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PARAISARIA, A NEW GENUS FOR *ISARIA DUBIA*, THE ANAMORPH OF *CORDYCEPS GRACILIS*

BY R. A. SAMSON

Centraalbureau voor Schimmelcultures, P.O. Box 273, 3740 AG Baarn, The Netherlands

AND B. L. BRADY

Commonwealth Mycological Institute, Ferry Lane, Kew, Richmond, Surrey, TW9 3AF, U.K.

The new genus *Paraisaria* is proposed for *Isaria dubia*. The entomogenous hyphomycete, frequently occurring on larvae of species of *Hepialus* (Lepidoptera, Hepialidae), is characterized by white, loose synnemata consisting of verticillately-branched conidiophores with flask-shaped sympodially proliferating phialides. The conidiogenous cells give rise to one-celled, hyaline conidia in heads. Single-ascospore isolations confirmed earlier suggestions that this hyphomycete is the anamorph of *Cordyceps gracilis*.

Isaria dubia was described by Delacroix (1893) on larvae of *Hepialus lupulinus* collected near Rouen, France. Delacroix compared the fungus with species of *Clavaria* and *Thelephora*, because he observed basidium-like structures with sterigmata. No type material seems to have been preserved, but during our studies on entomogenous fungi we have encountered several specimens which agree with the original descriptions and illustrations. Recently we also obtained two pure cultures, one grown from ascospores of *Cordyceps gracilis* Dur. & Mont. Examination of *Isaria dubia* *in vivo* and *in vitro* showed that the species does not fit any hyphomycete genus and therefore the following new genus is proposed.

Paraisaria gen. nov.

Conidiophora hyalina synnematibus laxis pennatis coacta, repetite verticillata et verticillos terminales cellularum conidiogenarum ferentia. Cellulae conidiogenae phialidicae, lageniformes, saepe sympodialiter in 1-4 collula proliferantes. Conidia continua, hyalina, levia, successione basipetali capitula mucida formantia. Genus entomogenum. Teleomorphosis *Cordyceps* Fr.

Species typica *Isaria dubia* Delacr.

Conidiophores hyaline, with both verticillately-branched and terminal whorls of branches and conidiogenous cells, aggregated into loose feather-like synnemata. *Conidiogenous cells* phialidic, flask-shaped, frequently sympodially proliferating to give rise to 1-4 phialide necks. *Conidia* one-celled, hyaline, smooth-walled, produced in basipetal succession in slimy heads. Entomogenous. Teleomorph: *Cordyceps* Fr.

Paraisaria dubia (Delacr.) comb. nov.

Isaria dubia Delacr., *Bull. Soc. Mycol. Fr.* 9: 264 (1893), basionym.

Teleomorph: *Cordyceps gracilis* Dur. & Mont. in Durieu, *Fl. Alger. Crypt.* 1: 449 (1846).

Larvae covered by pale yellow mycelium bearing several synnemata. The interior of the body white and chalky without resting spores. *Conidiophores* on the host hyaline, repeatedly verticillate, bearing either whorls of branches or of conidiogenous cells and aggregated into loose feather-like synnemata up to 10 mm long. *Conidiogenous cells* phialidic, $4-6.4 \times 2.4-3.2 \mu\text{m}$, frequently sympodially proliferating, with a swollen venter giving rise to 1-6 sharply narrowed necks, $1.6-2.4 \times 0.8-1.5 \mu\text{m}$. *Conidia* narrowly cylindrical to fusiform, one-celled, hyaline, smooth-walled, $3.2-4.8 \times 0.8 \mu\text{m}$, produced in basipetal succession and aggregating in heads or fascicles.

Growth in pure culture obtained from either conidia or from germinating ascospores. Colonies on malt extract, oatmeal or Sabouraud maltose agar slow-growing, white to cream-coloured to pale yellow, velvety, forming several distinct synnemata after 2-3 weeks. *Conidiophores*, conidiogenous cells and conidia as on the host.

Teleomorph. The anamorph is often found growing alone on the host but also occurs in association with the teleomorph. The teleomorph was not observed in pure culture. It forms striking solitary stromata, 15-90 mm long, with a deep chrome yellow stipe terminating in a globose or ellipsoid capitate fertile region, $2.5 \times 2-4 \text{ mm}$, red or ochraceous, with numerous perithecial ostioles over the surface. According to Mains

Fig. 1. *Cordyceps gracilis* on *Hepialus* sp. (A) IMI 713. Both teleomorph and anamorph; (B) IMI 713, as above. Copy of photograph at CMI, (C) IMI 16573 (a). Copy of photograph, Rothamsted Experimental Station, Harpenden. Teleomorph *in situ*; (D) IMI 16573 (a). As above. Bars = 1 cm.

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Fig. 2. *Paraisaria dubia*. Camera-ludica drawings of conidiophores and conidia.

(1958) 'perithecia are completely embedded, 560–840 × 200–360 μm; asci are cylindrical, 400–528 × 4–6 μm; ascospores are filiform, multi-septate, breaking into one-celled fragments, 6–8 × 1–1.5 μm.' These fragments germinate to give the anamorph.

