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## The genus *Akanthomyces* on spiders from Taiwan

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**Abstract:** *Akanthomyces ampullifer*, *A. araneorum*, *A. novoguineensis* and a new species *A. ovalongatus* are described from dead spiders in Taiwan. *Akanthomyces ovalongatus* is characterized by its globose to subglobose conidiogenous cells that have an abruptly narrowed neck, and obovoid, oblong to ellipsoidal conidia. In these features, *A. ovalongatus* resembles *A. araneorum*, *A. arachnophilus* and *A. novoguineensis*, but it can be readily separated from these species either by roughness of conidiogenous cells, or by morphological characters of conidia. A key to the thirteen known species of *Akanthomyces* is provided.

**Key Words:** Araneae, Clavicipitales, Hyphomycetes, systematics, taxonomy

### INTRODUCTION

The genus *Akanthomyces* was established by Lebert in 1858 to accommodate a single species, *A. aculeatus* Leb., found in France. The same species was later reported from several collections on moths in North and South America (Mains, 1950). *Akanthomyces* is characterized by producing white, cream or flesh-colored cylindrical, attenuated synnemata covered with a hymenium of phialides. These conidiogenous cells are either ellipsoidal, cylindrical, or narrowly cylindrical and gradually or abruptly tapering to a more or less distinct neck. Conidia are unicellular, hyaline, in short or long chains (Lebert, 1858; Mains, 1950; Vincent et al., 1988). The circumscription of *Akanthomyces* was later emended and revised by Mains (1950). He also described in detail and illustrated *A. aculeatus* Lebert, *A. ampullifer* (Petch) Mains, and *A. araneorum* (Petch) Mains. Since then, several species of *Akanthomyces* associated with insects or spiders have been described by Samson and Evans (1974),

and Samson and Brady (1982). So far all the known *Akanthomyces* species described are parasites of insects or spiders, except *A. johnsonii* (Massee) Vincent et al., a saprobe described from decaying leaves and herbaceous litter (Mains, 1950; Samson and Evans, 1974; Samson and Brady, 1982; Vincent et al., 1988). Recently, Hywel-Jones (1996) monographed the genus *Akanthomyces* on spiders in Thailand, including three new species: *A. koratensis* Hywel-Jones, *A. cinereus* Hywel-Jones, and *A. websteri* Hywel-Jones. He also provided a key to the known species of *Akanthomyces* on spiders.

During a 6 yr survey of insect and spider pathogens in Taiwan that has been in progress since 1989, several spider cadavers were found to be infested by *Akanthomyces* species. Three species were identified as *A. ampullifer*, *A. araneorum* and *A. novoguineensis* Samson & Brady. A fourth species is reminiscent of *A. arachnophilus* (Petch) Samson & Evans, but differs from that species in having much larger, oblong to broadly obovate or ellipsoid conidia, and in characters of the conidiogenous cells. It is proposed here as new species.

An account of *Akanthomyces* species occurring on spiders in Taiwan follows. Cultures were grown on oatmeal agar (Difco) incubated at 25°C in darkness for 7 d to 2 mo. Specimens are deposited in the Plant Pathology and Entomology Department, National Taiwan University, Taiwan, Republic of China. Cultures are deposited in the Culture Collection and Research Center, Hsinchu, Taiwan. Color nomenclature is from Kornerup and Wanscher (1978).

### DESCRIPTIONS OF THE SPECIES

*Akanthomyces ampullifer* (Petch) Mains, Mycologia 42: 573. 1950. FIG. 1 A–C

Host covered by floccose, yellowish white, pale yellow to light yellow (4A2–4) mycelium from which numerous synnemata arise. Synnemata of variable length; long synnemata solitary, arising from the central dorsal part of the host, 5 mm long, ca. 100 µm wide; short synnemata, numerous, arising from the peripheral dorsal part of the host, circular, erect, short, simple, clavate, 480–720 µm long, 80–290 µm diam; both kinds of synnemata yellowish gray (4B2), pubescent, pulverulent towards the apex, composed

