

# *Aspergillus* section *Nidulantes* (formerly *Emericella*): Polyphasic taxonomy, chemistry and biology

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**Abstract:** *Aspergillus* section *Nidulantes* includes species with striking morphological characters, such as biserial conidiophores with brown-pigmented stipes, and if present, the production of ascospores embedded in masses of Hülle cells with often reddish brown ascospores. The majority of species in this section have a sexual state, which were named *Emericella* in the dual name nomenclature system. In the present study, strains belonging to subgenus *Nidulantes* were subjected to multilocus molecular phylogenetic analyses using internal transcribed spacer region (ITS), partial  $\beta$ -tubulin (*BenA*), calmodulin (*CaM*) and RNA polymerase II second largest subunit (*RPB2*) sequences. Nine sections are accepted in subgenus *Nidulantes* including the new section *Cavernicolus*. A polyphasic approach using morphological characters, extrolites, physiological characters and phylogeny was applied to investigate the taxonomy of section *Nidulantes*. Based on this approach, section *Nidulantes* is subdivided in seven clades and 65 species, and 10 species are described here as new. Morphological characters including colour, shape, size, and ornamentation of ascospores, shape and size of conidia and vesicles, growth temperatures are important for identifying species. Many species of section *Nidulantes* produce the carcinogenic mycotoxin sterigmatocystin. The most important mycotoxins in *Aspergillus* section *Nidulantes* are aflatoxins, sterigmatocystin, emestrin, fumitremorgins, asteltoxins, and paxillin while other extrolites are useful drugs or drug lead candidates such as echinocandins, mulundocandins, calbistrins, varitriols, variecolins and terrain. Aflatoxin B<sub>1</sub> is produced by four species: *A. stellatus*, *A. miraensis*, *A. olivicola*, and *A. venezuelensis*.

**Key words:** *Ascomycetes*, *Eurotiales*, Multi-gene phylogeny, Sterigmatocystin.

**Taxonomic novelties:** **New section:** Section *Cavernicolus* A.J. Chen, Frisvad & Samson; **New species:** *Aspergillus angustatus* A.J. Chen, Frisvad & Samson, *A. aurantiopurpureus* A.J. Chen, Frisvad & Samson, *A. botswanensis* A.J. Chen, Frisvad & Samson, *A. dromiae* A.J. Chen, Frisvad & Samson, *A. israelensis* A.J. Chen, Frisvad & Samson, *A. latilabiatus* A.J. Chen, Frisvad & Samson, *A. savannensis* A.J. Chen, Frisvad & Samson, *A. stercorarius* A.J. Chen, Frisvad & Samson, *A. sulphureoviridis* A.J. Chen, Frisvad & Samson, *A. viridicatenatus* A.J. Chen, Frisvad & Samson.

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## INTRODUCTION

The species of *Aspergillus* fall into distinct clusters, which have been called “groups” by Thom & Church (1926), Thom & Raper (1945) and Raper & Fennell (1965). These groups do not have nomenclatural standing and therefore Gams *et al.* (1985) introduced formal names for these groups as subgenera and sections. Subgenus *Nidulantes* contained five sections, namely sections *Nidulantes*, *Versicolores*, *Usti*, *Terrei*, and *Flavipedes*. Several investigations were conducted for nearly 20 years to test the taxonomic hypotheses based on phenotypic analysis. Peterson (2008) and Peterson *et al.* (2008) assessed phylogenetic relationships across *Aspergillus* using four loci and they accepted sections *Nidulantes*, *Usti*, *Ochraceorosei*, *Sparsi* and three hypothetical sections *Raperi*, *Silvati*, *Bispori*. Varga *et al.* (2010a, 2010b) introduced sections *Aenei* and *Sparsi* based on *CaM*, *BenA* and ITS sequence data, whereas Houbraken *et al.* (2014) accepted eight sections namely *Aenei*, *Bispori*, *Cremeri*, *Nidulantes*, *Ochraceorosei*, *Silvati*, *Sparsi* and *Usti* in subgenus *Nidulantes*. Until now approximately 100 species have been described in this subgenus. The indoor relevant species in *Aspergillus* subgenus *Nidulantes* section *Versicolores* are closely

related to species in section *Nidulantes* (Raper & Fennell 1965, Klich 1993, Jurjevic *et al.* 2012).

*Aspergillus* section *Nidulantes* accommodates *Aspergillus nidulans* and other species producing biserial conidiophores with pale brown pigmented stipes, and if present, the ascospores embedded in masses of Hülle cells (Frisvad & Samson 2004, Horie 1978, 1979, 1980, Kong & Qi 1986, Horie *et al.* 1989, 1990, 1996a,b, 1998, 2000, Raper & Fennell 1965, Samson & Mouchacca 1975, Stchigel & Guarro 1997, Thom & Raper 1939, Zalar *et al.* 2008 and others). The majority of section *Nidulantes* species are able to produce a sexual state and those species were, in the dual name nomenclature system, assigned to the genus *Emericella*. Because of the adoption of the “one fungus: one name” nomenclatural system, all *Emericella* species have been transferred to *Aspergillus* (Samson *et al.* 2014). Most former *Emericella* species belong to *Aspergillus* subgenus *Nidulantes* section *Nidulantes*. The only exceptions are: 1) *Aspergillus heterothallicus* (= *Emericella heterothallica*), the only known heterothallic species in subgenus *Nidulantes*, currently classified in *Aspergillus* subgenus *Nidulantes* section *Usti* (Houbraken *et al.* 2007, Samson *et al.* 2011), and 2) *A. bicolor* (= *E. bicolor*), *A. discophorus* (= *E. discophora*), *A. foeniculicola*

(=*E. foeniculicola*), and *A. spectabilis* (= *E. spectabilis*) classified in *Aspergillus* subgenus *Nidulantes* section *Aenei* (Varga et al. 2010a).

The morphology of the ascospores including colour, shape, size and ornamentation are of particular importance for species delineation and identification in *Emericella* (Thom & Raper 1939, Christensen & Raper 1978, Horie 1980, Christensen & States 1982, Ismail et al. 1995, Zalar et al. 2008, Matsuzawa et al. 2012, Guarro et al. 2012, Kritmitzas et al. 2013). Nowadays multiple methods are applied for species recognition and for example Frisvad & Samson (2004) applied a polyphasic analysis and described *A. venezuelensis* (= *E. venezuelensis*) based on morphological characters, extrolites and phylogenetic analyses. Using molecular phylogenetics, morphological data and growth temperatures Matsuzawa et al. (2012) discussed the species concept in *Emericella* and found that several species including *A. nidulans* (= *E. nidulans*), *A. dentatus* (= *E. dentata*), *A. sublatus* (= *E. sublata*), *A. montenegroi* (= *E. montenegroi*), *A. nidulans* var. *latus* (= *E. nidulans* var. *lata*), *A. quadrilineatus* (= *E. quadrilineata*), *A. miyajii* (= *E. miyajii*), *A. parvathecicus* (= *E. parvathecica*) and *A. acristatus* (= *E. acristata*) were undistinguishable by phylogenetic analysis alone. Therefore, they suggested to evaluate phylogenetic, morphological and physiological characters to identify species in this genus or section.

