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Mycopappus quercus sp. nov., causing frosty mildew in *Quercus acutissima*

Yasuo Suto* **and Mikiko Kawai**

Shimane Prefecture Forest Research Center, Shinji-cho, Yatsuka-gun, Shimane 699–0401, Japan

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The causal fungus of frosty mildew in *Quercus acutissima* was taxonomically studied. Brown spots with conical white to yellowish tufts of the causal fungus developed on the leaves, followed by successive defoliation. The fungus was regarded as a new species of *Mycopappus*, *M. quercus*, from the morphology of the multicellular propagules. The ascogenous stage and true conidia of the fungus were not observed, although sclerotia were formed on the fallen diseased leaves.

Key Words——frosty mildew; *Mycopappus quercus*; *Quercus acutissima*.

Since 1986, a leaf spot disease in *Quercus acutissima* Carr. "Kunugi" in Japanese has been a problem in nurseries and young planted stands in Shimane Prefecture, Japan. Suto (1993, 1994) described the disease and named it frosty mildew, "Shirotsubu-hagare-byo" in Japanese, but did not identify the causal fungus, because the conidial and ascogenous stages of the fungus were not observed.

Multicellular propagules of the fungus are abundantly produced on the lesions of the living leaves, and this fungus can be identified from the propagules. The purpose of the present paper is to describe the symptoms and signs of the disease and the morphology of the causal fungus based on the propagules, and discuss the taxonomy of the fungus.

Symptoms and signs The disease occurred on seedlings and young planted trees of *Q. acutissima* up to 15 years of age (Suto, 1993, 1994). From early September, flaccid brown to red-brown spots appear on the leaves, which soon enlarge circularly or irregularly, often spreading to the leaf margins and becoming confluent. The spots occasionally consist of alternating pale and dark brown necrotic zones, or brown necrotic and green healthy tissues. The infected leaves are prematurely shed. The young shoots of the seedlings are occasionally infected, being killed and turning brown. Conical white to yellowish tufts, multicellular propagules of the causal fungus, are scattered on the adaxial surface of the infected leaves and on the infected shoots, being visible with the naked eye (Fig. 1).

Small thin black discoids, sclerotia of the fungus, are apparently formed only after the leaves have fallen to the ground (Fig. 2A).

Morphology of the fungus Propagules epiphyllous, multicellular, conical, white to yellowish, gregarious, large, composed of a stroma-like base and tufts of hyphal appendages. Propagules are dislodged at a slight touch and disseminated. Stroma-like bases globose to subglobose, 200–630 μm wide, 180–400 μm high, composed of hyaline, clavate end hyphae, 27–75(–125) × 11–21 μm, 1–3(–5) septate, apices obtuse. Hyphal appendages long, cylindrical, 480–830 × 4–5 μm, multiseptate, aggregated in dense fascicles to form 1–5, usually 1–2 conical erect structures. Parental stromas subcuticular, immersed-erumpent, 50–100 × 90–125 μm, composed of hyaline, interlocking hyphae, detaching from the propagule along a broad plane (Figs. 3, 4).

Development of the propagules of the fungus was examined on the natural lesions and the infected lesions that were artificially inoculated with the propagules. Parental stroma became raised and broke the cuticula and epidermal cells of the adaxial surface of the leaves. A small conical structure composed of only hyphal appendages developed at first. Then clavate hyphae were formed from the basal part of the hyphal appendages. The claviform hyphae multiplied and densely aggregated to form a stroma-like base as the hyphal appendages developed longer (Fig. 3A, B). The hyphal appendages flared loosely and separately after wetting.

Sclerotia scattered on the fallen leaves, formed within the leaf tissue, becoming erumpent, orbicular, 3–4 × 0.7–1.2 mm, black, containing remnants of the leaf parenchyma and vascular elements. Rind melanized, 120–240 μm thick. Medullary hyphae hyaline, densely packed (Fig. 2B).