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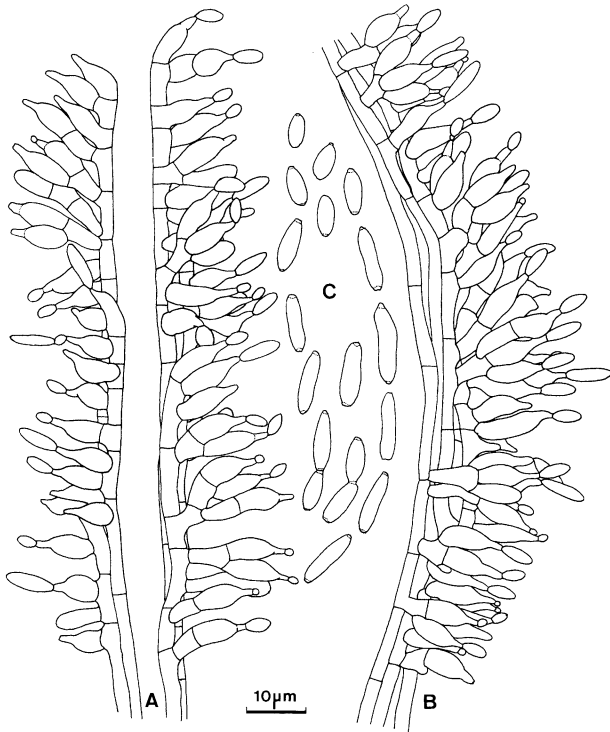


FIG. 1. A–C. Conidiogenous cells and conidia of *Akanthomyces ampullifer*. On spider *Ar. 98*.

of compact longitudinal parallel hyphae. Hyphae of synnema 1.6–2.4 µm wide, septate, hyaline, smooth. Phialides arising from the outer hyphae or lateral cells of the synnemata, 6.4–13.9(–15.5) × 3.6–4.4 µm, forming a hymenial layer, or sparsely arising from the hyphae or lateral cells of the hyphae, consisting of an ellipsoidal to cylindrical venter, 4.8–11.5 × 3.6–4.4 µm, hyaline, abruptly tapering into a distinctly long neck, 1.6–3.6(–4.8) × 1.0–1.7 µm, smooth. Conidia in a short chains, one-celled, cylindrical, 6.0–11.5 × 2.1–3.2 µm, occasionally curved, often with distinctly apiculate ends, hyaline, smooth. Teleomorph not observed.

*Specimen examined.* REPUBLIC OF CHINA. TAIWAN: Taipei County, Sanhsia, Manyuehyuan, on spider *Ar. 98*, 20 Jan. 1995, *L. S. Hsieh*.

*Akanthomyces aranearum* (Petch) Mains, *Mycologia* 42: 574. 1950. FIG. 2 A, B

Host covered by white, yellowish white (4A2) to grayish yellow (4B2–3) mycelium from which numerous (about 12) synnemata arise. Synnemata arising from all parts of the host, clavate, 0.8–1.8 mm long, slender, 62–74 µm thick below, simple or occasionally slightly branched, sometimes pubescent below, dark brown (7F5–7) to brown (7E6–7), becoming yellowish white (4A2) to orange white (5A2) towards the

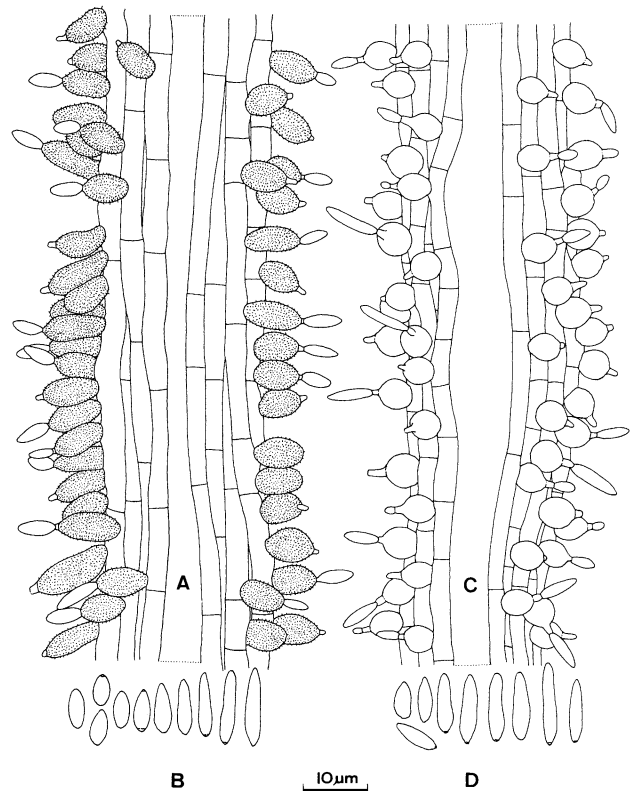


FIG. 2. Conidiogenous cells and conidia of *Akanthomyces aranearum*. A, B, on spider *Ar. 45* and *A. novoguineensis*. C, D, on spider *Ar. 29*. Note that conidiogenous cells of *A. aranearum* are distinctly roughened (A), and *A. novoguineensis* are mostly globose to subglobose with a constricted, narrow neck (C).