*Aspergillus* section *Nidulantes* species are widely distributed in nature and are believed to play significant roles in decomposition processes (Raper & Fennell 1965). The most well-known species *A. nidulans*, with the whole genome being sequenced in 2005 (Galaghan et al. 2005), occupies a place of prominence second only to *Neurospora* in the field of fungal genetics, being used to study a wide range of subjects including recombination, DNA repair, mutation, cell cycle control, nucleokinesis, pathogenesis, metabolism, and experimental evolution (Pontecorvo et al. 1954, Herbert & Arst 1976, Dean & Timberlake 1989, Schoustra et al. 2006, Todd et al. 2007). In addition to its role as genetic model, *A. nidulans* has been demonstrated as causative agent of diverse infections in humans. It was identified in cases of otomycosis, mycetoma, keratitis, sinusitis and pulmonary aspergilloma and was recognised as a major cause of invasive aspergillosis (IA) in patients with chronic granulomatous disease (CGD) (Baylet et al. 1968, Doby & Kombila-Favry 1978, Joshi et al. 1985, Segal et al. 1998, Henriet et al. 2012). Other species in section *Nidulantes* and *Versicolores* such as *A. delacroixii* (= *A. spinulosporus*), *A. dentatus*, *A. protuberus*, *A. quadrilineatus*, *A. sublatus*, *A. unguis*, *A. sydowii*, *A. stellatus*, *A. versicolor* and *A. hongkongensis* have also been reported in human infections (Polacheck et al. 1992, de Hoog et al. 2000, Verweij et al. 2008, Arabatzis et al. 2011, Yu et al. 2013, de Fontbrune et al. 2014, Sabino et al. 2014, Tsang et al. 2016).

Members of *Aspergillus* section *Nidulantes* produce a high number of secondary metabolites: such as aflatoxins and sterigmatocystins, echinocandins and mulundocandins, penicillins, terreins, and many others (Turner 1971, Cole & Cox 1981, Turner & Aldridge 1983, Frisvad 1985, Liu & Shen 2011, Saito et al. 2016). In general, similar metabolites can occur in phylogenetically closely related species, for example *A. varicolor* (= *E. varicolor*), *A. filifer* (= *E. filifera*), *A. stella-maris* (= *E. stella-maris*), *A. olivicola* (= *E. olivicola*), *A. venezuelensis* (= *E. venezuelensis*) and *A. stellatus* (= *E. stellata*) all produce the octaketides shamixanthones, emericellin and arugosins, while *A. pluriseminatus* (= *E. pluriseminata*), a phylogenetically species distant from these, showed an entirely distinctive extrolite profile

(Zalar et al. 2008). Anidulafungin, a semisynthetic lipopeptide antifungal drug of the echinocandin type, is derived from a fermentation product of *A. spinulosporus* (syn. *A. nidulans* var. *echinulatus*) (Nyfeler & Keller-Schierlein 1974), *A. parvathecicus*, *A. navahoensis*, *A. quadrilineatus*, *A. rugulosus* and *A. pachycristatus* (= "*Aspergillus nidulans* var. *roseus*" nomen nudum) (Boeckner & Kastner 1981, Klich et al. 2001, de la Cruz et al. 2012, Matsuzawa et al. 2012, Bills et al. 2014, Yue et al. 2015). Aflatoxin production is observed in *A. stellatus* (= *E. stellata*), *A. venezuelensis* (= *E. venezuelensis*) and *A. olivicola* (= *E. olivicola*) (Frisvad & Samson 2004, Frisvad et al. 2004, Zalar et al. 2008). Recently, a fungal natural product aspergillomarasmine A (AMA) was identified from extracts of *A. versicolor* (strain WAC-138). This compound combined with a carbapenem antibiotic has therapeutic potential to address the clinical challenge of MBL (metallo- $\beta$ -lactamase)-positive carbapenem-resistant Gram-negative pathogens (King et al. 2014).

In this study, we delineate the sections of *Aspergillus* subgenus *Nidulantes* using a phylogenetic analysis of a combined data set of partial ITS,  $\beta$ -tubulin (*BenA*), calmodulin (*CaM*) and RNA polymerase II second largest subunit (*RPB2*) gene sequences. Subsequently, the taxonomy of section *Nidulantes* was investigated using a polyphasic approach including sequence analyses, morphological and physiological characterisation, and extrolite profiles.

## MATERIAL AND METHODS

### Fungal strains

Isolates used in this study were obtained from: 1) CBS, culture collection of CBS-KNAW Fungal Biodiversity Centre, Utrecht, The Netherlands; 2) IBT, culture collection of the DTU Systems Biology, Lyngby, Denmark; and 3) CGMCC, China General Microbiological Culture Collection Centre, Beijing, China). Isolates deposited in the working collection of the Applied and Industrial Mycology department (DTO) housed at CBS-KNAW were also included in this study. An overview of strains is listed in Table 1.

### DNA extraction, PCR amplification and sequencing

Strains were grown for 1 wk on MEA prior to DNA extraction. DNA was extracted using the Ultraclean™ Microbial DNA isolation Kit (MoBio, Solana Beach, U.S.A.) and stored at  $-20^{\circ}\text{C}$ . ITS, *BenA*, *CaM*, and *RPB2* were amplified and sequenced using methods and primers as previously described (Houbraken & Samson 2011, Samson et al. 2014).

### Phylogenetic analysis

The phylogenetic relationship between species was studied using a combined data set containing ITS, *BenA*, *CaM* and *RPB2* sequences, individual single gene phylogenies were also generated to resolve relationships among the species. Sequence alignments were generated with MAFFT v. 7 (Katoh & Standley 2013). The most suitable substitution model was determined using FindModel (Posada & Crandall 1998). Bayesian analyses

