
Two new species of *Cosmospora* (Nectriaceae, Hypocreales) from China

Luo, J.^{1,2} and Zhuang, W.Y.^{1*}

¹Key Laboratory of Systematic Mycology and Lichenology Laboratory, Institute of Microbiology, Chinese Academy of Sciences, Beijing 100101, P.R. China

²Graduate University of Chinese Academy of Sciences, Beijing 100049, P.R. China

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Two new species, *Cosmospora gigas* and *C. cupularis*, and their anamorphs are described and illustrated. Their morphological affinities to related taxa are discussed. Phylogenetic relationships of the two new species with some fungi of the Nectriaceae are revealed based on analyses of the ITS1-5.8S-ITS2 and 28S rDNA partial sequences. The results indicate their taxonomic position in *Cosmospora*, a genus that as currently defined, is not monophyletic.

Key words: morphology, sequence analysis, taxonomy.

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*Corresponding author W.-Y. Zhuang; e-mail: zhuangwy@im.ac.cn

Introduction

Cosmospora was established in 1862 and is typified with *C. coccinea* Rabenh. (Rossman *et al.*, 1999). Members of the genus were assigned previously to *Nectria* subgenus *Cosmospora* (Rabenh.) Sacc., *Dialonectria* (Sacc.) Cooke, *Nectria episphaeria*-group and *Chrysogluen* Briosi & Farneti (Saccardo, 1883; Booth, 1959; Rogerson, 1970; Samuels, 1976; Rossman, 1983; Samuels *et al.*, 1990; Samuels *et al.*, 1991). They are characterized by small-sized perithecia with glabrous surface or with few to numerous hairs arising from the wall surface, having adjacent perithecial wall cells joined by fine pores, consisting of parallel hyphal elements in papilla, and connected with several anamorphic genera (Rossman *et al.*, 1999). Fifty-six species of the genus are currently accepted, and 15 have been reported from China (Rossman *et al.*, 1999; Fröhlich and Hyde, 2000; Samuels and Nirenberg, 2000; Zhuang and Zhang, 2002; Hosoya and Tubaki, 2004; Nong and Zhuang, 2005).

On collecting trips to Huisun Forestry Farm in Nantou County of Taiwan and Tianmushan in Hangzhou City of Zhejiang in 2005, two interesting nectriaceous fungi with hairy

and cupulate perithecia when dry were encountered. Based on Rossman *et al.* (1999), these specimens were determined to be two undescribed species of *Cosmospora*. To determine their close relatives in the genus and phylogenetic position in the Nectriaceae, analyses of the ITS1-5.8S-ITS2 and 28S rDNA partial sequences of the collections and related members of the family were carried out. Two species of *Bionectria* Speg., the closest relative to the Nectriaceae, were selected as outgroup. The results indicate that the two new species of *Cosmospora* are close-related and that *Cosmospora* as currently defined is not monophyletic.

This work is a continuation of our taxonomic studies on nectriaceous fungi from China (Zhuang, 2000; Zhuang and Zhang, 2002; Zhang and Zhuang, 2003a,b; Nong and Zhuang, 2005; Luo and Zhuang, 2007; Zhuang *et al.*, 2007).

Material and methods

Morphological study

Following the methods by Rossman *et al.* (1999), single-spore isolation, reactions to KOH and lactic acid solutions of ascomata, and detailed observation of anatomic features were

Table 1. Materials used in this study.

Taxon	ITS1-5.8S-ITS2		28S rDNA	
	Collection no. or source ^a	GenBank accession no.	Collection no. or source ^a	GenBank accession no.
<i>Bionectria ochroleuca</i> (Schwein.) Schroers & Samuels	CBS 376.55	AF358239	G.J.S. 90-227	AY489716
<i>B. pityrodes</i> (Mont.) Schroers	CBS 102033	AF210672	ATCC 208842	AF193239
<i>Calonectria morgani</i> Crous, Alfenas & M.J. Wingf.	ATCC 46300	AF493968	ATCC 11614	U17409
<i>Corallomyces</i> <i>repens</i> (Berk. & Broome) Rossman & Samuels	NRRL 20420	AJ557830		
	NHRC-FC042	AJ558114	HMAS 76860	DQ119553
<i>Cosmospora chaetopsinae</i> (Samuels) Rossman & Samuels			HMAS 83362	DQ119554
<i>C. chaetopsinae-catenulatae</i> (Samuels) Rossman & Samuels			A.R. 2741	U17407
<i>C. coccinea</i> Rabenh.			HMAS 76861	DQ119555
<i>C. consors</i> (Ellis & Everh.) Rossman & Samuels	HMAS 76861	EF121861 ^b	HMAS 97514	EF121870
<i>C. cupularis</i> J. Luo & W.Y. Zhuang	HMAS 97514	EF121864	G.J.S. 88-29	AY015625
<i>C. episphaeria</i> (Tode) Rossman & Samuels			HMAS 99592	EF121869
<i>C. gigas</i> J. Luo & W.Y. Zhuang	HMAS 99592	EF121853	HMAS 83363	DQ119556
<i>C. glabra</i> (Rossman) Rossman & Samuels			HMAS 83366	DQ119558
<i>C. vilior</i> (Starbäck) Rossman & Samuels	R.V. olrim161	AY618257	G.J.S. 96-186	AY015626
	ATCC 16217	U57673	ATCC 16217	U57348
<i>Haematonectria haematococca</i> (Berk. & Broome) Samuels & Nirenberg	SUF 1328	AF150477	HMAS 83364	DQ119559
	SUF 1329	AF150478	HMAS 83372	DQ119564
<i>H. ipomoeae</i> (Halst.) Samuels & Nirenberg	NRRL 22101	AF178398	DAOM 216608	AY281098
<i>Lanatonectria flavolanata</i> (Berk. & Broome) Samuels & Rossman	HMAS 97516	EF121860	HMAS 76869	DQ119565
	HMAS 76869	EF121862	HMAS 83374	DQ119566
<i>L. flocculenta</i> (Henn. & E. Nyman) Samuels & Rossman	HMAS 76873	EF121858		
	HMAS 97517	EF121868	HMAS 83378	DQ119568
<i>L. oblongispora</i> Y. Nong & W.Y. Zhuang			ATCC 22228	AY489732
<i>Leuconectria clusiae</i> (Samuels & Rogerson) Rossman, Samuels & Lowen	G.J.S. 92-7	AF220976	A.R. 2706	U17412
<i>L. grandis</i> Y. Nong & W.Y. Zhuang	HMAS 98302	EF121859	HMAS 98302	EU031441
<i>Nectria australiensis</i> Seifert			HMAS 83397	DQ119569
<i>N. cinnabarina</i> (Tode) Fr.	NBRC 30679	AB237663	CBS 713.97	AF193237
	NRRL 20484	L36626		
<i>N. mariannaeae</i> Samuels & Seifert	NBRC 7060	AB099509	DAOM 226709	AY283553
	NBRC 6987	AB111492		
<i>N. pseudotrichia</i> (Schwein.) Berk. & M.A. Curtis	HMAS 97518	EF121865	K.A.S. 791	AY288102
			CBS 102034	U17410
<i>N. sinensis</i> Teng			HMAS 83356	DQ119571
<i>Nectriadiella camelliae</i> (Shipton) Crous & C.L. Schoch	ATCC 38571	AF220960	CBS 111794	AY793432
	CPC 10451	AY793452		
<i>Neocosmospora vasinfecta</i> E.F. Sm.	NRRL 22499	AY381140	J.P. 936	U17406
	NRRL 22500	AY381143	RSA 1898	U47836
<i>Neonectria radicolica</i> (Gerlach & L. Nilsson) Mantiri & Samuels	A.R. 2553	AF220968	DAOM226721	AY283552
	C.T.R. 7-322	AF220969	A.R. 2553	NRU17415
<i>N. veuillotiana</i> (Sacc. & Roum.) Mantiri & Samuels	HMAS 97519	EF121866		
<i>Neonectria</i> sp.	HMAS 97520	EF121867		
<i>Pseudonectria rousseliana</i> (Mont.) Wollenw.			A.R. 2716	U17416
<i>Viridispora diparietispora</i> (J.H. Mill., Giddens & A.A. Foster) Samuels & Rossman			A.R. 2674	U17411
			ATCC 13214	U17413