upper fertile portion, composed of parallel hyphae. Hyphae of synnema smooth, hyaline to orange (6A7), dark orange (5A8), sometimes swollen, 3.2–6.0 µm wide. Phialides scattered, forming a dense layer on the hyphae of synnemata, consisting of a globose to ellipsoid venter, hyaline to greenish white (30A2), 5.3–12.1 × 3.8–6.3 µm, asperulate to verrucose, abruptly narrowing into a short, smooth neck, 0.8–2.0 µm long, 0.8–1.6 µm wide. Conidia narrowly obclavate, often acute at the lower end, narrowing upward, rounded or obtuse at the upper end, one-celled, hyaline, smooth, catenulate, 4.4–11.4 × 1.9–2.6 µm. Teleomorph not observed.

*Specimen examined.* REPUBLIC OF CHINA. TAIWAN: Taipei County, Wulai, on spider *Ar. 45*, 27 Jun. 1991, *L. S. Hsieh*.

*Akanthomyces novoguineensis* Samson & Brady, *Trans. Brit. Mycol. Soc.* 79: 571. 1982. FIG. 2 C, D

Host covered by yellowish white to light yellow (4A2–4) mycelium from which numerous (up to 50)

aculeate synnemata arise. Mycelium hyaline, smooth, 2.4–4.6  $\mu\text{m}$  wide; hyphae sometimes slightly swollen and bearing solitary, globose, 4.4–5.6  $\mu\text{m}$  diam phialides with sharply constricted necks. Synnemata arising from all parts of the host, white to yellowish white, narrowing to an acuminate apex, 0.7–4.7 mm long, 110–350  $\mu\text{m}$  wide, bearing phialides in a hymenium along the whole length. Hyphae septate, hyaline, smooth or slightly rough, 2.6–5.0  $\mu\text{m}$  wide. Phialides consisting of a globose to subglobose venter, hyaline, smooth, 5.2–7.1  $\times$  4.8–6.0  $\mu\text{m}$ , constricted abruptly to a distinct, narrow neck, 1.4–1.8  $\times$  0.8–1.6  $\mu\text{m}$ . Conidia in short chains, one-celled, hyaline, smooth, narrowly cylindrical to fusiform, sometimes apiculate at one or both ends, occasionally curved, 6.4–11.1  $\times$  1.4–2.9  $\mu\text{m}$ . Teleomorph not observed.

*Specimens examined.* REPUBLIC OF CHINA. TAIWAN: Nantou County, Puli, Lienhuachih, on spider *Ar.* 29, 5 Sep. 1990, *Tzy-Mei Lin*; same location, on spider *Ar.* 33, 29 Sep. 1990, *W. J. Wu*; Nantou County, Luku, Shanlinchi, on spider *Ar.* 43, 10 May 1991, *L. S. Hsieh*.

**Akanthomyces ovalongatus** Hsieh, Tzean et Wu, sp. nov. FIGS. 3, 4

Aranea hospes mycelio pruinoso albo ad aurantio-albo (5A2) cooperta, multis synnematibus aculeatis instructa. Synnemata erecta, undique e hospite enascentia, simplicia an raro exigue ramosa, alba ad griseo-aurantiaca (5–6B3), 2.2–9.0 mm longa, 112–520  $\mu\text{m}$  lata. Hyphae hyalinae, septatae, ramosae, (2.3–) 2.5–3.7(–4.2)  $\mu\text{m}$  latae. Cellulae conidiogenae phialidicae, seu solitariae vel laxe compactae e mycelio enascentes, seu e synnematibus disseminatae vel coactae; e parte basilari globosa, subglobosa, cylindrica vel ellipsoidea, 6.0–8.7  $\times$  4.0–6.4  $\mu\text{m}$ , in collum angustum, 1.4–3.2  $\mu\text{m}$  longum, 0.8–1.8  $\mu\text{m}$  latum, attenuatae, glabrae; conidia catenis brevibus adhaerentia, ellipsoidea, ovata vel oblonga, 6.0–10.3  $\times$  2.4–4.4  $\mu\text{m}$ , unicellularia, hyalina, glabra. Status teleomorphus ignotus.