Taxonomy of the fungus

The morphological characteristics of the multicellular propagules mentioned above suggest that the present

* Present address: 5–11–46, Agenogi, Matsue-shi, Shimane 690–0015, Japan

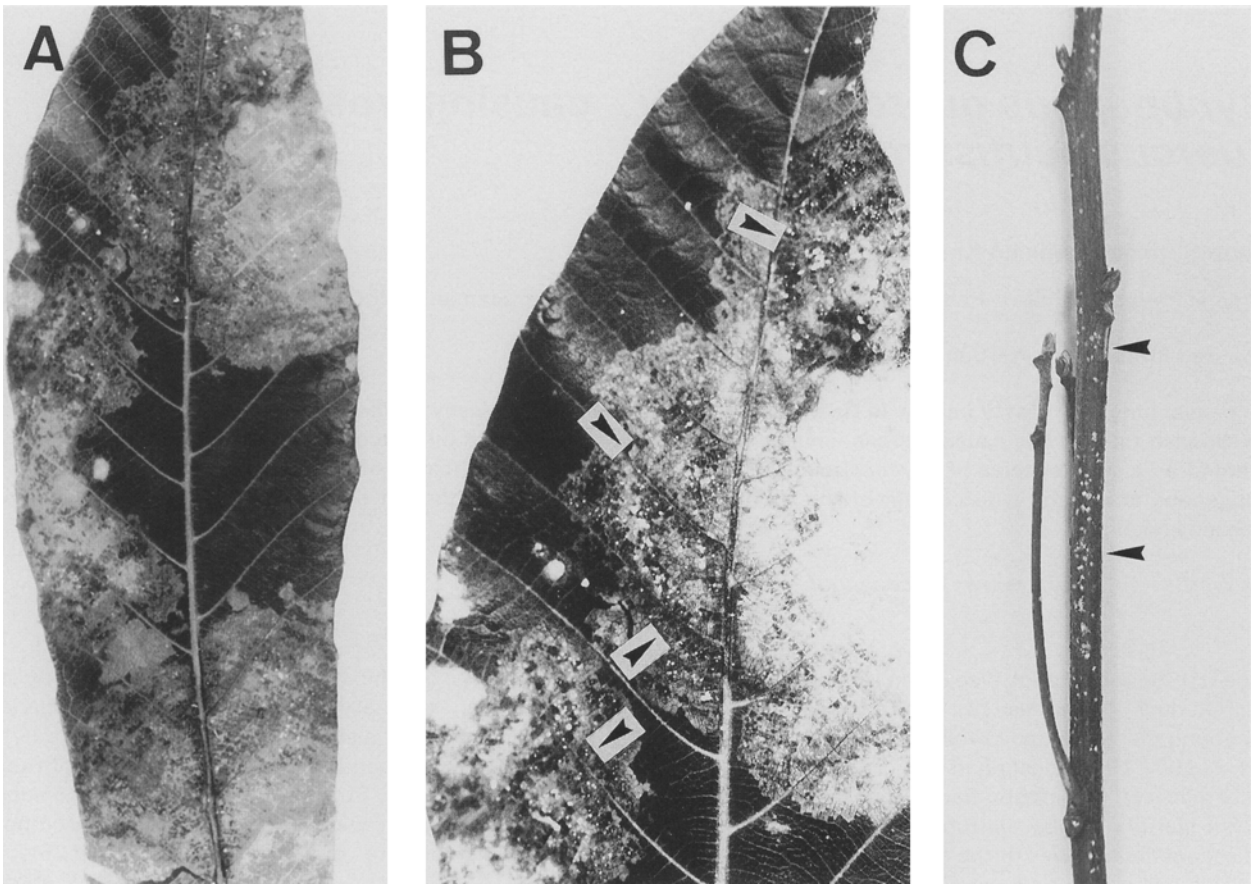

Fig. 1. Symptoms and signs of leaf spots in *Quercus acutissima*.
A, B. Brown leaf spots with white tufts of fungal propagules (arrows) on the adaxial surface of leaf (B: extended view). C. Brown shoot tip with white tufts of fungal propagules (arrows).

fungus belongs to the genus *Mycopappus* Redhead et G. P. White (1985), Agonomycetaceae, Aognomycetales, Hyphomycetes, Deuteromycotina. Redhead and White (1985) recorded two species of this genus: *M. aceris* (Dearn. et Barthol.) Redhead et G. P. White, as the type species, on *Acer macrophyllum* Pursh; and *M. alni* (Dearn. et Barthol.) Redhead et G. P. White on *Alnus rubra* Bong. and *A. sinuata* (Regel) Rydb. These fungi are distributed in Canada and U.S.A. Harada and Tubaki (1993) found a large concentric leaf spot of *Aesculus turbinata* Blume in Aomori and Akita Prefectures, Japan, and Wei et al. (1998) reported a new *Mycopappus* species, *M. aesculi* C. Z. Wei, Y. Harada et Katum., as the causal fungus (Table 1).