^aA.R. = A. Rossman; C.T.R. = C.T. Rogerson; G.J.S. = G.J. Samuels; K.A.S. = K.A. Seifert; J.P. = J. Polishook; R.V. = R. Vasiliauskas; ATCC = American Type Culture Collection, Bethesda, MD, U.S.A.; CBS = Centraalbureau voor Schimmelcultures, Utrecht, The Netherlands; DAOM = Department of Agriculture, Ottawa, Mycology, Canada; NBRC = NITE Biological Resource Center, Department of Biotechnology, National Institute of Technology and Evaluation, Chiba, Japan; NHRC = National Hematology Research Centre, 4A, Novozykovsky, Proezd, Russia; NRRL = National Center for Agricultural Utilization Research, U.S. Dept. of Agriculture, Peoria, IL, USA; RSA = Rancho Santa Anna culture collection; SUF = Culture Collection of *Fusarium* in Sinshu University, Japan.

^bNumbers in boldface indicating newly submitted sequences.

undertaken. For anatomic study, longitudinal sections through ascomata were made with a freezing microtome (YD-1508-III, Yidi Medical Appliance Factory, Jinhua, Zhejiang) at a thickness of ca 10 μm . Specimens studied are deposited in the Mycological Herbarium, Institute of Microbiology, Chinese Academy of Sciences (HMAS). Description of colony color follows Ridgway (1912). Cultures are deposited in the Key Laboratory of Systematic Mycology & Lichenology Laboratory, Institute of Microbiology, Chinese Academy of Sciences.

DNA extraction

Mycelium was harvested from colonies on PDA grown for 1-2 weeks and DNA was extracted (Wang and Zhuang, 2004). Some sequences of presumed relatives and outgroup members were retrieved from GenBank. All material used in this study is shown in Table 1.

PCR and sequencing

Nuclear rDNA ITS1-5.8S-ITS2 and LSU was amplified by using the primer pairs, ITS5-ITS4 (White *et al.*, 1990), and LROR-LR5 (Rehner and Samuels, 1994; Vilgalys and Hester, 1990). The PCR reaction mixture (50 μl) consisted of 5 μl 10 \times PCR buffer, 3 μl MgCl_2 (25 mM), 2.5 μl sense primer (10 μM), 2.5 μl antisense primer (10 μM), 1 μl dNTP (10 mM each), 2.5 μl DNA template, 0.5 μl *Taq* polymerase (5 U/ μl) (Bio Basic Inc.) and 33 μl ddH₂O. Reactions were performed on the GeneAmp PCR System 2400 (Perkin Elmer) with cycling conditions of a denaturation at 95°C for 5 minutes, followed by 37 cycles of denaturation at 94°C for 30 seconds, annealing at 52°C (ITS region) and 55°C (28S rDNA) for 30 seconds and elongation at 72°C for 60 seconds, with a final extension step at 72°C for 5 minutes to complete the reactions. The PCR products were purified by using 3S Spin PCR Product Purification Kit (Shenergy Biocolor for Life Science Co., Ltd.), then sequenced with the same primer pairs used in PCR in both directions on an ABI 3730 DNA analyzer by BGI LifeTech Co., Ltd. The obtained sequences were checked and edited manually by using BioEdit 5.0.9 (Hall, 1999).

Phylogenetic analyses

All sequences were aligned using ClustalX V.1.8 (Thompson *et al.*, 1997) and

visually adjusted where necessary. Maximum parsimony trees were inferred using heuristic search with 1000 replicates of random sequence addition by using PAUP 4.0b10 (Swofford, 2002). Gaps were treated as missing data and all characters were equally weighted. Clades were bootstrapped for 1000 replicates with TBR (tree bisection reconnection) branch swapping method. Two species of the *Bionectriaceae*, *Bionectria ochroleuca* and *B. pityroides*, were selected as outgroup.