*HOLOTYPE.* REPUBLIC OF CHINA. TAIWAN: Taipei City, Yang-Ming-Shan National Park, on spider *Ar.* 113, 2 Aug. 1995. *L. S. Hsieh* (PPH 24, deposited in the herbarium of the Department of Plant Pathology and Entomology, National Taiwan University, Taipei, Taiwan, R. O. C.; Isotype IMI). The ex-type culture PPH 24E was deposited in the Culture Collection and Research Center (CCRC 33385), Hsinchu, Taiwan, R. O. C.

Spider host covered by powdery white to orange white (5A2) mycelium. Synnemata erect, arising from all parts of the host, numerous, simple or occasionally branched, white to grayish orange (5–6B3), 2.2–

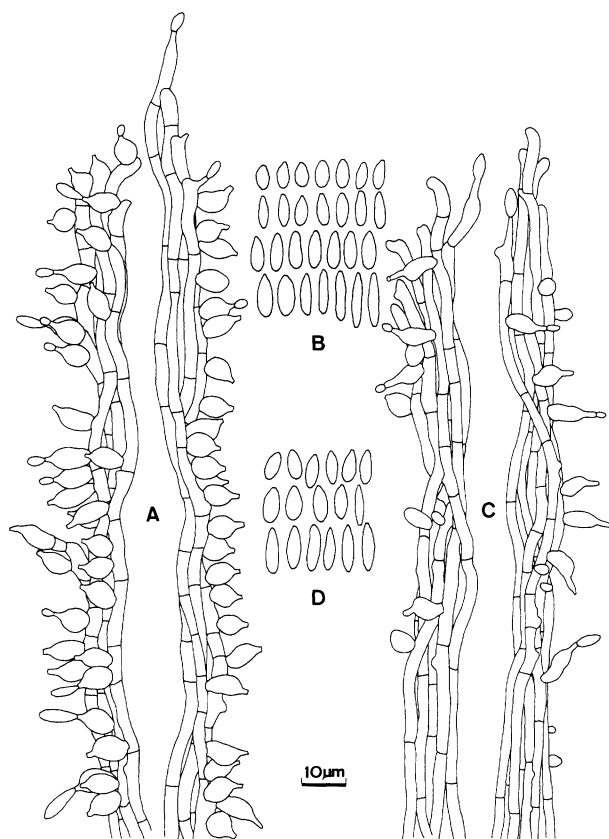


FIG. 3. *Akanthomyces ovalongatus*. Conidiogenous cells and conidia. A, B, on naturally infested host. C, D, on oatmeal agar. On spider *Ar.* 113.

9.0 mm long, 112–520  $\mu\text{m}$  wide. Hyphae of synnema hyaline, septate, branched, (2.3–)2.5–3.7(–4.2)  $\mu\text{m}$  wide. Conidiogenous cells phialidic, either arising from the mycelium and solitary, or loosely compacted into a layer, or arising from synnemata and scattered to crowded over the length of the synnema. Phialides consisting of a globose to subglobose, cylindrical or ellipsoidal basal part, 6.0–8.7  $\times$  4.0–6.4  $\mu\text{m}$ , and an abruptly narrowed neck, 1.4–3.2  $\mu\text{m}$  long, 0.8–1.8  $\mu\text{m}$  wide, smooth. Conidia in short chains, ellipsoidal, obovate to oblong, 6.0–10.3  $\times$  2.4–4.4  $\mu\text{m}$ , sometimes apiculate at one end, one-celled, hyaline, smooth. Teleomorph not observed.

Colonies on oatmeal agar at 25°C in darkness growing slowly, 25–36 mm diam after 2 mo. Mycelium hyaline to white, plane felty to velutinous. Submerged hyphae septate, smooth, hyaline, infrequently branched, 2.4–6.0  $\mu\text{m}$  wide, pigments grayish orange (5–6B3), grayish brown to reddish brown (8E3–5). Colony reverse grayish brown, reddish brown to dark brown (9F5). Aerial hyphae septate, smooth, hyaline, branched, swollen near the septa, 2.4–9.1  $\mu\text{m}$  wide. Exudate in aerial mycelium limited or absent. Synnemata erect, semi-erect, or procumbent, straight or