Propagules of the present fungus are larger than those of the other three *Mycopappus* fungi. The stroma-like base is composed of short, clavate end hyphae, whereas that of the other fungi is composed of interlocking hyphae, although that of *M. alni* bears shorter clavate to ovoid end cells from the stroma-like base. The hyphal

Table 1. *Mycopappus* spp. and their teleomorph, synanamorph, sclerotium stage, host, and distribution.

Species	Teleomorph	Synanamorph	Sclerotium stage	Host	Distribution
Mycopappus sp.[a]	–	–	+	*Quercus acutissima*	Japan (Chugoku district)
M. aceris[b]	*Mycosphaerella mycopappi*[c]	*Stigmina zilleri*[d]	–	*Acer macrophyllum*	Canada and U.S.A.
M. aesculi[e]	*Mycodidymella aesculi*[e]	*Blastostroma aesculi*[e]	–	*Aesculus turbinata*	Japan (Aomori and Akita Pref.)
M. alni[b]	–	–	+ microsclerotium on PDA	*Alnus rubra* and *A. sinuata*	Canada and U.S.A.

[a] The authors; [b] Redhead and White (1985); [c] Funk and Dorworth (1988); [d] Funk (1987); [e] Wei et al. (1998).

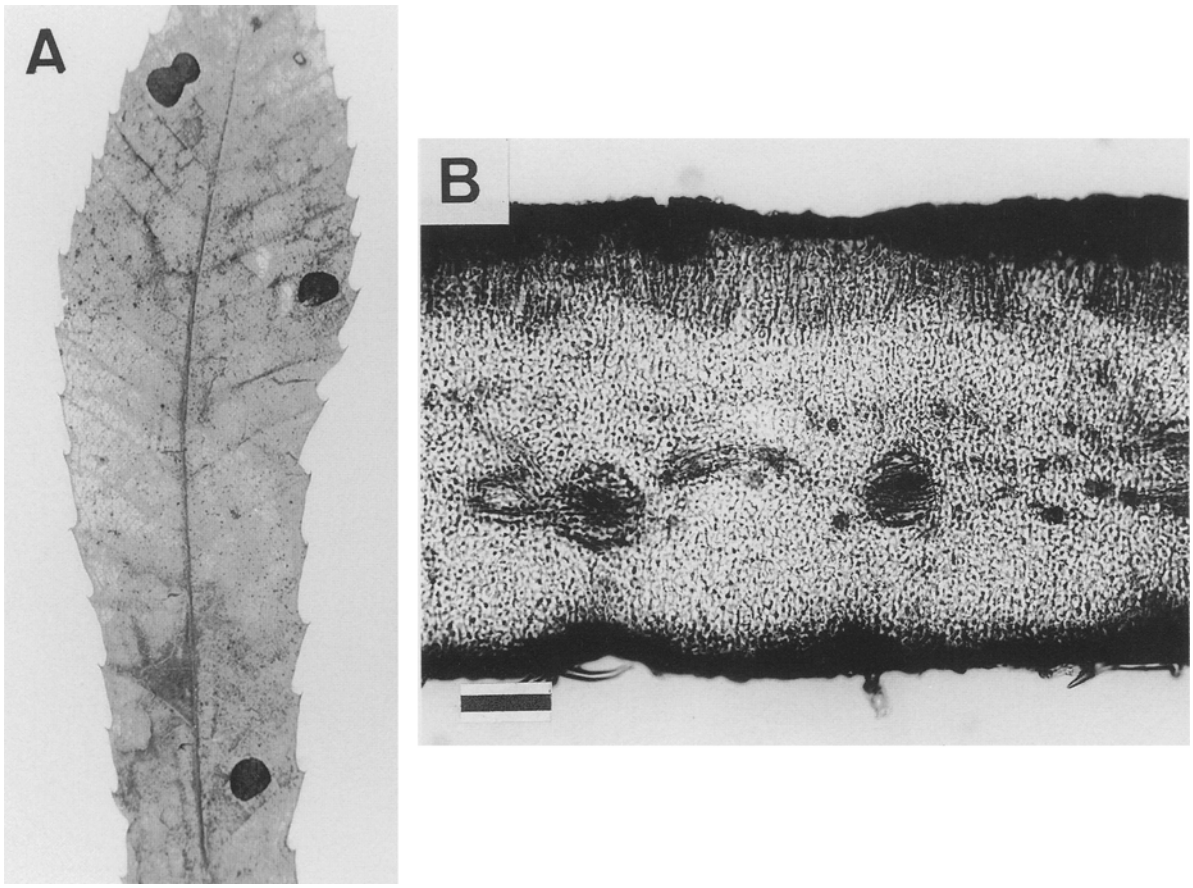

Fig. 2. Sclerotia on a diseased fallen leaf of *Quercus acutissima*.
A. Black and discoidal sclerotia on a diseased fallen leaf. B. Vertical section of sclerotium. Scale bar: 200 μm.

appendages of the present fungus arise from detachable base cells of the propagule, whereas those of the other fungi arise from superficial stroma-like base cells by apical growth. The hyphal appendages of the present fungus and *M. alni* densely fasciculate to form a conical erect structure, whereas those of *M. aceris* and *M. aesculi* do not. The stroma-like base of the present fungus, *M. aesculi*, and *M. alni* is borne on a broad plane, whereas that of *M. aceris* is borne on a narrow isthmus (Table 2).