Results and Discussion

Taxonomy

Cosmospora gigas J. Luo & W.Y. Zhuang, **sp. nov.** (Figs 1, 2, 4-15, 24)

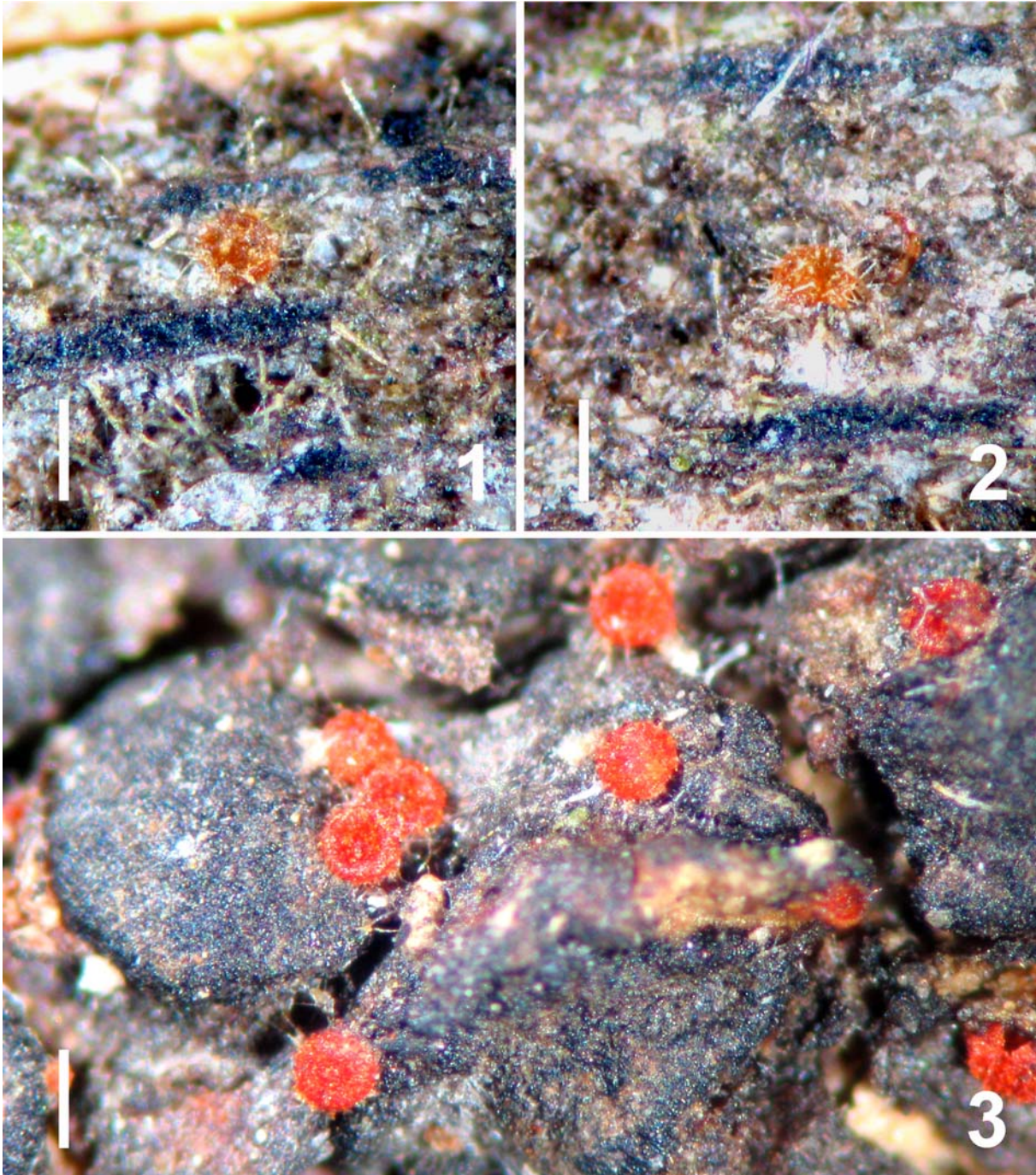
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Etymology: The specific epithet refers to the large-sized macroconidia produced by the fungus.

Peritheciis globosis, papillatis, siccis cupulatis, 165-240 μm diam.. *Pilis* raris, subcylindricis, 1-2-septatis, 19-50 \times 5.5-11 μm . *Ascis* clavatis, 8-sporis, 60-76 \times 8-12 μm . *Ascosporis* ellipsoideis, uniseptatis, striatis, 13.5-23 \times 5.5-7 μm .

Ascomata perithecial, solitary, non-stromatic, superficial, subglobose, with a small papilla, 155-190 μm high, 165-240 μm diam., cupulate when dry, orange-red when fresh, turning dark red in 3% KOH and yellow in lactic acid; hairs arising from ascomatal surface, sparse, clavate to subcylindrical, with a slightly enlarged upper portion, pale orange, straight, mostly 1 to 2-septate, smooth, shortest around ostiole and longer below, 19-50 μm long, 7-11 μm wide at apex and 5.5-8 μm below, walls up to 1.5 μm thick. *Ascomatal wall* 19-27 μm thick, of two regions; outer region 13.5-19 μm thick, of thin-walled, angular to somewhat elongate cells; inner region 2.5-7 μm thick, of thin-walled, very narrow cells. *Asci* clavate to subfusoid, 8-spored, apex simple, 60-76 \times 8-12 μm ($n = 20$). *Ascospores* subfusoid, some with one side flat, uniseptate, not constricted at septum, occasionally slightly broader at septum, yellowish, striate, uniseriate to irregularly biseriolate, 13.5-23 \times 5.5-7 μm ($n = 20$).