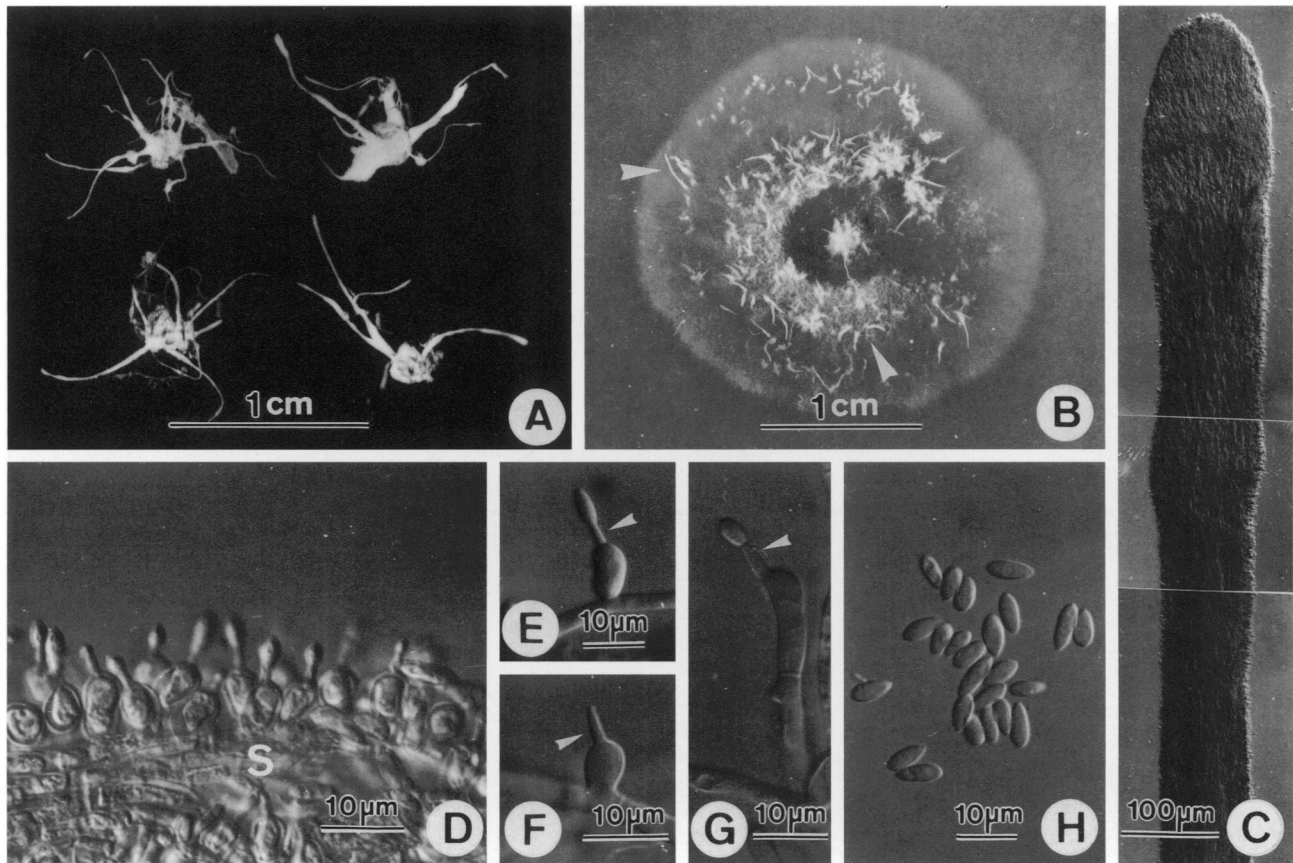


FIG. 4. *Akanthomyces ovalongatus*. A. Synnemata arising from infested spiders. B. Synnemata produced on oatmeal agar at 25°C, in darkness after incubation for 2 mo (arrow heads). C. Synnema from spider host, cylindrical and covered with a hymenium of conidiogenous cells. D. Conidiogenous cells subglobose densely disposed on a synnema from spider. E, F. Conidiogenous cells arising from synnemata, with an abruptly attenuated neck (arrow heads). G. Conidiogenous cell from oatmeal agar arising from end of a mycelial hypha with a distinct neck (arrow head). H. Conidia from spider.