Specimens examined:

Herbarium specimens (all on larvae): IMI 713 *Hepialus* sp., Harpenden, Herts., 5 Apr. 1945, A. Smith, mostly teleomorph but good photograph of material in both states. IMI 16573 (a) *Hepialus* sp., Harpenden, 16 May 1947, A. Smith (sent in by P. H. Gregory no. 727), teleomorph and anamorph (atypical). IMI 41601 *Hepialus* sp., 3 June 1950, C. J. La Touche, University of Leeds, teleomorph and anamorph on insect, with dried culture. IMI 56133 *Hepialus* sp., in ground at Heston, Cambs., 25 March 1954, T. J. Lagowski, not very good material. IMI 73449 unidentified Lepidoptera, Nant Crafnant, Trefrew, N. Wales, 17 May 1958, J. Manners, teleomorph. IMI 80974 unidentified Lepidoptera, in bracken in soil, Radnor, 27 May 1960, G. M. Waterhouse and S. M. Francis teleomorph. IMI 204098 and 212191 *H. sylvina*, Dereham, Norfolk, March 1976 and 10 March 1977, R. E. Evans, anamorph. IMI 214624 *H. lupulinus*, Dereham, Norfolk, June 1977, R. E. Evans, anamorph. IMI 271635 *Hepialus* sp., Ashford, Kent, 26 Apr. 1976, A. Frisby, (sent in by S. K. Mardell as H39), anamorph.

Living cultures:

CBS 951.73 = strain 90/73, single ascospore isolate of *Cordyceps gracilis* made by E. Müller-Kögler, Darmstadt, F.R.G., from unidentified insect. CBS 680.77 = strain V54, isolated by N. Wilding from *Hepialus* sp., collected at Wye, Kent.

Since no holotype is available, IMI 41601 is here indicated as neotype of *Isaria dubia*.

DISCUSSION

Recently Lauritzen (1971) and Laessøe (1982) described *Cordyceps gracilis* from Norway and Denmark respectively with the *Paraisaria* anamorph as a typical species on *Hepialus* larvae.

The genetic association of *P. dubia* with *Cordyceps gracilis* has also been suggested by Petch (1932), Favre (1942), Kobayasi (1941) and Mains (1958). The strain CBS 951.73 grown from single ascospores confirms these earlier observations.

In the genus *Isaria* Pers. about 200 heterogeneous taxa have been included which belong more satisfactorily in various other hyphomycete form genera. Von Arx (1970) redefined *Isaria*, proposing *I. felina* (DC.) Fr. as the lectotype species.

amorph; (B) IMI 713, as above.
Camsted Experimental Station,

Fig. 3. *P. dubia*. Scanning electron micrographs of conidiogenous structures of CBS 680.77 Bars = 10 μ m.

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Following this concept of the genus *I. amorpha* Höhnelt (= *Beauveria amorpha* (Höhnelt) Samson & Evans, 1982) was also accepted by de Hoog (1972). When the history of *Isaria* is traced back it becomes clear that *I. agaricina* Pers. is the only original species sanctioned by Fries (1832), and this species thus represents the holotype of the genus. As stated by Gams (1971: 141 foot-note) the genus concept then coincides with that of *Tilachlidium* Preuss.

Isaria has also been typified by several authors (e.g. Clements & Shear, 1931) with *I. farinosa* Holm: Fr. However this species is congeneric with *Paecilomyces variotii* Bainier (Samson, 1974); other phialidic species are classified in *Akanthomyces* Lebert (= *Insecticola* Mains), *Gibellula* Cavara or *Hirsutella* Pat. (Mains, 1950; Samson & Evans, 1973). *Isaria dubia* cannot be accommodated suitably in any of the above-mentioned genera, because it combines verticillate conidiophores with frequently sympodially-proliferating truly flask-shaped phialides and conidia in heads.

Paraisaria bears some resemblance to *Syngliocladium* Petch (1932), based on *S. araneorum* Petch on a spider. In a later paper, Petch (1942) proposed two more species, *S. cleoni* (Wize) Petch (= *Acremonium cleoni* Wize) and *S. intricatum* Petch, which both produce sclerotial masses of the anamorph genus *Sorospora* Sorok. within the insect body. Petch (1942) had not observed these sclerotial masses in the type species, but he suggested that the sclerotial mass might have fallen out, since the body of the spider was broken before it was collected. The only extant type specimen of *S. araneorum*, which is poorly preserved, contains a stipitate *Stilbella*-like fungus with phialides arranged in a hymenium-like pattern. In herb. IMI there is a specimen, IMI 27578, labelled: '*Syngliocladium* sp. on *Agriotes* sp. (collected by H. C. Gough) associated with *Sorospora*'; Petch (1942) examined this specimen and based on it his new combination *S. cleoni*. The specimen is in poor condition but contains *Sorospora*-like resting spores and synnemata with conidiogenous structures similar to those described by Speare (1917, 1920) as *Sorospora uvella* (Krass.) Giard.

In herb. K a specimen, labelled *Syngliocladium intricatum*, is preserved on a white grub (*Phyllophaga anxia* Lec.) which is also similar to the specimens Speare (1917, 1920) described as *Sorospora uvella* on several species of cutworm in the U.S.A. The specimen contains much external pale yellow mycelium and loose synnemata. Petch (1942) considered this to be the *Syngliocladium* 'conidial state' of *Sorospora uvella*. Without cultural studies however, it is difficult to confirm his suggestions.

The conidiogenous structure of *Paraisaria* bears

some resemblance to two other phialidic genera: *Sesquicillium* W. Gams and *Tolypocladium* W. Gams. In *Sesquicillium* the conidia are, however, produced in dry imbricate chains on pairs of a terminal and subterminal phialide. In the *Beauveria*-like genus *Tolypocladium* the conidia are produced in heads, and the clustered phialides which proliferate rarely have only a thin short neck. Although we have encountered *T. cylindrosporum* W. Gams on insects on a few occasions, we have never observed synnematos development.

Granulomanus araneorum (Petch) de Hoog & Samson (de Hoog, 1978) is superficially reminiscent of *Paraisaria*. This fungus is a synanamorph of *Torrubiella*, frequently occurring with the anamorph *Gibellula*. The conidiophores of *Granulomanus* are undifferentiated, while the phialides bear some conidiiferous protrusions. The conidia are single-celled, but not produced in heads.

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