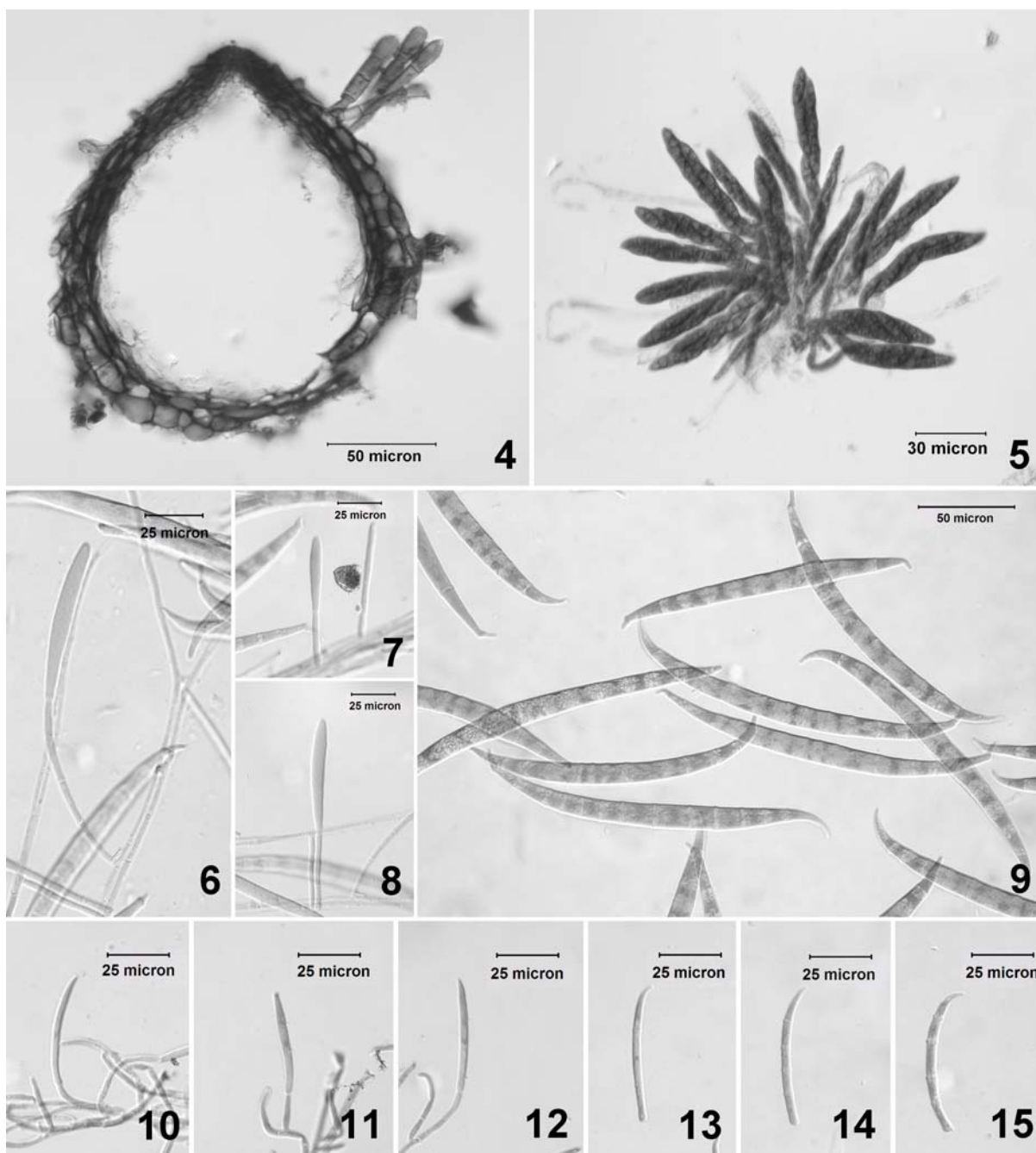
Colonies on PDA 2 cm in diameter after 4 days in dark at 24°C; Rhodonite Pink; surface felty; aerial mycelium sparse; colony reverse pigmented, Apricot Buff. Colonies on CMD reaching 1.5 cm after 4 days in the dark at 24°C; Pale Cinnamon-Pink, aerial mycelium



Figs 1-3. Ascomata on natural substrata: **1-2.** *Cosmospora gigas* (HMAS 99592). **3.** *C. cupularis* (HMAS 97514). Scale bars = 200 μm .

absent to spare; colony reverse pigmented, Pale Salmon Color. *Conidiophores* from aerial mycelium unbranched, erect, septate, $41-82 \times 2.7-4 \mu\text{m}$; conidiophores from sporodochia unbranched to branched, slightly curved, $27-41 \times 2.7-4 \mu\text{m}$. *Conidia* from aerial mycelium curved, falcate with a pedicellate foot cell and an attenuated apical cell, thin-walled, 9-14-

septate; 9-septate: $139-169 \times 11-12 \mu\text{m}$ (n = 20); 10-septate: $147.5-172 \times 11-13.5 \mu\text{m}$ (n = 20); 11-septate: $153-191 \times 11-13.5 \mu\text{m}$ (n = 20); 12-septate: $169-199 \times 12-13.5 \mu\text{m}$ (n = 20); 13-septate: $164-199 \times 11-15 \mu\text{m}$ (n = 20); 14-septate: $172-205 \times 2.3-13.5 \mu\text{m}$ (n = 5). *Conidia* from sporodochia slightly curved, falcate with a pedicellate foot cell and an



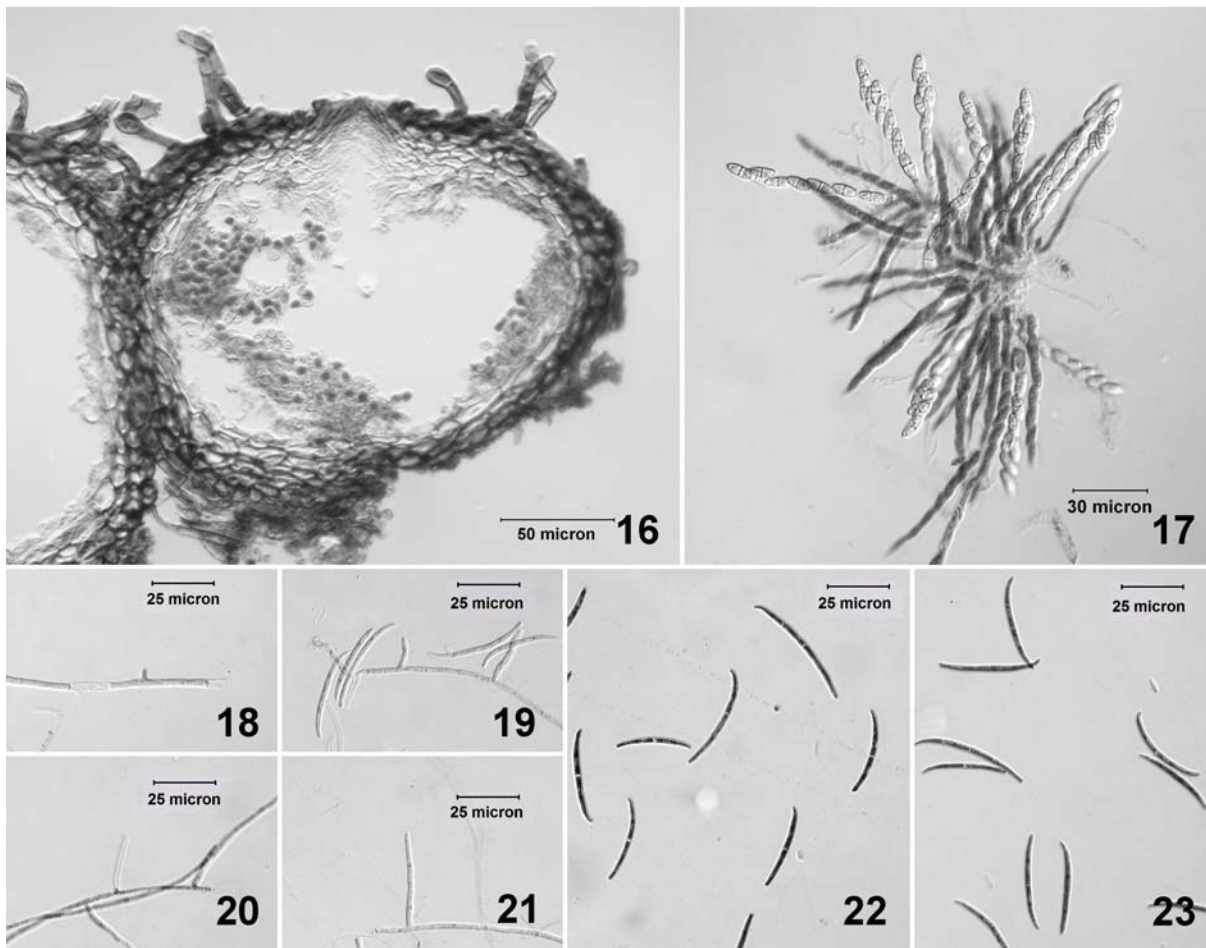
Figs 4-15. Morphology of *Cosmospora gigas* (HMAS 99592): **4.** Median section of an ascoma showing hairs on the surface; **5.** Asci with ascospores; **6-8.** Conidiophores in sporodochia; **9.** Conidia arising from sporodochia; **10-12.** Conidiophores from aerial mycelium; **13-15.** Conidia from aerial mycelium. **6-15** on PDA.