slightly curved, white, aculeate, up to 2.7 mm long, 160–400  $\mu\text{m}$  wide at base, sometimes forked at base, developing in inconspicuous concentric rings or scattered, composed of smooth, parallel, hyaline hyphae 1.8–4.0(–4.8)  $\mu\text{m}$ . Phialides sparse, scattered on the synnemata, or occasionally solitary, arising from the end of an aerial hypha, consisting of a globose, subglobose to ellipsoid basal part, 7.1–12.7  $\times$  4.4–6.0  $\mu\text{m}$ , and a cylindrical venter that becomes almost abruptly constricted to a short neck, 2.0–5.6  $\times$  1.2–2.2  $\mu\text{m}$ , smooth. Conidia in short chains of three or fewer, ellipsoidal, obovate to oblong or broadly obovoid, 6.5–12.7  $\times$  2.8–4.0  $\mu\text{m}$ , sometimes apiculate at one end, one-celled, hyaline, smooth. Chlamydospores absent. Teleomorph unknown.

#### DISCUSSION

During a six yr survey conducted from 1989 in Taiwan, 7 of 117 spider cadavers collected were infested by *Akanthomyces*, and designated as Ar. 29, 33, 43,

45, 69, 98, 113, respectively. The infested spiders usually inhabited the lower surface of broad leaves herbs or shrubs in humid and shaded areas. Of these, Ar. 69 was immature, and could not be identified to species. Ar. 29, 33, and 43 were identified as *A. novoguineensis*, and Ar. 29 was selected as a voucher specimen for illustration and diagnosis. The conidial sizes of Ar. 29, Ar. 33 and Ar. 43 were 6.4–11.1  $\times$  1.4–2.9  $\mu\text{m}$ , (5.7–)7.5–14.0  $\times$  1.8–2.9  $\mu\text{m}$ , and 5.6–15.9 (–19.8)  $\times$  1.4–2.9  $\mu\text{m}$ , respectively. Conidia of Ar. 29 and Ar. 33 are smaller than conidia in the type specimen of *A. novoguineensis* (10.5–17.5  $\times$  1.5–3  $\mu\text{m}$ ), which was described from Papua New Guinea by Samson and Brady (1982), but comparable to conidia in the specimen (5.7–11.0  $\times$  1.0–1.6  $\mu\text{m}$ ) collected in Thailand by Hywel-Jones (1996). Obviously, there is a transition in the conidial size among isolates. The specimen Ar. 45 from Taiwan is a typical *A. aranearum*, with verrucose phialides and obclavate conidia. These unusual features were well documented previously (Samson and Evans, 1974; Hywel-Jones, 1996).