From these morphological characteristics of the propagules, the present fungus can be distinguished as a different species of *Mycopappus*.

Mycopappus quercus Suto et M. Kawai, sp. nov.
Figs. 1–4

Propagula epiphylla, multicellularia, conica, nieva vel flavida, gregaria, ex basi stromatoidea et appendicibus hyphoideis composita, disseminata et pro propagula fungentia. Basis stromatoidea globosa vel subglobosa, 200–630 × 180–400 μm, ex hyphis hyalinis clavatis 27–75(–125) × 11–21 μm 1–3(–5) septatis apice obtusis composita. Appendices hyphoideae longae, cylindricae, septatae, 480–830 × 4–5 μm, fasciculatae vel dense aggregatae et 1–5 (fere 1–2) structuras conicas formantes. Stromata parentalia subcuticularia, immersa vel erumpentia, 50–100 × 90–125 μm, ex hyphis hyalinis composita.

Etymology: Named after its host genus.

Holotype: On living leaves of *Quercus acutissima* Carr. (Kunugi) – Ouda, Shimane Pref. 6 Oct. 1986, T. Ito (SFH-1164, deposited in the Herbarium of Shimane Prefecture Forest Research Center, Shinji-cho, Yatsuka-gun, Shimane, Japan).

Other specimens examined: On living leaves of *Q. acutissima* – Ouda, Shimane Pref. (SFH-1165); Muyukaichi, Shimane Pref. (SFH-1167); Kakinoki, Shimane Pref. (SFH-1168); Saigo, Shimane Pref. (SFH-1286); Nita, Shimane Pref. (SFH-1367, 1443, 1444); Goka, Shimane Pref. (SFH-1386, 1441); Kanagi, Shimane Pref. (SFH-1419); Tsuma, Shimane Pref. (SFH-1439, 1440). Sclerotium stage only: On fallen leaves of *Q. acutissima* – Ouda, Shimane Pref. (SFH-1166); Muyukaichi, Shimane Pref. (SFH-1359); Saigo, Shimane Pref. (SFH-1302, 1449); Goka, Shimane Pref. (SFH-1360, 1442); Kanagi, Shimane Pref. (SFH-1419); Fuse, Shimane Pref. (SFH-1450).