**Table 1.** Strains used in this study.

Species name	Section	Collection no.	Substrate and origin	GenBank accession nr.			
				ITS	<i>BenA</i>	<i>CaM</i>	<i>RPB2</i>
<i>Aspergillus amoenus</i>	<i>Nidulantes</i>	NRRL 4838 <sup>T</sup>	<i>Berberis</i> sp. fruit, Germany	EF652480	JN853946	JN854035	JN853824
<i>A. angustatus</i>	<i>Nidulantes</i>	CBS 273.65 <sup>T</sup> = DTO 319-H8	<i>Mangifera indica</i> root, Mali	EU448283	AY339993	EU443984	KU867013
<i>A. askiburgiensis</i>	<i>Nidulantes</i>	CBS 134374 <sup>T</sup> = CCF 4716 = CCF 4428 = NRRL 62818 = IBT 33114 = IBT 32911	Ex cave sediment, Czech Republic	LN873939	LN873952	LN873965	LN873984
<i>A. asperescens</i>	<i>Nidulantes</i>	CBS 110.51 <sup>T</sup> = NRRL2252 = NRRL 4770 = ATCC 11079 = DSM 871 = IMI 046813 = QM 1946 = WB 2252 = WB 4770 = WB 5038 = IBT 19363 = DTO 021-F4	Soil from cave, Somerset, England, UK	EF652475	EF652299	EF652387	EF652211
		CBS 116.53 = DTO 020-G8	Soil from cave, Wales, UK	KU866661	KU866888	KU866689	KU866940
		CBS 117.53 = IBT 22590 = WB 4738 = DTO 020-G9	Bat dung in cave, Krakow, Poland	KU866662	KU866899	KU866690	KU866941
<i>A. astellatus</i>	<i>Nidulantes</i>	CBS 261.93 <sup>T</sup> = CBS 134.55 = NRRL 2396 = ATCC 16817 = IMI 61455 = IMI 61455ii = NRRL A-1634 = QM 1910 = WB 2396 = IBT 21902 = IBT 22589 = DTO 010-I7	Leaf, South Seymour, Baltra, Ecuador	EF652446	EF652270	EF652358	EF652182
		CBS 135.55 = NRRL 2397 = IMI 350353 = NRRL A-2295 = QM 1911 = WB 2397 = DTO 011-G9	Dead leaf, Galapagos, Seymour Island, Ecuador	EU448273	AY339994	EU443975	KU866936
<i>A. aurantiobrunneus</i>	<i>Nidulantes</i>	CBS 465.65 <sup>T</sup> = NRRL 4545 = NRRL 2775 = IMI 074897 = LCP 84.2354 = ATCC 16821 = WB 4545 = DSL 48 = IMI 139821 = IBT 22880 = DTO 047-G7	Canvas haversack for respirator, Australia	EF652465	EF652289	EF652377	EF652201
<i>A. aurantiopurpureus</i>	<i>Nidulantes</i>	CBS 140608 <sup>T</sup> = IBT 12601 = DTO 060-A7	Kangaroo rat cheek pouch, Sevilette National Wildlife Refuge, New Mexico, USA	KU866588	KU866824	KU866711	KU866966
		CBS 140609 = IBT 12604 = DTO 061-B9	Kangaroo rat cheek pouch, Sevilette National Wildlife Refuge, New Mexico, USA	KU866593	KU866826	KU866716	KU866970
<i>A. aureolatus</i>	<i>Nidulantes</i>	CBS 190.65 <sup>T</sup> = NRRL 5126 = ATCC 16810 = IMI 136527 = IMI 136527ii = WB 5126 = IBT 18471 = IBT 22670 = DTO 053-C1	Air, Beograd, Serbia	EF652501	EF652325	EF652413	EF652237
		CBS 138434 = DTO 131-G5	Unknown source	KU866663	KU866898	KU866726	KU866985
<i>A. austroafricanus</i>	<i>Nidulantes</i>	NRRL 233 <sup>T</sup>	Cape town, South Africa	JQ301891	JN853963	JN854025	JN853814
<i>A. botswanensis</i>	<i>Nidulantes</i>	CBS 314.89 <sup>T</sup> = DTO 047-I4	Forest soil, at base of <i>Diospyros mespiliformis</i> (ebony tree), Okavango Delta, Island Forest Area, Botswana	KU866572	KU866812	KU866695	KU866949
<i>A. caespitosus</i>	<i>Nidulantes</i>	CBS 103.45 <sup>T</sup> = NRRL 1929 = ATCC 11256 = IMI 16034 = MUCL 13587 = NCTC 6972 = NCTC 6973 = QM 7399 = WB 1929 = IBT 10624 = DTO 053-D1	Soil, Fayetteville, Arkansas, USA	EF652428	EF652252	EF652340	EF652164
		CBS 654.74 = DTO 053-D3	Desert soil, Western Desert, Egypt	KU866578	KU866891	KU866701	KU866955
		IBT 4097 = DTO 325-C1	Salt marsh soil, Kuwait	KU866669	KU866907	KU866789	KU867054
<i>A. corrugatus</i>	<i>Nidulantes</i>	CBS 191.77 <sup>T</sup> = NHL 2763 = IMI 212201 = IBT 22829 = DTO 047-I9	Soil under <i>Saccharum officinarum</i> , Nakorn Pathom, Thailand	KU866574	KU866814	KU866696	KU866951
<i>A. creber</i>	<i>Nidulantes</i>	NRRL 58592 <sup>T</sup>	Indoor air sample, California, USA	JQ301889	JN853980	JN854043	JN853832
<i>A. croceus</i>	<i>Nidulantes</i>	CBS 134396 <sup>T</sup> = CCF 4405 = NRRL 62495 = IBT 33602	Ex cave sediment, Spain	LN873931	LN873944	LN873957	LN873976
<i>A. cvjetkovicii</i>	<i>Nidulantes</i>	NRRL 227 <sup>T</sup>	Soil, New Jersey, USA	EF652440	EF652264	EF652352	EF652176
<i>A. desertorum</i>	<i>Nidulantes</i>	CBS 653.73 <sup>T</sup> = IBT 21899 = NRRL 5921 = IMI 343076 = DTO 048-A1	Grey soil, Egypt	EF652505	EF652329	EF652417	EF652241
		CBS 654.73 = IBT 21900 = DTO 047-I1	Grey soil, Egypt	KU866571	KU866811	KU866694	KU866948
		CBS 655.73 = IBT 21901 = DTO 319-I8	Grey soil, Egypt	KU866619	KU866861	KU866757	KU867020

(continued on next page)

Table 1. (Continued).