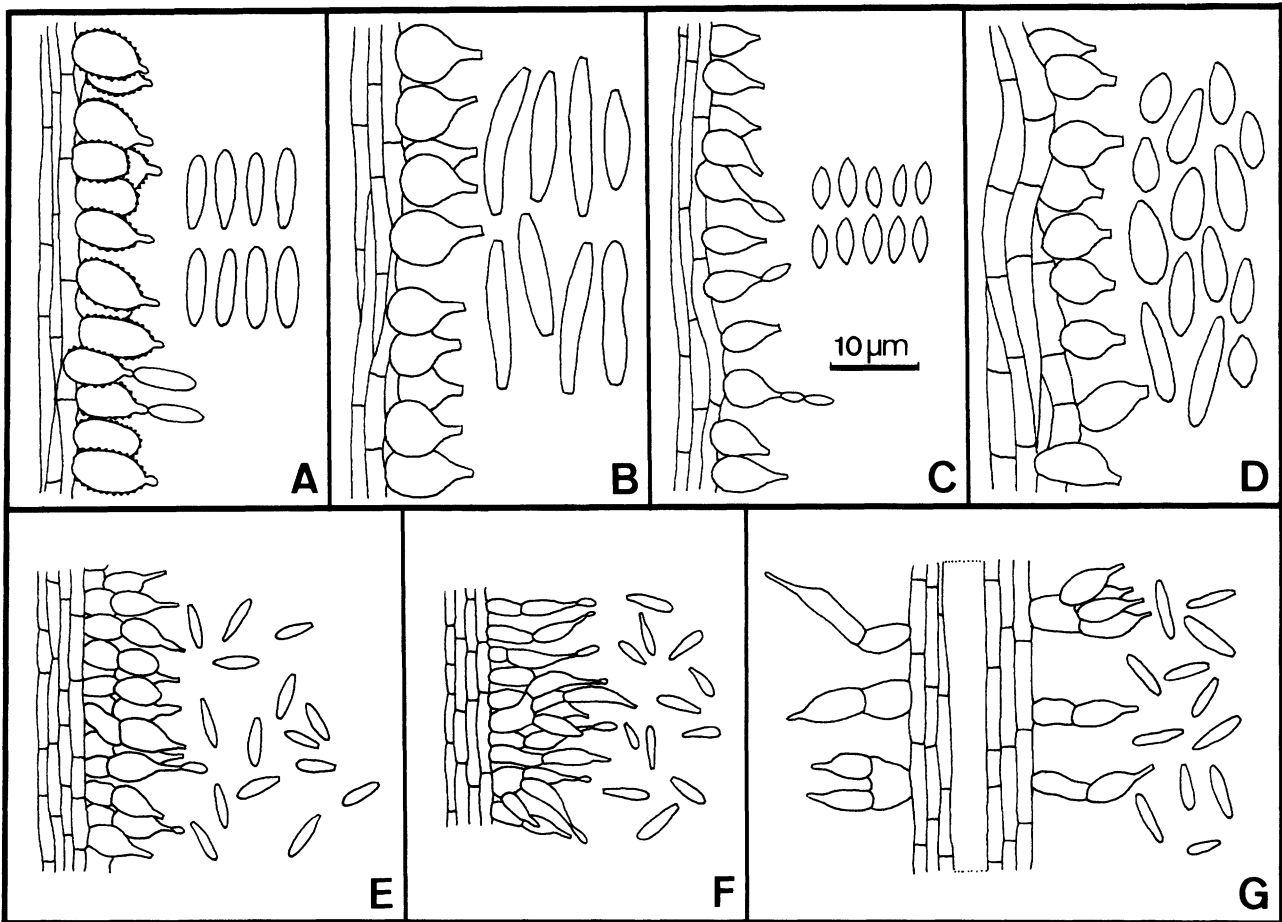


FIG. 5. Illustrations of conidiogenous cells and conidia of 7 species of *Akanthomyces* parasitic on spiders. A. *A. araneorum*. B. *A. novoguineensis*. C. *A. arachnophilus*. D. *A. ovalongatus*. E. *A. koratensis*. F. *A. cinereus*. G. *A. websteri*. A–C and E–G are redrawn with permission from R. A. Samson and N. L. Hywel-Jones, respectively. All figures are to the same scale.

The specimen *Ar. 98* is *A. ampullifer*. This is the first report of *A. ampullifer* from a spider; it typically occurs on dipteran gnats (Mains, 1950).

The collection *Ar. 113* is morphologically distinct from all described species of *Akanthomyces* and is proposed as the new species, *A. ovalongatus*. *Akanthomyces ovalongatus* can be separated from the six previously described *Akanthomyces* species that occur on spiders, *A. araneorum*, *A. novoguineensis*, *A. arachnophilus*, *A. koratensis*, *A. cinereus*, and *A. websteri* (Mains, 1950; Samson and Evans, 1974; Hywel-Jones, 1996) by the shape, size and roughness of the phialides, and/or by the shape and size of the conidia (FIG. 5 A–G). *Akanthomyces ovalongatus* can also be readily distinguished from *A. aculeatus*, the type species of the genus *Akanthomyces*, which is associated with mosses, by its much larger conidia ( $6.0\text{--}10.3 \times 2.4\text{--}4.0 \mu\text{m}$  vs  $3\text{--}6 \times 2\text{--}3 \mu\text{m}$ ), although both species have similar ellipsoidal or obovoid conidia. Phialides of *A. ovalongatus* in agar culture are sparse, slender, and cylindrical or ellipsoidal, somewhat reminiscent of *A. ampullifer* (Mains, 1950). Comparison *A. ova-*

*longatus* with the holotype of *A. ampullifer* ( $\equiv$  *Hymenostilbe ampullifera* Petch, FH727) demonstrated that phialides and conidia of the latter species were noticeably narrower.

The morphology of synnemata and conidiogenous cells of *A. ovalongatus* developed on naturally infected spider considerably differed from that found in agar culture. On spiders, the phialides are dense, and form a hymenial layer covering the synnemata, and consist of globose to subglobose basal parts, whereas on agar culture, the phialides are loosely dispersed along the length of the synnemata, and the basal parts of the phialides usually are narrower, ellipsoidal or cylindrical in shape. Moreover, the synnemata on spider hosts are longer and wider than on culture media ( $2.2\text{--}9.0 \text{ mm} \times 112\text{--}520 \mu\text{m}$  vs  $2.7 \text{ mm} \times 160\text{--}400 \mu\text{m}$ ).