As noted above, our collections of the fungus are limited to Shimane Prefecture. However, we identified the fungal specimens on leaves of *Q. acutissima* sent to us from the following prefectures as *M. quercus*: Hiroshima Pref. (Sept. 1991), Tottori Pref. (Oct. 1996), and

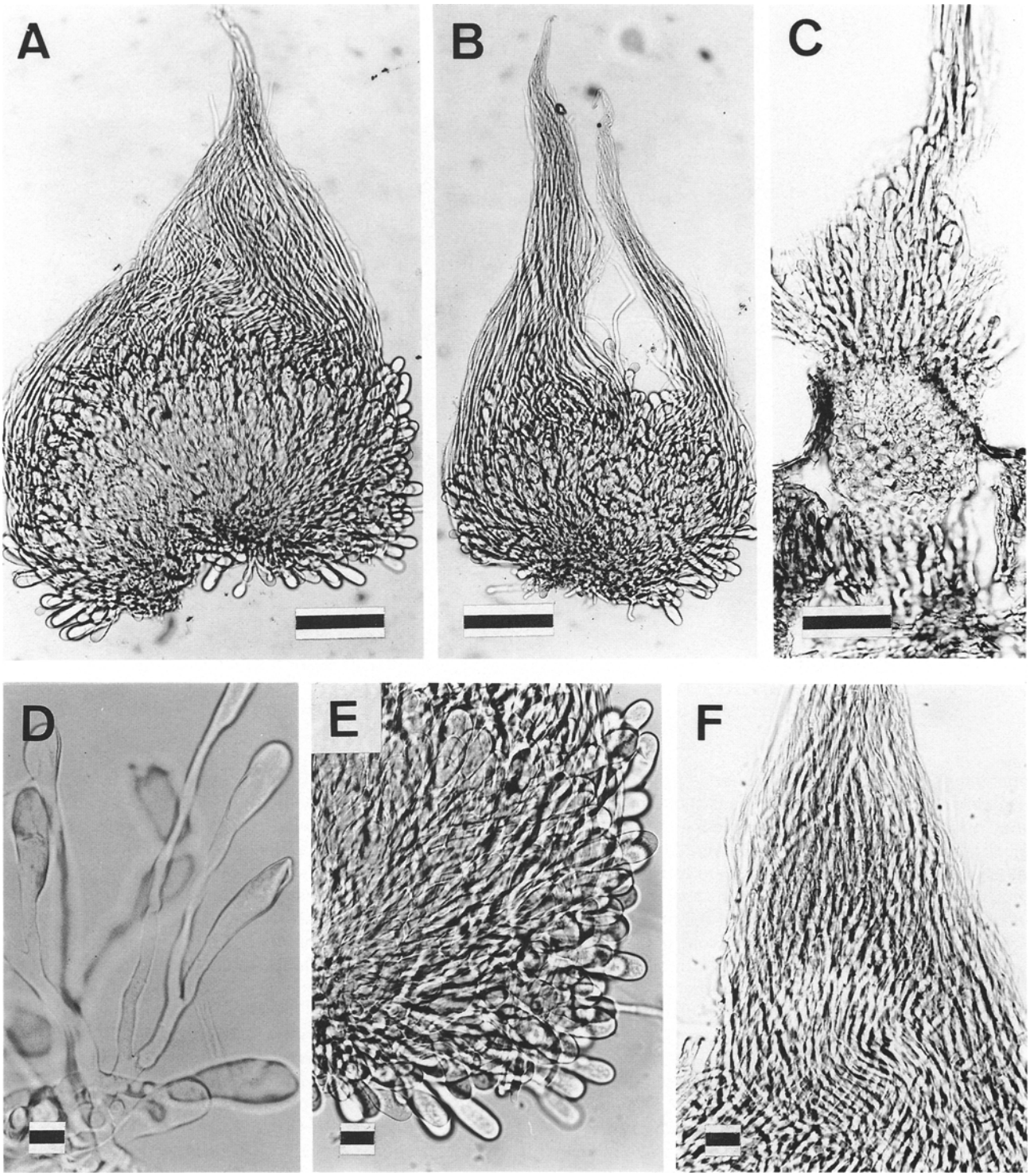

Fig. 3. Multicellular propagules of *Mycopappus quercus*.
A, B. Propagules disseminated from leaf surface. C. Parental stroma of propagule in vertical section. D. Young claviform hyphae composing stroma-like base. E. Stroma-like base of propagule. F. Conical structure of hyphal appendages. Scale bars: A, B, C = 100 μm, D = 10 μm, E, F = 20 μm.