Species name	Section	Collection no.	Substrate and origin	GenBank accession nr.			
				ITS	BenA	CaM	RPB2
<i>A. dromiae</i>	<i>Nidulantes</i>	CBS 140633 <sup>T</sup> = IBT 25166 = DTO 059-H5	<i>Dromia erythropus</i> (crab, Crustacea), Morro of Garapáta, Mochima Bay, Venezuela	KU866580	KU866885	KU866703	KU866958
		CBS 140639 = IBT 20996 = DTO 325-C7	<i>Dromia erythropus</i> (crab, Crustacea), Morro of Garapáta, Mochima Bay, Venezuela	KU866672	KU866909	KU866792	KU867057
<i>A. falconensis</i>	<i>Nidulantes</i>	CBS 271.91 <sup>T</sup> = IFM 4997 = NHL 2999 = ATCC 76117 = IBT 14808 = DTO 048-A2	Soil with steppe-type vegetation of Sabaneta, Falcon State, Coro City, Venezuela	KU866575	KU866815	KU866697	KU866952
		CBS 989.72 = IBT 22830 = DTO 048-A3	Arid soil, of recent reclamation and cultivated with corn, New Valley Region, Western Desert, Dakhla Oasis, 12 km NW of Mut, Egypt	KU866576	KU866816	KU866698	KU866953
		CBS 126188 = IBT 23426 = RMF N172 = DTO 060-A1	A1 horizon soil, Halile Rest Camp south of Dolemile Hill, Popane woodland (savanna), Namibia	KU866584	KU866820	KU866707	KU866962
		IBT 25692 = DTO 061-C1	Soil, Namibia	KU866594	KU866827	KU866717	KU866971
		CBS 650.73A = DTO 319-I6	Grey soil, Kharga Oasis, near Kharga Town, Egypt	KU866617	KU866859	KU866755	KU867018
		CBS 650.73D = DTO 320-C4	Grey soil, Kharga Oasis, near Kharga Town, Egypt	KU866631	KU866870	KU866769	KU867033
		CBS 650.73B = DTO 324-D5	Grey soil, Kharga Oasis, near Kharga Town, Egypt	KU866643	KU866877	KU866781	KU867046
		CBS 650.73C = IBT 22846 = DTO 319-I7	Grey soil, Kharga Oasis, near Kharga Town, Egypt	KU866618	KU866860	KU866756	KU867019
<i>A. filifer</i>	<i>Nidulantes</i>	CBS 113636 <sup>T</sup> = IBT 23443 = DTO 011-A5	Hypersaline water, Secovlje salterns, Adriatic coast, Slovenia	EU448277	EF428372	EU443973	KU866932
		CBS 128791 = IFM 54282 = CBM FA-865 = DTO 098-H8 (ex-type of <i>A. chinensis</i> )	Kara Kuri Lake, near Mt. Kungur, Pamire plateau, Xinjiang Province, China	AB249003	AB248345	AB476806	KU866982
		CBS 113637 = IBT 23438 = DTO 011-A6	Hypersaline water, Secovlje salterns, Slovenia	EU448276	KU866887	EU443972	KU866933
		CBS 114510 = IBT 28015 = DTO 011-A7	Raisins, Catamarca Province, Tinogasta, Argentina	EU448278	KU866896	EU443974	KU866934
		CBS 128790 = IFM 54232 = DTO 098-H9	Kara Kuri Lake, near Mt. Kungur, Pamire plateau, Xinjiang Province, China	AB248963	AB248305	KU866724	KU866983
<i>A. foveolatus</i>	<i>Nidulantes</i>	CBS 279.81 <sup>T</sup> = IBT 22847 = IFM 4547 = NHL 2839 = NBRC 30559 = IFO 30559 = IBT 22847 = DTO 320-D2	Herbal drug of <i>Tribulus terrestris</i> , India	KX423658	KX423622	KX423635	KU867034
		CBS 542.83 = DTO 319-I2	Litter, Spain	KU866615	KU866857	KU866754	KU867016
<i>A. fruticosus</i>	<i>Nidulantes</i>	CBS 486.65 <sup>T</sup> = NRRL 4903 = ATCC 16823 = IMI 139279 = O-1077 = QM 8033 = WB 4903 = IBT 33973 = DTO 047-H8	Soil, Colorado Desert, California	EF652483	EF652307	EF652395	EF652219
<i>A. fructus</i>	<i>Nidulantes</i>	NRRL 239 <sup>T</sup>	Date fruit, California, USA	EF652449	EF652273	EF652361	EF652185
<i>A. griseoaurantiacus</i>	<i>Nidulantes</i>	CBS 138191 <sup>T</sup> = DTO 267-D8	House dust, Micronesia	KJ775553	KJ775086	KJ775357	KU866988
<i>A. hongkongensis</i>	<i>Nidulantes</i>	HKU49 <sup>T</sup> = NBRC 110693 = NCPF 7870 = BCRC FU30360	From the big toenail of a man with onychomycosis in Hong Kong, China	AB987907	LC000552	LC000565	LC000578
<i>A. israelensis</i>	<i>Nidulantes</i>	CBS 140627 <sup>T</sup> = IBT 24293 = DTO 325-E2	Evaporation pond, Ein Bokek, Dead Sea, Israel	KU866677	KU866915	KU866797	KU867062
		CBS 140628 = IBT 24364 = DTO 325-E3	Evaporation pond, Ein Bokek, Dead Sea, Israel	KU866678	KU866916	KU866798	KU867063
<i>A. jaipurensis</i>	<i>Nidulantes</i>	CBS 952.97 <sup>T</sup> = IMT 378525 = FMR 6232 = IBT 23715 = DTO 320-A9	Soil, Jaipur, Rajasthan, India	KU866623	AY339988	KU866761	KU867024
		CBS 100253 = DTO 325-D8 = IBT 23714	Soil, Jaipur, India	KU866675	KU866913	KU866795	KU867060

Table 1. (Continued).

Species name	Section	Collection no.	Substrate and origin	GenBank accession nr.			
				ITS	<i>BenA</i>	<i>CaM</i>	<i>RPB2</i>
<i>A. jensenii</i>	<i>Nidulantes</i>	NRRL 58600 <sup>T</sup>	Indoor air sample, Montana, USA	JQ301892	JN854007	JN854046	JN853835
<i>A. latilabiatum</i>	<i>Nidulantes</i>	CBS 426.93 <sup>T</sup> = IBT 33959 = DTO 320-B2	Sheep dung, Kerzaz, Algeria	KU866624	KU866864	KU866762	KU867025
<i>A. latus</i>	<i>Nidulantes</i>	CBS 492.65 <sup>T</sup> = ATCC 16848 = IBT 22844 = IMI 074181 = NRRL 200 = QM 7425 = WB 200 = DTO 047-H2	Unknown source	KF465768	AB248334	KU866693	KU866946
		CBM-FA-669 (ex-type of <i>A. montenegroi</i> )	Soil, Brazil	–	AB248312	AB524041	–
		CBS 140630 = IFO 30906 = IBT 19356 = IFM 4553 = DTO 338-F7 (ex-type of <i>A. sublatus</i> )	<i>Geranium nepalense</i> , Japan	KU866683	KU866920	KU866804	KU867069
		CBS 236.65 = DTO 320-C1	Fruit, South Africa	KU866628	KU866867	KU866766	KU867030
		IBT 13352 = DTO 325-B9	Cereal, Kenya	KU866668	KU866883	KU866788	KU867053
		IBT 25906 = DTO 338-F9 = DTO 325-E9	Soil under <i>Erica</i> sp., Zachenberg, Greenland	KU866684	KU866921	KU866805	KU867070
<i>A. miraensis</i>	<i>Nidulantes</i>	CBS 140625 <sup>T</sup> = CGMCC 3.14984 = IBT 33946 = IBT 36278 = DTO 323-B2	Roots of <i>Polygonum macrophyllum</i> var. <i>stenophyllum</i> , Nyingchi County, Tibet, China	KU866642	KC342577	KU866780	KU867045
<i>A. multicolor</i>	<i>Nidulantes</i>	CBS 133.54 <sup>T</sup> = NRRL 4775 = ATCC 16804 = IFO 8133 = IBT 23157 = IMI 69857 = LSHBBB .356 = QM 1952 = WB 4281 = WB 4775 = DTO 053-C9	Forest soil, Giuba River, Somalia	EF652477	EF652301	EF652389	EF652213
<i>A. mulundensis</i>	<i>Nidulantes</i>	CBS 140610 <sup>T</sup> = DSMZ 5745 = IBT 33104 = DTO 316-C9	Soil, Bangladesh	KU866604	KU866833	KU866729	KU866989
<i>A. navahoensis</i>	<i>Nidulantes</i>	CBS 351.81 <sup>T</sup> = NRRL 13002 = ATCC 44663 = IMI 259971 = IMI 304939 = IBT 10950 = LCP 84.2561 = DTO 047-H7	Soil from native sand-dune shrub, Northern Arizona, Arizona, USA	EF652424	EF652248	EF652336	EF652160
<i>A. nidulans</i>	<i>Nidulantes</i>	CBS 589.65 <sup>T</sup> = NRRL 187 = ATCC 10074 = IHEM 3563 = IMI 126691 = IMI86806 = QM 1985 = Thom 4640.5 = WB 187 = DTO 047-H9	Froidchapelle, Belgium	EF652427	EF652251	EF652339	EF652163
		DTO 065-F9	Air, pharmaceutical factory, Vienna, Austria	KU866599	KU866831	KU866722	KU866977
		CBS 100522 = DTO 319-F7	Air, university hospital, Austria	KU866605	KU866848	KX423636	KU867005
		CBS 426.77 = IBT 22826 = DTO 319-H9	Grassland soil, Saudi Arabia	KU866613	KU866855	KU866752	KU867014
		CBS 100.20 = IBT 22895 = WB 4862 = IMI 091906 = LSHB Ac85 = NCPF 2182 = NCTC 3786 = WB 189 = DTO 320-B8	Foot mycetoma, Tunisia	KU866627	KU866866	KU866765	KU867029
		CBS 240.90 = DTO 320-C2	Wound at back of head, 10 year old male, after craniotomy, Netherlands	KU866629	KU866868	KU866767	KU867031
		CGMCC 3.06385 = DTO 322-H9	Moldy bamboo, Yunnan province, China	KU866638	KU866873	KU866776	KU867041
		CBS 114.63 = NRRL 4908 = ATCC 16829 = IBT 22839 = IMI 126693 = QM 8172 = WB 4908 = IBT 22839 = DTO 047-G8 (ex-type of <i>A. dentatus</i> )	Finger nail, Delhi, India	EF652488	AY573552	EF652400	EF652224
<i>A. olivicola</i>	<i>Nidulantes</i>	CBS 119.37 <sup>T</sup> = IBT 21903 = IBT 26499 = DTO 011-A8 = DTO 002-I2	Decaying fruit, Verona, Italy	EU448268	AY339996	EU443986	KU866923
		CBS 597.65 = IBT 21904 = IBT 10994 = DTO 011-A9	Fruit, Italy	EU448267	AY339997	EU443985	KU866935
		CGMCC 3.00670 = DTO 322-A9	Unknown source, Czech	KU866632	KU866904	KU866770	KU867035
<i>A. omanensis</i>	<i>Nidulantes</i>	CBM FA-700 <sup>T</sup> = IFM 54275	Forest soil, Oman	–	AB248347	AB524047	–
<i>A. pachycristatus</i>	<i>Nidulantes</i>	IFM 55265 <sup>T</sup> = NBRC 104790	Soil, Pichan, Xinjiang, China	–	AB375875	AB524062	–
		IBT 10999 = DTO 060-A3	<i>Amaranthus</i> flowerhead, kangaroo rat burrow, Portal Arizona, USA	KU866585	KU866821	KU866708	KU866963