attenuated apical cell, thin-walled, 0-5-septate; 0-septate: $24-63 \times 2.7-4 \mu\text{m}$ ($n = 20$); 1-septate: $35-60 \times 2.7-4 \mu\text{m}$ ($n = 20$); 2-septate: $43-60 \times 2.7-4 \mu\text{m}$ ($n = 20$); 3-septate: $52-76 \times 2.7-4 \mu\text{m}$ ($n = 20$); 4-septate: $60-73 \times 2.7-5.5 \mu\text{m}$ ($n = 20$); 5-septate: $63-84 \times 4-5.5 \mu\text{m}$ ($n = 20$). *Chlamydospores* not observed.

Material examined: CHINA. Taiwan: Nantou, Huisun Forestry Farm, 700 m alt., on rotten stem of

bamboo associated with other fungi, 22 August 2005, W.Y. Zhuang 6598, HMAS 99592 (**holotype**), ex type culture HMAS 173239; *ibid.*, W.Y. Zhuang 6595, HMAS 97513 (**paratype**).

Notes: The combination of perithecial morphology, positive reaction to KOH or lactic acid, and a slow-growing *Fusarium* anamorph indicates that this is a member of *Cosmospora*. Ten species of the genus have been described



Figs 16-23. Morphology of *Cosmospora cupularis* (HMAS 97514): **16.** Median section of ascomata showing hairs on the surface; **17.** Asci with ascospores; **18-20.** Conidiophores; **22-23.** Conidia. **18-23** on CMD.

with hairy perithecia. Their anamorphs while known are mostly in *Fusarium* section *Episphaeria* (Booth, 1971), except for 2 having *Acremonium*-like or *Volutella* sp. (Samuels, 1977; Samuels *et al.*, 1991; Rossman and Samuels, 1993; Rossman *et al.*, 1999). *Cosmospora gigas* is easily distinguished from the above by the uniquely cupulate perithecia when dry, striate ascospores, and a *Fusarium gigas*-like anamorph.

Fusarium gigas Speg. was described previously from a carbonaceous pyrenomycete on bamboo from Paraguay, which has the largest *Fusarium* spores so far recorded that makes it distinct in the genus (Booth, 1971). In the single-spore culture obtained from *Cosmospora gigas*, two types of conidia were discovered. The macroconidia are 9-14-septate and $139\text{--}205 \times 11\text{--}15 \mu\text{m}$, which are identical with those described, measured, and illustrated based on examinations of authentic material of *Fusarium gigas* on nature substrates by Booth (1971);

however, macroconidia of *C. gigas* did not occur on nature substrate but only in culture. The microconidia are falcate, much narrower and shorter, and with 0-5 septa. Falcate microconidia have never been reported in *F. gigas*, as well as any existing species of *Fusarium*.

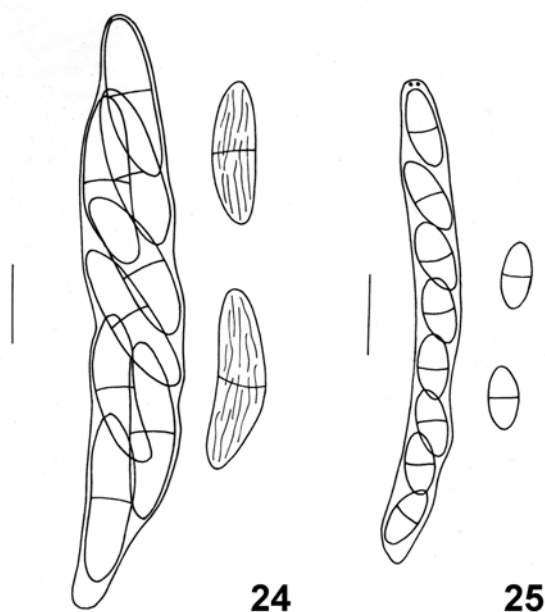
***Cosmospora cupularis* J. Luo & W.Y. Zhuang, sp. nov.** (Figs 3, 16-23, 25)

MycoBank: 511340

Etymology: The specific epithet refers to the perithecial shape of the fungus when dry.

Peritheciis globosis, papillatis, siccis cupulatis, $165\text{--}218 \mu\text{m}$ diam. *Pilis* raris, subcylindricis, 2-3-septatis, $11\text{--}68 \times 4\text{--}7 \mu\text{m}$. *Ascis* clavatis, 8-sporis, $57\text{--}77 \times 5.5\text{--}8 \mu\text{m}$. *Ascosporis* ellipsoideis, uniseptatis, spinulosis, $9.5\text{--}12.5 \times 4\text{--}5.5 \mu\text{m}$.