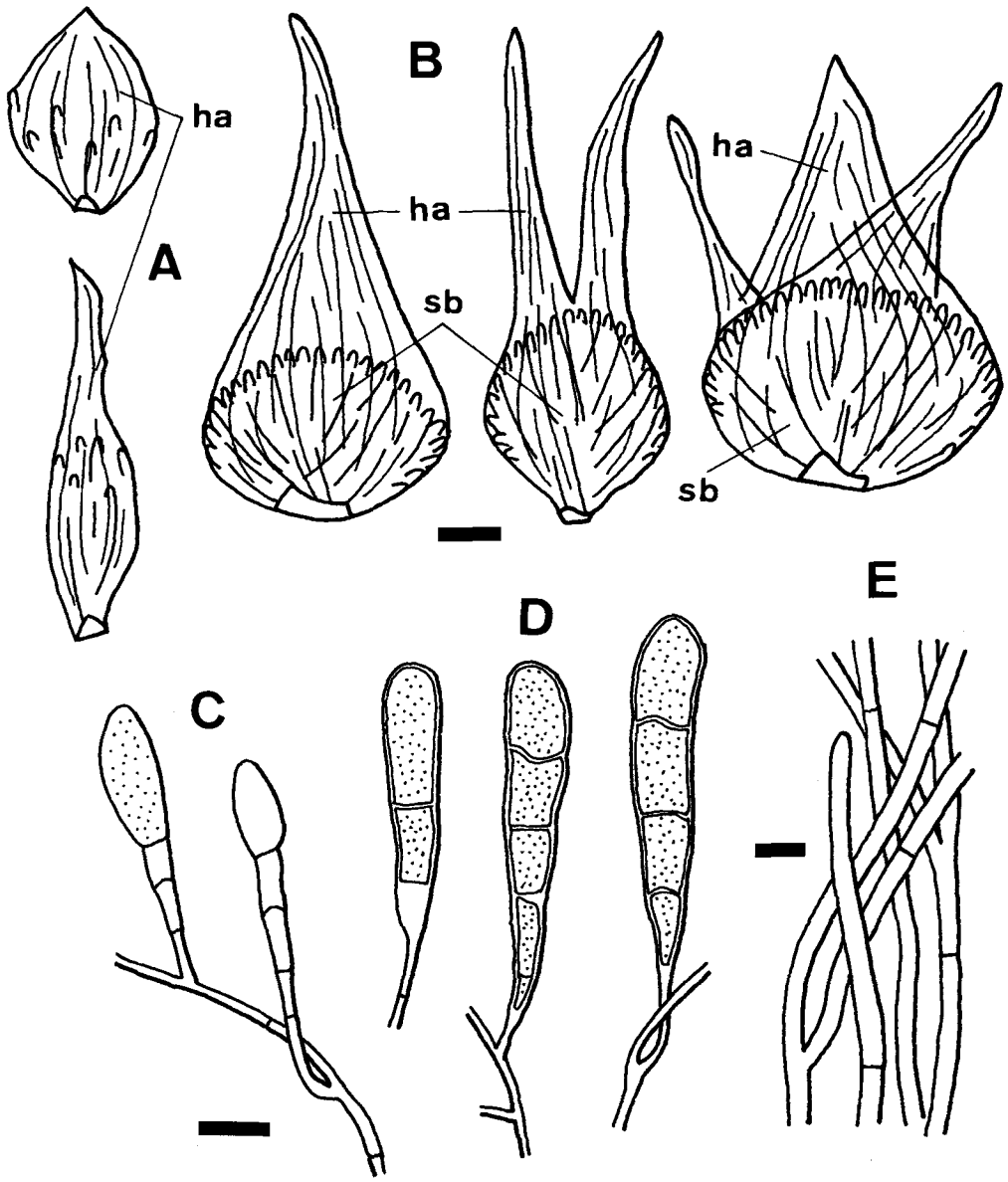

Fig. 4. Multicellular propagules of *Mycopappus quercus*.
A, B. Diagrammatic illustrations of premature (A) and mature (B) propagules; stroma-like base (sb), conical structure of hyphal appendages (ha). C, D. Young (C) and developed (D) claviform hyphae composing stroma-like base. E. Hyphal appendages. Scale bars: A, B = 100 μm, C = 20 μm, D = 5 μm.