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Table 1. (Continued).

Species name	Section	Collection no.	Substrate and origin	GenBank accession nr.			
				ITS	BenA	CaM	RPB2
		IBT 23550 = NRRL 11440 = SRRC 1173 = ATCC 58397 = Lilly A42335 = DTO 060-A5	Soil, Indiana, USA	KU866587	KU866823	KU866710	KU866965
		IBT 22934 = DTO 061-C5	Soil, La Paz, Mexico	KU866595	KU866828	KU866718	KU866972
		CBS 198.88 = DTO 324-D8	Flower head, USA	KU866644	KU866878	KU866782	KU867047
		IBT 10993 = DTO 325-A6	<i>Amaranthus</i> flower heads, Arizona, USA	KU866645	KU866879	KU866783	KU867048
		IBT 12268 = DTO 325-B1	Old Cotton Research Center, Phoenix, Arizona, USA	KU866666	KU866881	KU866786	KU867051
		IBT 24499 = DTO 325-E4	Saltern, Secovlje, Slovenia	KU866679	KU866917	KU866799	KU867064
		IBT 28593 = DTO 325-F2	Air in factory, Denmark	KU866680	KU866918	KU866800	KU867065
<i>A. pluriseminatus</i>	<i>Nidulantes</i>	CBS 100523 <sup>T</sup> = FMR 5588 = IMI 370867 = DTO 011-H1	Soil, Jaipur, Rajasthan, India	KU866566	AY339989	EU443988	KU866937
		CBS 102705 = DTO 010-I8	Soil, Jaipur, Rajasthan, India	KU866565	KU866806	KU866686	KU866926
<i>A. protuberus</i>	<i>Nidulantes</i>	CBS 602.74 <sup>T</sup> = NRRL 3505 = ATCC 18990 = QM 9804	Deteriorated rubber-coated electric cable, Yugoslavia	EF652460	EF652284	EF652372	EF652196
<i>A. purpureus</i>	<i>Nidulantes</i>	CBS 754.74 <sup>T</sup> = NRRL 6133 = IMI 334937 = LCP 82.3323 = DTO 047-H5	Desert soil, Egypt	EF652506	EF652330	EF652418	EF652242
<i>A. puulaauensis</i>	<i>Nidulantes</i>	NRRL 35641 <sup>T</sup>	Dead hardwood branch, subalpine dry forest, Hawaii, USA	JQ301893	JN853979	JN854034	JN853823
<i>A. qinqixianii</i>	<i>Nidulantes</i>	CBS 128788 <sup>T</sup> = IFM 55020 = CMB-FA- 866 = DTO 098-H6	Desert soil, Xinjiang Province, China	KU866600	AB524360	AB524051	KU866980
		CBS 128789 = DTO 098-H7	Desert soil, Xinjiang Province, China	KU866601	KU866894	KU866723	KU866981
<i>A. quadrilineatus</i>	<i>Nidulantes</i>	CBS 591.65 <sup>T</sup> = NRRL 201 = ATCC 16816 = IMI 089351ii = IMI 89351 = IBT 22897 = LSHBA 546 = QM 7465 = Thom 4138.N8 = WB 201 = DTO 048-A9	Soil, New Jersey	EF652433	EF652257	EF652345	EF652169
		CBS 937.73 = IBT 23429 = DTO 020-I9 (ex-type of <i>A. floriformis</i> )	Desert soil, Egypt	KU866568	KU866808	KU866691	KU866942
		CBS 119.55 = NRRL 2394 = NRRL A- 4030 = ATCC 16839 = IBT 11111 = IMI 061453 = LCP 84.2558 = QM 1908 = WB 2394 = DTO 047-G6 (ex- type of <i>A. nidulans</i> var. <i>acristatus</i> )	Exposed fabric, New Mexico	EF652444	AY573549	AB476805	KU866945
		CBS 493.65 = NRRL 4904 = ATCC 16822 = IMI 139280 = LCP 84.2553 = QM 8034 = WB 4904 = DTO 047-H4 (Neotype of <i>A. parvathecus</i> )	Man skin, California	KU866570	AB243111	AB524048	KU866947
		CBS 125.55 = DTO 048-A8	Culture contaminant, Recife, Brazil	KU866577	KU866817	KU866699	KU866954
		CBS 113684 = DTO 319-F9	Nails, Uttar Pradesh	KU866607	KU866850	KU866746	KU867007
		CBS 118.51 = DTO 319-G2	Netherlands	KU866609	KU866852	KU866748	KU867009
		CBS 467.88 = DTO 320-C3	Garden soil, Spain	KU866630	KU866869	KU866768	KU867032
		CGMCC 3.04661 = DTO 322-D3	Unknown source, Japan	KU866634	KU866871	KU866772	KU867037
		CGMCC 3.06393 = DTO 322-I8	Soil, Yunnan province, China	KU866639	KU866874	KU866777	KU867042
		CBS 126215 = IBT 23423 = DTO 325- D5	Surface sandy dune soil, desert, Namibia	KU866674	KU866912	KU866794	KU867059
		CBM-FA-833 (ex-type of <i>A. miyajii</i> )	Unknown	–	AB243110	AB524040	–
		CBS 853.96 = IBT 28023 = DTO 320-A8	Unknown source, Spain	KU866622	KU866863	KU866760	KU867023
<i>A. recurvatus</i>	<i>Nidulantes</i>	CBS 496.65 <sup>T</sup> = NRRL 4902 = ATCC 16809 = IMI 136528 = O-566 = QM 7972 = WB 4902 = IBT 23271 = DTO 053-C8	Dung of lizard, desert area near Blythe, California	EF652482	EF652306	EF652394	EF652218
		CBS 126259 = RMF 7730 = DTO 195- D8	Soil (dung, arid site, animal litter), Africa	KU866603	KU866832	KU866727	KU866986
<i>A. rugulosus</i>	<i>Nidulantes</i>	CBS 133.60 <sup>T</sup> = NRRL 206 = ATCC 16820 = IMI 136775 = QM 1987 = Thom 4138.T11 = WB 206 = IBT 22820 = DTO 321-H1	Soil, New Jersey, USA	EF652434	EF652258	EF652346	EF652170