Ascomata perithecial, solitary or 2 to 3 in a group, non-stromatic, superficial, subglobose to globose, $165\text{--}200 \mu\text{m}$ high, $165\text{--}218 \mu\text{m}$ diam., with a small papilla, cupulate when dry, red when fresh, dark red when dry, dark red in 3% KOH, yellow in lactic acid; hairs arising



Figs 24-25. Ascus with ascospores and free ascospores of *Cosmospora* spp. **24.** *C. gigas* (HMAS 99592). **25.** *C. cupularis* (HMAS 97514). Scale bar = 10 μ m.

from ascomatal surface, sparse, subcylindrical or tapering towards apex, yellowish, straight to curved, flexuous, mostly 2 to 3-septate, smooth, 11-68 μ m long, 4-6.5 μ m wide at apex, 4-7 μ m wide at base, walls up to 2.7 μ m thick. *Ascomatal wall* 16.5-25 μ m thick, of 2 regions; outer region 11-16.5 μ m thick, of angular to elongate cells, with lumina 5.5-11 \times 2.5-5.5 μ m, walls 1.5-2.5 μ m thick; inner region 5.5-11 μ m thick, of angular cells. *Asci* cylindrical when young, sometimes becoming clavate with a long and narrow stalk at maturity, 8-spored, with an apical ring, 57-77 \times 5.5-8 μ m (n = 20). *Ascospores* ellipsoid, 9.5-12.5 \times 4-5.5 μ m (n = 20), not or slightly constricted at septum, yellowish, spinulose when young and becoming smooth-walled at maturity, uniseptate, 1-2-seriate.

Colonies on PDA 1.6 cm in diameter after 4 days in dark at 24°C; Purplish Lilac; surface velvety; aerial mycelium compact; colony reverse pigmented, Cinnamon-Rufous. Colonies on CMD reaching 1.4 cm after 4 days in the darkness at 24°C; Buff-Pink; aerial mycelium sparse; colony reverse pigmented, Pale Vinaceous-Pink. *Conidiophores* unbranched, septate or not, each branch bearing a single phialide, 2.7-35.5 μ m long, 1.5-4 μ m at base, ca. 1.5 μ m at tip of phialides. *Conidia* falcate,

thin-walled, slightly curved, with an indistinctly pedicellate foot cell and a narrowed apical cell, hyaline, 1-4-septate; 1-septate: 32.5-52 \times 1.5-2.7 μ m (n = 20); 2-septate: 41-57 \times 1.4-2.7 μ m (n = 20); 3-septate: 41-74 \times 2.7-4 μ m (n = 20); 4-septate: 52-79.5 \times 2.7-4 μ m (n = 11). *Chlamydospores* not observed.

Material examined: CHINA. Zhejiang: Hangzhou, Taihuyuan, 500 m alt., on fruitbodies of a black ascomycete (*Stylodothis* sp.) on twigs of an unidentified tree, 6 September 2005, J. Luo and W.Y. Li 6790-2, HMAS 97514 (**holotype**), ex type culture HMAS 173240.

Notes: The combination of perithecial morphology, positive reaction to KOH or lactic acid, and a *Fusarium* anamorph indicates that this is a member of *Cosmospora*. *Cosmospora cupularis* is characterized by cupulate perithecia when dry, presence of sparse hairs, and striate ascospores. Among species of the genus, *C. consors*, *C. papilionacearum* (Seaver) Rossman & Samuels and *C. tungurahwana* (Petr.) Rossman & Samuels are similar to *C. cupularis* in perithecial surface covered with sparse hairs but with smooth to spinulose ascospores. *Cosmospora consors* differs in the laterally pinched perithecia when dry, shorter asci 40-55(-65) \times 5-6(-8) μ m, narrower ascospores (9-)10-11(-13) \times 3-4 μ m, and a *Volutella* anamorph (Samuels, 1977; Samuels *et al.*, 1990). *Cosmospora papilionacearum* differs in the laterally pinched perithecia when dry, and much larger asci 65-100 \times 10-15 μ m and ascospores 14-19(-28) \times (5-)5.3-6.7(-8) μ m (Seaver, 1909; Samuels *et al.*, 1991). *Cosmospora tungurahwana* differs in the larger perithecia 280-370(-500) \times 190-250(-500) μ m, which are laterally pinched when dry, longer perithecial hairs 100 \times 7 μ m, and much larger asci (90-)95-113(-120) \times (13-)16-23 μ m and ascospores 28-37(-42) \times 8-13.5(-16) μ m (Samuels *et al.*, 1991).

It is also similar to *Cosmospora gigas* in the cupulate perithecia covered with sparse hairs but differs significantly from the latter in shape and size of the asci, shape, size and surface morphology of the ascospores, and anamorphic state as well as the substrate.

Placement of new species in *Cosmospora*

In our ITS tree, *Cosmospora gigas* and *C. cupularis* are closely related to *C. vilior* with 71% bootstrap value (Fig. 26). A similar result