Okayama Pref. (Jan. 1999). The fungus is considered to be widely distributed in the Chugoku district, situated in the western part of Honshu, Japan.

The ascogenous stage of the present fungus has not been observed on the fallen diseased leaves in the field or after several treatments to produce ascocarps from the sclerotia. Moreover, the synanamorph stage has not been observed on the propagules or on the leaf lesions.

Discussion

The present fungus belonging to *Mycopappus* on *Q. acutissima* is clearly distinguished from the three known *Mycopappus* species, *M. aceris*, *M. aesculi*, and *M. alni*, by the morphological characteristics of multicellular propagules. Moreover, the host tree species of each fungus is different and the symptoms induced by these fungi are different, although *M. aceris* and *M. aesculi* develop similar concentric ring spots.

The large multicellular propagules of the present fungus are abundantly formed on the adaxial leaf surface, and this is one of the noticeable signs to diagnose the disease. However, we could not observe conidial formation from them and did not use sporodochia to describe them, unlike the case of *M. aesculi* described by Wei et al. (1998). In inoculation tests by Suto (1993, 1994),

Table 2. Morphological characteristics of *Mycopappus* spp.

Species	Stroma-like base	Hyphal appendage	Parental stroma
Mycopappus sp.[a]	epiphyllous, white to yellowish, globose to subglobose, 200–630 × 180–400 μm, composed of hyaline, clavate end hyphae, 27–75(–125) × 11–21 μm, 1–3(–5) septate	cylindrical, 480–830 × 4–5 μm, multiseptate, densely fasciculated, to form conical erect structure	subcuticlar, immersed-erumpent, 50–100 × 90–125 μm, composed of hyaline, interlocking hyphae, detaching from the propagule along a broad plane
M. aceris[b]	epiphyllous, white, lenchform, approx. 150 μm diam, composed of branched moniliform interlocking hyphae formed from subglobose to oblong cells 8–15 × 5–15 μm	cylindrical, 100–300 × 4.5–6 μm, 2–4 septate, 10–25 hyphae, sparsely	erumpent, composed of a mass of short, branched, interwoven hyphae, 4–5 μm diam, detaching from the propagule at narrow isthmus
M. aesculi[c]	epiphyllous, white to yellowish, globose to subglobose, 200–325 μm diam, composed of hyphae formed from hyaline, subglobose to oblong cells, 10–15 × 7.5–13.5 μm	cylindrical, 143–190 × 5–7.5 μm, 5–7 septate	immersed-erumpent
M. alni[b]	epiphyllous, white, subglobose, composed of branched moniliform interlocking hyphae formed from swollen cells, 9–15 μm diam	cylindrical, 250–400 × 5–6.6 μm, 2–6 septate, densely fasciculated to form a conical erect structure	subcuticlar, erumpent, composed of a disc of interwoven short-branched hyphae, 5–6 μm diam, detaching from the propagule along a broad plane

[a] The authors; [b] Redhead and White (1985); [c] Wei et al. (1998).

leaf spots with abundant propagules that resembled those on the naturally infected leaves developed, when a single propagule was inoculated on the abaxial leaf surface. The propagules of the fungus are considered to infect the leaves by penetrating through stomata, because *Q. acutissima* lacks stomata on the adaxial leaf surface. In inoculation tests using *M. aesculi* (Wei et al., 1998), the symptoms on the leaves appeared when a single sporodochium was inoculated on the abaxial leaf surface.

Neither the ascogenous nor synanamorph stage of the fungus was observed on the lesions. The teleomorph and synanamorph of *M. aceris* have been described as *Mycosphaerella mycopappi* A. Funk et Dorworth (1988) and *Stigmina zilleri* A. Funk (1987), respectively. The teleomorph and the synanamorph of *M. aesculi* have been described as *Mycodidymella aesculi* C. Z. Wei, Y. Harada et Katum. and *Blastostroma aesculi* C. Z. Wei, Y. Harada et Katum., respectively (Wei et al., 1998).

Natural production of sclerotia in the present *M. quercus* is one of the features in the life cycle distinguishing it from the other *Mycopappus* species. *M. alni* produced microsclerotia on PDA medium (Redhead and White, 1985). The sclerotia of the present fungus did not show the apothecium stage. The role of the sclerotia in the life cycle of the fungus remains unknown.

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