None of the three *Akanthomyces* species found on spiders in Taiwan has been found correlated with a teleomorph. Hywel-Jones (1996) reported six *Akanthomyces* species from Thailand and also found no evidence of a teleomorphic connection. On the other

hand, Samson and Evans (1974), studying Ghanaian specimens, found a constant association of *A. pistillariiformis* (Pat.) Samson & H. C. Evans with an ascomycetous teleomorph similar to *Cordyceps tuberculata* (Lib.) Maire but that showed a great variation in perithecial form.

While constructing a key for the known *Akanthomyces* species based on the published descriptions, *A. pistillariiformis* was found to be extremely similar to *A. angustisporus* Mains in morphological characters of conidiogenous cells and conidia, although the host, synnema color and branching patterns varied (Mains, 1950). Unfortunately, the holotype of *A. angustisporus* was not available for loan, because it consists of a single larva with a small and fine synnema attached (MICH, R. Fogel, personal communication). Therefore, comparative study of these two species to clarify the puzzle was not possible. Pending comparison of the respective type specimens, host preference and synnemata are used to distinguish *A. pistillariiformis* and *A. angustisporus*. However, Samson and Evans (1974) indicated that such features may be variable depending on host species and habits. Here we key out the thirteen described *Akanthomyces* species. Some epithets that were orthographically incorrect in gender, have been corrected (International Code of Botanical Nomenclature Arts. 62.1 and 62.2a).

#### KEY TO SPECIES OF AKANTHOMYCES

1. Saprobiic; conidia broadly fusoid, ends somewhat truncate, with minute frills . . . . . *A. johnsonii*
1. Parasitic on spiders or insects; conidia not as above . . . . . 2
  2. Parasitic on spiders . . . . . 3
  2. Parasitic on insects . . . . . 9
3. Phialides verrucose; conidia obclavate . . . . . *A. araneorum*
3. Phialides smooth; conidia not as above . . . . . 4
  4. Phialides mostly arising from basal cells perpendicular to the synnemata . . . . . 5
  4. Phialides mostly not arising from basal cells perpendicular to the synnemata . . . . . 7
5. Phialides often cylindrical, synnemata multiple . . . . .
5. Phialides often ellipsoidal, synnemata simple . . . . . 6
  6. Phialides hymenial, covering the synnemata except the sterile brown base . . . . . *A. koratensis*
  6. Phialides scattered, covering the length of the creamish synnemata . . . . . *A. websteri*
7. Conidia cylindrical, curved,  $10.5\text{--}17.5 \times 1.5\text{--}3 \mu\text{m}$  . . . . . *A. novoguineensis*
7. Conidia oblong, fusiform, ellipsoidal, obovoid to clavate, smaller . . . . . 8
  8. Conidia fusiform, with acute ends,  $4.5\text{--}5.5 \times 1.5\text{--}3.0 \mu\text{m}$  . . . . . *A. arachnophilus*
  8. Conidia oblong, obovate or broadly ellipsoidal,  $6.0\text{--}10.3 \times 2.4\text{--}4.4 \mu\text{m}$  . . . . . *A. ovalongatus*

9. Conidia often in long chains of more than 3, minute,  $2.5\text{--}3 \times 1\text{--}1.6 \mu\text{m}$  . . . . . *A. gracilis*
9. Conidia often in short chains of less than 3, longer than above . . . . . 10
  10. Conidia often longer than  $6 \mu\text{m}$  . . . . . *A. ampullifer*
  10. Conidia often shorter than  $6 \mu\text{m}$  . . . . . 11
11. Conidia broadly ellipsoidal or obovoid, acute at lower end,  $3\text{--}6 \times 2\text{--}3 \mu\text{m}$  . . . . . *A. aculeatus*
11. Conidia narrowly fusiform or clavate,  $4.5\text{--}6 \times 1.2\text{--}1.4(5) \mu\text{m}$  . . . . . 12
  12. Synnemata flesh colored, simple or branched,  $8\text{--}13 \times 0.2\text{--}0.6 \text{mm}$ ; associated with coleopteran hosts . . . . . *A. angustisporus*
  12. Synnemata white to creamish, often simple, rarely branched,  $1\text{--}6 \times 0.05\text{--}0.3 \text{mm}$ ; associated with lepidopteran hosts . . . . . *A. pistillariiformis*

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