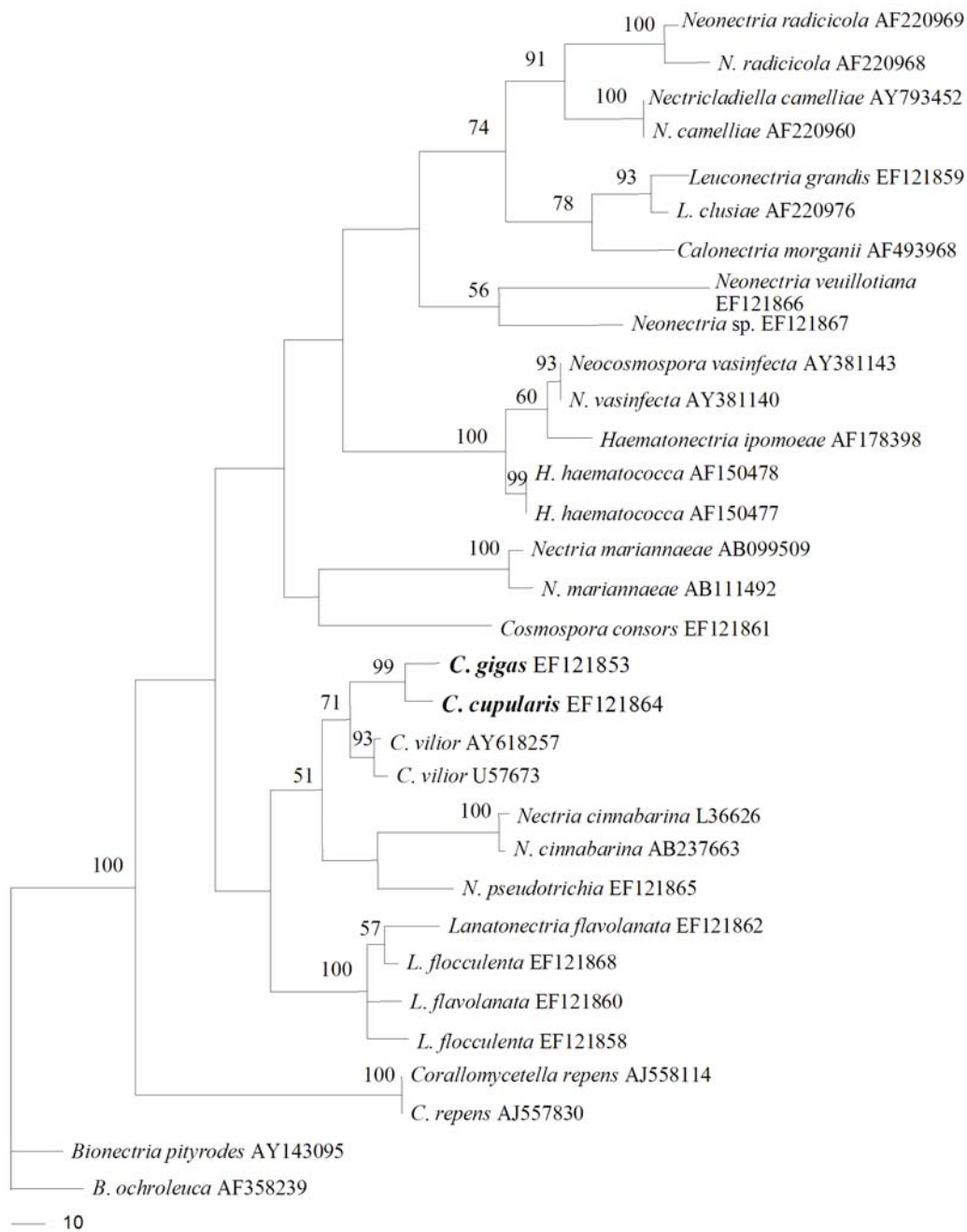


Fig. 26. One of two most parsimonious trees inferred from sequences of ITS1-5.8S-ITS2. Tree length = 1006, consistency index (CI) = 0.5209, homoplasy index (HI) = 0.4791, retention index (RI) = 0.7190, rescaled consistency index (RC) = 0.3745. Bootstrap values $\geq 50\%$ from 1000 replicates are noted above internodes. TreeBase: SN3741-17185.

was found in the 28S tree that these three species and other two, *C. episphaeria* and the type species of the genus *C. coccinea*, are together with 84% bootstrap support (Fig. 27). *Cosmospora coccinea*, *C. episphaeria* and *C. vilior* belong to *Cosmospora sensu stricto*. They represent *Cosmospora* having *Fusarium*, *Acremonium*, or *Verticillium* anamorphs. Both new species group with members of *Cosmo-*

spora sensu stricto and have *Fusarium* anamorphs, which confirms their placement in *Cosmospora*. In addition, *Cosmospora gigas* and *C. cupularis* are close-associated with 99% bootstrap value in the ITS tree and 90% in the 28S tree, which is consistent with the morphological data that both are of cupulate perithecia when dry.

