2509 F, GenBank JX898864).

(3) ***Neoërysiphe galeopsidis*** (≡ *Erysiphe galeopsidis* DC.).

N. galeopsidis is the most common and widespread powdery mildew on rosemary, reported from South Africa, Asia [Japan], the Caucasus region, Europe [France, Germany,

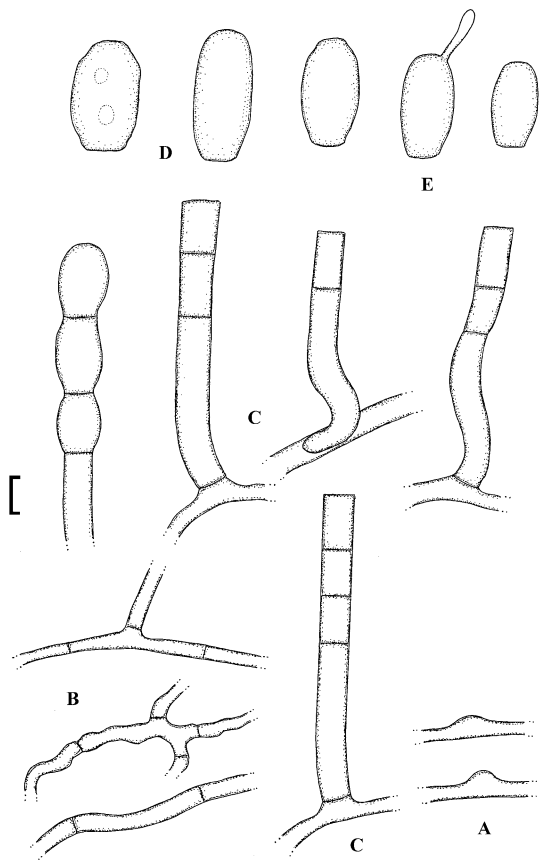

Fig. 3 – Drawing of the anamorph of *Golovinomyces orontii* on *Rosmarinus officinalis*. **A** Hyphal appressoria. **B** Superficial hyphae. **C** Conidiophores. **D** Conidia. **E** Conidium with germ tube. Bar: 10 µm.

Poland] and New Zealand (Amano 1986, Braun 1987, 1995, Karis 1995, Tanda & Hirose 2003, Brandenburger & Hagedorn 2006, Jage et al. 2010, Braun & Cook 2012). The anamorph of this species is easily distinguishable from the conidial states of the two *Golovinomyces* species by its lobed appressoria.

(4) ***Leveillula duriaei*** (Lév.) U. Braun (≡ *Erysiphe duriaei* Lév.).

Previous records of *Leveillula* on rosemary from France, Greece, Israel and former Yugoslavia (Amano 1986) were assigned to *L. taurica s. lat.* (Jaczewski 1927, Golovin 1956, Amano 1986). Voytyuk et al. (2009) reassessed *Leveillula* material on rosemary from Israel, previously reported by Rayss (1940) as *L. taurica*, and referred it to *L. duriaei*. Braun & Cook (2012) listed *Rosmarinus* as host genus of the latter species as well.

Key to powdery mildew anamorphs on *Rosmarinus officinalis*

1. Mycelium internal and external, superficial; conidiophores emerging through stomata; conidia formed singly, dimorphic; primary conidia broadly ellipsoid (-lanceolate), apically pointed, 35–80 × 12–25 µm, secondary conidia ± cylindrical, 40–65 × 12.5–23 µm ..... *Leveillula duriaei*

1* Mycelium only external, superficial; conidiophores arising from superficial hyphae; conidia formed in chains (catenescent), ellipsoid-ovoid, doliiform, smaller, usually not longer than 40 µm 2

2. Hyphal appressoria lobed; foot-cells of the conidiophores 25–50 µm long …….. ..... *Neoërysiphe galeopsidis*

2* Hyphal appressoria indistinct to nipple-shaped; foot-cells of the conidiophores longer, up to about 80 µm 3

3. Foot-cells of the conidiophores straight, cylindrical, arising from the upper surface of supporting hyphae (not proven to occur on *R. officinalis*) ..... *Golovinomyces biocellatus*

3* Foot-cells of the conidiophores arising from the upper part of the supporting hyphae, and then straight to distinctly sinuous or arising laterally and curved at the base …….. ..... *Golovinomyces orontii*

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