Table 1. (Continued).

Species name	Section	Collection no.	Substrate and origin	GenBank accession nr.			
				ITS	<i>BenA</i>	<i>CaM</i>	<i>RPB2</i>
		CBS 200.75 = IBT 22848 = IMI 131554 = NRRL 3651 = QM 9184 = DTO 047-I8 (ex-type of <i>A. cleistominutus</i> )	Soil, Kaulbhaskar, agricultural farm at Allahabad	KU866573	KU866813	AB476810	KU866950
		IBT 12265 = DTO 061-D7	Unknown source	KU866596	KU866829	KU866719	KU866975
		CBS 113407 = DTO 319-F8	Bat faecal pellet, near Gaba, Oman	KU866606	KU866849	KU866745	KU867006
		CBS 117.50 = IBT 22519 = DTO 319-G1	Manure, Thunder Bay, Ontario, Canada	KU866608	KU866851	KU866747	KU867008
		CBS 130.48 = IBT 22837 = DTO 319-H5	Unknown source	KU866611	KU866853	KU866750	KU867011
		CGMCC 3.06394 = DTO 322-I9	Corn flour, Yunnan province, China	KU866640	KU866875	KU866778	KU867043
		IBT 10998 = DTO 325-A7	<i>Amaranthus</i> flower heads, Denmark	KU866664	KU866880	KU866784	KU867049
		IBT 13207 = DTO 325-B8	<i>Dipodomys ordii</i> cheek pouch, Sevilleta National Wildlife Refuge, Socorro County, New Mexico, USA	KU866667	KU866882	KU866787	KU867052
		IBT 31140 = DTO 325-F3	Saltern, Secovlje, Slovenia	KU866681	KU866919	KU866801	KU867066
<i>A. savannensis</i>	<i>Nidulantes</i>	CBS 140607 <sup>T</sup> = IBT 23422 = DTO 059-H6	A1 horizon soil, in Halili Rest Camp, south of Dolomite Hill (savanna), Namibia	KU866581	KU866818	KU866704	KU866959
		CBS 126213 = IBT 23421 = RMF N171A = DTO 061-B8	A1 horizon soil, Halile Rest Camp south of Dolemile Hill, Popane woodland, savanna, Namibia	KU866592	KU866825	KU866715	KU866969
<i>A. spelunceus</i>	<i>Nidulantes</i>	CBS 497.65 <sup>T</sup> = NRRL 4989 = ATCC 16838 = IMI 211389 = NRRL A-3676 = QM 8898 = WB 4989 = IBT 33967 = DTO 053-C4	Dead cane crickets, floor of Laurel Creek Cave, West Virginia	EF652490	EF652314	EF652226	EF652402
<i>A. spinulosporus</i>	<i>Nidulantes</i>	CBS 120.55 <sup>T</sup> = NRRL 2395 = ATCC 16825 = IBT 22841 = IMI 061454 = LCP 84.2557 = QM 1909 = WB 2395 = IBT 22841 = DTO 047-G9	Soil, Buenos Aires, Argentina	EF652445	AY573553	EF652357	EF652181
		CBS 564.80 = IBT 22840 = IMI 250977 = TRTC 48545 = DTO 047-H1	Culture contaminant, Canada	KU866569	KU866809	KU866692	KX423662
		DTO 065-F7	Air, pharmaceutical factory, Vienna, Austria	KU866598	KU866830	KU866721	KU866976
		CGMCC 3.05277 = DTO 322-D6	Moldy pork, Sichuan province, China	KU866635	KU866872	KU866773	KU867038
		IBT 23829 = DTO 325-D9	Indoor air, factory, Denmark	KU866676	KU866914	KU866796	KU867061
<i>A. stella-maris</i>	<i>Nidulantes</i>	CBS 113638 <sup>T</sup> = IBT 23439 = DTO 011-A2	Hypersaline water, Secovlje salterns, Slovenia	EU448269	KU866886	EU443978	KU866929
		CBS 114378 = IBT 28013 = DTO 010-I6	Leaf litter, National Agronomic Institute, Tunisia	EU448271	KU866906	EU443980	KU866925
		CBS 113639 = IBT 23441 = DTO 011-A3	Hypersaline water, Secovlje salterns, Slovenia	EU448270	EF428367	KU866687	KU866930
		CBS 124670 = DTO 319-H1	Finger nails, Athens, Greece	KU866610	KU866900	KU866749	KU867010
<i>A. stellatus</i>	<i>Nidulantes</i>	CBS 598.65 <sup>T</sup> = NRRL 1858 = ATCC 16819 = IBT 32665 = IBT 21908 = IMI 136778 = QM 6835 = WB 1858 = IBT 32730 = DTO 327-F3	Soil, Panama	EF652426	EF652250	EF652338	EF652162
		CBS 668.82 = DTO 010-I5	Seed, India	EU448281	AY339992	KU866685	KU866924
		IBT 25137 = DTO 059-H2	Mangrove tree branch with <i>Isognomon</i> sp., surface water, Mochima Bay, Venezuela	KU866579	KU866889	KU866702	KU866957
		IBT 25113 = DTO 059-I7	<i>Pyura vittata</i> (red ascidia, tunicate, urochordata), sand bottom with corals, 2-3 m deep water, 23°C, Cabruta, Mochima Bay, Venezuela	KU866583	KU866890	KU866706	KU866961