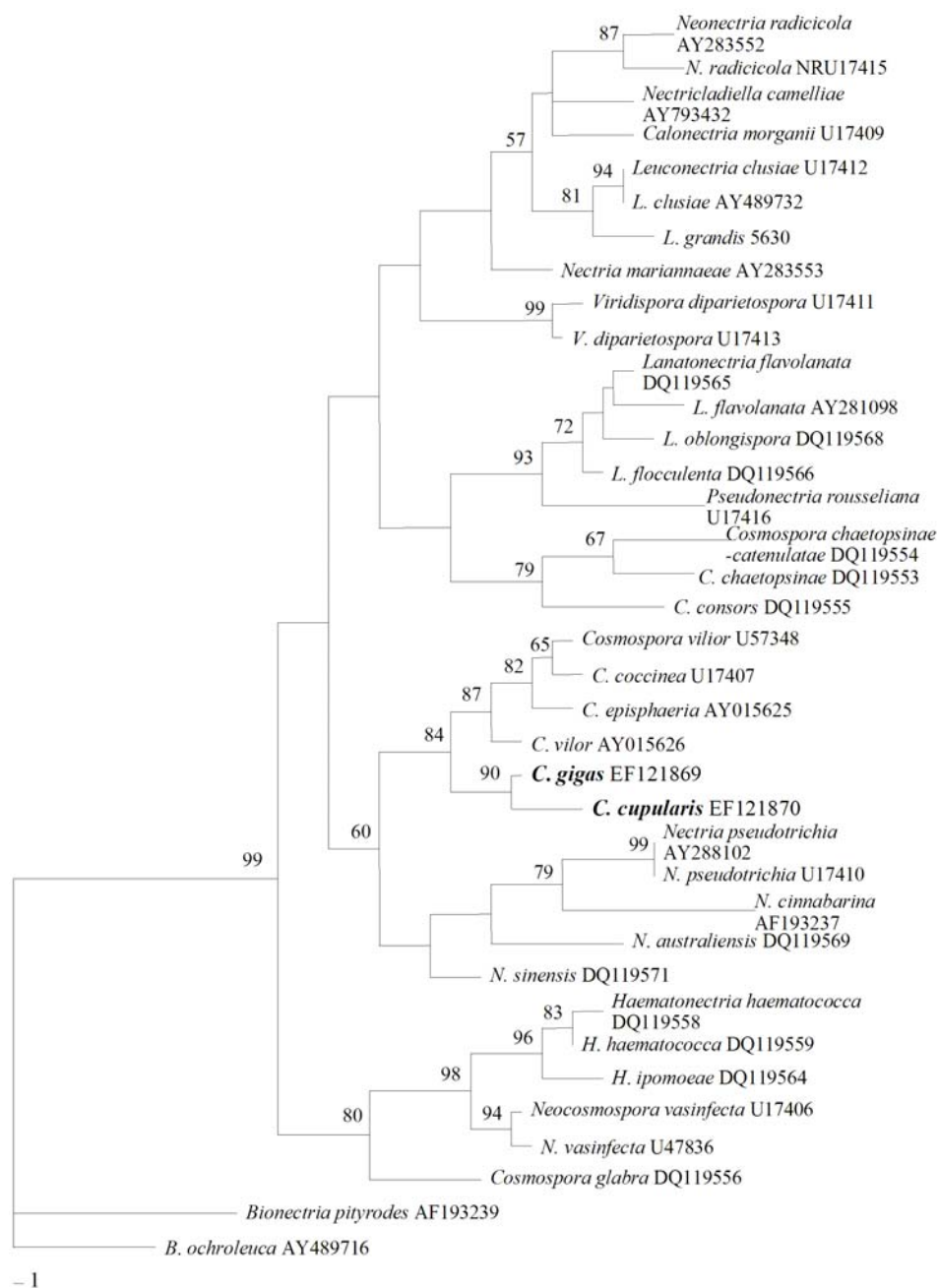


Fig. 27. One most parsimonious tree inferred from 28S rDNA D1 and D2 regions. Tree length = 438, consistency index (CI) = 0.4817, homoplasy index (HI) = 0.5183, retention index (RI) = 0.6886, rescaled consistency index (RC) = 0.3317. Bootstrap values $\geq 50\%$ from 1000 replicates are noted above internodes. TreeBase: SN3741-17187.

Polyphyly in Cosmospora

Analyses of both ITS region and 28S rDNA partial sequences indicate that members of the *Nectriaceae* group together with very high bootstrap supports and that a few natural groups are recognizable within the family (Figs 26, 27). *Leuconectria* Rossman, Samuels & Lowen with its two known species and *Lanatonectria* Samuels & Rossman with four of its five known taxa are well-established

genera and monophyletic groups. Close relationship has been detected between *Lanatonectria* and *Pseudonectria* Seaver, which is also evidenced by their morphological similarities. *Haematonectria* Samuels & Nirenberg and *Neocosmospora* E.F. Sm. are together as one group with high bootstrap values. Whereas, situation in the genus *Cosmospora* is quite different.

Some species of *Cosmospora* were involved in the previous studies on phylogeny of *Fusarium* (O'Donnell, 1993; Summerbell and Schroers, 2002). Our recent work based on analysis of 28S rDNA partial sequences from 11 genera of the *Nectriaceae* indicated that *Cosmospora* in the current sense is polyphyletic (Zhang and Zhuang, 2006). A similar result was observed in this study. In the ITS tree (Fig. 26), *Cosmospora cupularis*, *C. gigas* and *C. vilior* group together while *C. consors* groups with “*Nectria*” *mariannaeae*. The latter species was excluded from *Nectria sensu stricto* but could not be placed in any other genus (Samuels *et al.*, 2006). In the 28S tree (Fig. 27), *Cosmospora gigas*, *C. cupularis* and *C. episphaeria* having *Fusarium* anamorphs, *C. coccinea* (the type species of *Cosmospora*) with a *Verticillium* anamorph, and *C. vilior* with an *Acremonium* anamorph group together with 84% support. They are related to *Nectria* species tested and possibly represent the typical *Cosmospora*. *Cosmospora chaetopsinae*, *C. chaetopsinae-catenulatae* and *C. consors* with *Chaetopsina* and *Volutella* anamorphs group together with 79% support. *Cosmospora glabra* with a *Fusarium* anamorph groups with *Haematonectria* and *Neocosmospora* with 80% support. Our results indicate obviously that *Cosmospora* as currently circumscribed is used in a very broad sense and the genus is not monophyletic.

A key to the known species of *Cosmospora* in China

1. Anamorph *Volutella* *C. consors*
1. Anamorph *Chaetopsina* 2
1. Anamorph *Acremonium*-like 3
1. Anamorph *Fusarium* 6
1. Anamorph unknown 10
2. Ascospores smooth or spinulose, 8.5-12 × 2-3.2(-3.5) μm *C. chaetopsinae*
2. Ascospores spinulose, (10-)12-15 × 3-4.3 μm *C. chaetopsinae-catenulatae*
3. Lignicolous, ascospores (8-)9-13(-15) × 4-5.5(-6) μm. *C. rishbethii* (C. Booth) Rossman & Samuels
3. Fungicolous or associated with other fungi 4
4. Ascospores warted, 11-13(-13.5) × 6.5-7.5 μm *C. henanensis* Y. Nong & W.Y. Zhuang
4. Ascospores spinulose to roughened 5

5. Ascospores 8-16(-18) × 4-7.5 μm *C. meliopsicola* (Henn.) Rossman & Samuels
5. Ascospores (6.5-)7-9(-10) × 4-5.5 μm *C. vilior*
6. Perithecia covered with hairs, cupulate when dry 7
6. Perithecia glabrous or slightly warted, not cupulate when dry 8
7. Ascospores striate, 13.5-23 × 5.5-7 μm *C. gigas*
7. Ascospores spinulose, 9.5-12.5 × 4-5.5 μm *C. cupularis*
8. Ascospores fusoid, 1-3-septate, 33-45 × 6.5-9.5 μm ... *C. glabra*
8. Ascospores fusoid-ellipsoid, 1-septate, shorter than 14 μm 9
9. Ascospores warted, 7.5-12(-14) × 3.5-5.5(-6) μm *C. episphaeria*
9. Ascospores spinulose, 9-10(-11) × (3.5-)4-5.5 μm *C. purtonii* (Grev.) Rossman & Samuels
10. Ascospores 9.5-12.5 × 2-2.8 μm *C. purpureocolla* J. Fröhl. & K.D. Hyde
10. Ascospores averaging > 3 μm wide 11
11. On bark, ascospores finely striate or spinulose, 9-13(-15) × 4.3-5.7 μm *C. effusa* (Teng) W.Y. Zhuang & X.M. Zhang
11. Fungicolous or associated with other fungi 12
12. Ascospores pale yellow, striate, (24.5-)26.5-38 × (6.5-)7.5-13(-14) μm *C. diminuta* (Berk.) Rossman & Samuels
12. Ascospores pale yellow, warted, 10-14.5 × 3.8-4.5 μm *C. damingshanica* W.Y. Zhuang & X.M. Zhang
12. Ascospores pale red, warted, 9-13 × 5-6.5 μm *C. nummulariae* (Teng) W.Y. Zhuang & X.M. Zhang

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