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Table 1. (Continued).							
Species name	Section	Collection no.	Substrate and origin	GenBank accession nr.			
				ITS	BenA	CaM	RPB2
		IBT 25306 = DTO 061-B5	Mangrove tree branch with <i>Isognomon</i> sp., surface water, Mochima Bay, Venezuela	KU866591	KU866895	KU866714	KU866968
		DTO 127-C6	Air sample bakery, USA	KU866602	KU866897	KU866725	KU866984
		CBS 136.55 = NRRL 4761 = ATCC 12069 = IMI 060316 = IMUR 256 = QM 6957 = WB 4761 = DTO 320-B6	Laboratory contaminant, Brazil	KU866626	AY339990	KU866764	KU867028
		CGMCC 3.06292 = DTO 322-F8	Glass pane, Tonghua, Liaoning province, China	KU866636	KU866903	KU866774	KU867039
		IBT 12233 = DTO 325-A9	Cotton-field near Gila Bend, Arizona, USA	KU866665	KU866905	KU866785	KU867050
		IBT 20986 = DTO 325-C6	Gorgonie (octocoral, Coelenterata) from rocky sand bottom, Mochima Bay, Venezuela	KU866671	KU866908	KU866791	KU867056
<i>A. stercorarius</i>	<i>Nidulantes</i>	CBS 428.93 <sup>T</sup> = IBT 28024 = DTO 320-B3	Dung ( <i>Uromastix acanthinurus</i> ), Kerzaz, Sahara, Algeria	KU866625	KU866865	KU866763	KU867026
<i>A. striatus</i>	<i>Nidulantes</i>	CBS 592.65 <sup>T</sup> = IBT 22824 = ATCC 16815 = NRRL 4699 = CBS 283.67 = IHEM 4515 = IMI 096679 = LCP 82.3319 = WB 4699 = DTO 320-D3	Mangrove mud, Kagh Islands	EF652470	EF652294	EF652382	EF652206
		CBS 451.75 = IBT 22822 = DTO 319-I1	Gorakhpur, Uttar Pradesh, India	KU866614	KU866856	KU866753	KU867015
		CBS 866.70 = IBT 22823 = DTO 320-A7	Gorakhpur, Uttar Pradesh, India	KU866621	KU866862	KU866759	KU867022
<i>A. subversicolor</i>	<i>Nidulantes</i>	NRRL 58999 <sup>T</sup>	Green coffee berries, India	JQ301894	JN853970	JN854010	JN853799
<i>A. sulphureoviridis</i>	<i>Nidulantes</i>	CBS 140626 <sup>T</sup> = IBT 21868 = DTO 325-D1	Indoor air, factory, Denmark	KU866673	KU866911	KU866793	KU867058
<i>A. sydowii</i>	<i>Nidulantes</i>	CBS 593.65 <sup>T</sup> = NRRL 250 = IMI 211384 = NRRL 254	Clinical Isolate, Waycross, Georgia, USA	EF652450	EF652274	EF652362	EF652186
<i>A. tabacinus</i>	<i>Nidulantes</i>	CBS 122718 <sup>T</sup> = NRRL 4791 = IFO 4098 = QM 9766 = WB 4791	Tobacco	EF652478	EF652302	EF652390	EF652214
<i>A. tennesseensis</i>	<i>Nidulantes</i>	NRRL 13150 <sup>T</sup>	Toxic dairy cattle feed, Tennessee, USA	JQ301895	JN853976	JN854017	JN853806
<i>A. undulatus</i>	<i>Nidulantes</i>	CBS 261.88 <sup>T</sup> = AS 3.4510 = IBT 28027 = DTO 011-A1	Soil, Hubei Province, Shennongjia, China	EU448275	EF428363	EU443989	KU866928
		CGMCC 3.00750 = DTO 322-B2	Unknown source, Germany	KU866633	KU866901	KU866771	KU867036
		CGMCC 3.06295 = DTO 322-G2	Soil, Shennongjia, Hubei province, China	KU866637	KU866902	KU866775	KU867040
<i>A. unguis</i>	<i>Nidulantes</i>	CBS 132.55 <sup>T</sup> = NRRL 2393 = ATCC 16812 = IMI 136526 = NRRL A-2391 = NRRLA-445 = QM 25B = WB 2393 = DTO 047-I5	Shoe leather, Philadelphia, Pennsylvania	EF652443	EF652267	EF652355	EF652179
		DTO 017-A6	Air in factory, Vienna, Austria	KU866567	KU866807	KU866688	KU866939
		CBS 131.55 = DTO 319-H6	Unknown resource, Brazil	KU866612	KU866854	KU866751	KU867012
		CBS 595.65 = NRRL 216 = ATCC 10073 = WB 216 = Thom 5706.1 = IMI 136525 = IBT 21610 = DTO 319-I5	Man, Belgium	KU866616	KU866858	FN594611	KU867017
		CBS 691.93 = DTO 320-A5	Banana-pulp, USA	KU866620	AB 248319	KU866758	KU867021
		CGMCC 3.06404 = DTO 323-A2	Soil, Beijing, China	KU866641	KU866876	KU866779	KU867044
		IBT 14723 = DTO 325-C2	Marine derived isolate, Bahamas	KU866670	KU866910	KU866790	KU867055
<i>A. varians</i>	<i>Nidulantes</i>	CBS 505.65 <sup>T</sup> = NRRL 4793 = ATCC 16836 = IFO 4114 = IMI 172297 = WB 4793 = IBT 22568 = DTO 073-B5	Unknown source	EF652479	EF652303	EF652391	EF652215
		IBT 12603 = DTO 063-I1	Cork, Portugal	KU866597	KX423620	KU866720	–
<i>A. venenatus</i>	<i>Nidulantes</i>	NRRL 13147 <sup>T</sup>	Toxic dairy cattle feed, Tennessee, USA	JQ301896	JN854003	JN854014	JN853803



Table 1. (Continued).

Species name	Section	Collection no.	Substrate and origin	GenBank accession nr.			
				ITS	<i>BenA</i>	<i>CaM</i>	<i>RPB2</i>
<i>A. venezuelensis</i>	<i>Nidulantes</i>	CBS 868.97 <sup>T</sup> = IBT 20956 = DTO 011-A4	In red mangrove, surface water, Rojo, Mochima Bay, Mochima Nat. Park, Sucre State, Venezuela	AJ874119	AY339998	EU443977	KU866931
<i>A. versicolor</i>	<i>Nidulantes</i>	CBS 583.65 <sup>T</sup> = NRRL 238 = ATCC 9577 = IFO 33027 = IMI 229970 <sup>T</sup> = JCM 10258 = QM 7478 = Thom 5519.57 = WB 238	Unknown	EF652442	EF652266	EF652354	EF652178
<i>A. violaceus</i>	<i>Nidulantes</i>	CBS 138.55 <sup>T</sup> = NRRL 2240 = ATCC 16813 = CECT2587 = IFO 8106 = IMI 061449ii = IMI 61449 = LCP 82.3318 = NRRL A-3156 = QM 1905 = UC4511 = WB 2240 = DTO 048-B2	Soil, Tafo, Ghana	EF652438	EF652262	EF652350	EF652174
		CBS 293.93 = NHL 3000 = DTO 010-19 (ex-type of <i>A. similis</i> )	Soil in date palm plantation, Basrah City, Iraq	EU448279	EF428374	EU443987	KU866927
<i>A. viridicatenatus</i>	<i>Nidulantes</i>	CBS 140629 <sup>T</sup> = IBT 31492 = DTO 325-F4	Root of <i>Gymnadenia conopsea</i> , Denmark	KU866682	KX423621	KU866802	KU867067
<i>A. aeneus</i>	<i>Aeni</i>	CBS 128.54 <sup>T</sup> = NRRL 4769 = ATCC 16803 = IMI 069855 = LSHBBB 355 = MUCL 13570 = QM 1945 = WB 4279 = WB 4769	Forest soil, Modilen near Guiba River, Somalia	EF652474	EF652298	EF652386	EF652210
<i>A. bicolor</i>	<i>Aeni</i>	CBS 425.77 <sup>T</sup> = NRRL 6364 = ATCC 36104 = IMI 216612	Soil from <i>Artemisia</i> grassland, Wyoming	EF652511	EF652335	EF652423	EF652247
<i>A. crustosus</i>	<i>Aeni</i>	CBS 478.65 <sup>T</sup> = NRRL 4988 = ATCC 16806 = IMI 135819 = NRRL A-3254 = QM 8910 = WB 4988	Man skin scrapings, Illinois	EF652489	EF652313	EF652401	EF652225
<i>A. discophorus</i>	<i>Aeni</i>	CBS 469.88 <sup>T</sup> = IBT 21910 = IMI 328717 = DTO 011-B1	Soil, Spain	EU448272	AY339999	EU443970	KX423661
<i>A. eburneocremeus</i>	<i>Aeni</i>	CBS 130.54 <sup>T</sup> = NRRL 4773 = ATCC 16802 = IMI 69856 = MUCL 13588 = QM 1949 = WB 4773	Forest soil, Somalia	EF652476	EF652300	EF652388	EF652212
<i>A. foeniculicola</i>	<i>Aeni</i>	CBS 156.80 <sup>T</sup> = ATCC 42155 = IMI 334933 = LCP 84.2560 = NHL 2777	<i>Foeniculum vulgare</i> seed, China	EU448274	EU443990	EU443968	KU867027
<i>A. heyangensis</i>	<i>Aeni</i>	CBS 101751 <sup>T</sup> = AS 3.4630	Cotton seed, China	FJ491520	FJ491521	FJ491522	KX423659
<i>A. karnatakaensis</i>	<i>Aeni</i>	CBS 102800 <sup>T</sup> = IBT 22153	Soil under coconut palm in coffeeplantation, Karnataka	EU482441	EU482438	EU482431	KU866956
<i>A. spectabilis</i>	<i>Aeni</i>	CBS 429.77 <sup>T</sup> = NRRL 6363 = ATCC 36105 = IMI 216611 = RMFH429	Coal mine spoil material, Wyoming	EF652510	EU482437	EF652422	EF652246
<i>A. cavernicola</i>	<i>Cavernicolus</i>	CBS 117.76 <sup>T</sup> = NRRL 6327	Wall of cave, Romania	EF652508	EF652332	EF652420	EF652244
		CBS 600.67 = ATCC 18351 = IMI 129961 = MUCL 15648 = VKM F-906 (ex-type of <i>A. amylovorus</i> )	Wheat starch, Ukraine	FJ531140	FJ531161	FJ531190	JN121538
<i>A. californicus</i>	<i>Cavernicolus</i>	CBS 123895 <sup>T</sup> = IBT 16748	Chamise chaparral ( <i>Adeonostoma fasciculatum</i> ) soil, San Gabriel Mountains, North of Claremont and near San Antonio Dam, California	FJ531153	FJ531180	FJ531128	KU866974
<i>A. egyptiacus</i>	<i>Cavernicolus</i>	CBS 656.73 <sup>T</sup> = NRRL 5920 = ATCC 32114 = IMI 141415	Sandy soil, under <i>Olea europaea</i> , Egypt	EF652504	EF652328	EF652416	EF652240
<i>A. kassunensis</i>	<i>Cavernicolus</i>	CBS 419.69 <sup>T</sup> = NRRL 3752 = IMI 334938	Soil, Syria	EF652461	EF652285	EF652373	EF652197
<i>A. subsessilis</i>	<i>Cavernicolus</i>	CBS 502.65 <sup>T</sup> = NRRL 4905 = ATCC 16808 = IMI 135820 = QM 4905 = QM 8035 = WB 4905	Desert soil, California, Mojave Desert, USA	EF652485	EF652309	EF652397	EF652221
<i>A. bisporus</i>	<i>Bisporus</i>	CBS 707.71 <sup>T</sup> = NRRL 3693 = ATCC 22527 = IMI 350350 = NRRL A-17271 = QM 9700	Soil injected into mouse, Maryland	EF661208	EF661121	EF661139	EF661077
<i>A. funiculosus</i>	<i>Ochraceorosei</i>	NRRL 4744 <sup>T</sup> = NRRL 2550 = NRRL A-6752	Soil, Nigeria	EF661223	EF661112	EF661175	EF661078
<i>A. ochraceoroseus</i>	<i>Ochraceorosei</i>	CBS 550.77 <sup>T</sup> = NRRL 28622 = ATCC 38873 = SRRC1432	Soil, Ivory Coast	EF661224	EF661113	EF661137	EF661074

(continued on next page)

Table 1. (Continued).

Species name	Section	Collection no.	Substrate and origin	GenBank accession nr.			
				ITS	BenA	CaM	RPB2
<i>A. rambellii</i>	<i>Ochraceorosei</i>	CBS 101887 <sup>T</sup> = ATCC 42001 = IBT 14580	Soil, Ivory Coast	AJ874116	JN217228	KU866700	JN121416
<i>A. silvaticus</i>	<i>Silvati</i>	CBS 128.55 <sup>T</sup> = ATCC 16843 = ATCC 46904 = IFO 8173 = IMI 061456 = NRRL 2398 = QM 1912 = WB 2398	Soil, Ghana	EF652448	EF652272	EF652360	EF652184
<i>A. ivoriensis</i>	<i>Raperi</i>	CBS 551.77 <sup>T</sup> = NRRL 22883	Soil, Ivory Coast	EF652441	EF652265	EF652353	EF652177
<i>A. raperi</i>	<i>Raperi</i>	CBS 123.56 <sup>T</sup> = NRRL 2641 = ATCC 16917 = IFO 6416 = IMI 70949 = NRRL 4778 = NRRL A-7462 = QM 1898 = WB 4221 = WB 4778	Grassland soil, Zaire	EF652454	EF652278	EF652366	EF652190
<i>A. amazonicus</i>	<i>Sparsi</i>	CBS 124228 <sup>T</sup>	Soil, Ecuador	–	FJ943939	FJ943936	KU866979
<i>A. anthodesmis</i>	<i>Sparsi</i>	CBS 552.77 <sup>T</sup> = NRRL 22884 = IMI 223070	Soil, Ivory Coast	FJ491662	EF661108	FJ491648	EF661039
<i>A. biplanus</i>	<i>Sparsi</i>	CBS 468.65 <sup>T</sup> = NRRL 5071 = ATCC 16858 = IMI 235602 = QM 8873 = WB 5071	Soil, Costa Rica	EF661210	EF661116	EF661130	EF661036
<i>A. conjunctus</i>	<i>Sparsi</i>	CBS 476.65 <sup>T</sup> = NRRL 5080 = ATCC 16796 = IMI 135421 = QM 8878 = WB 5080	Forest soil, Costa Rica	EF661179	EF661111	EF661133	EF661042
<i>A. diversus</i>	<i>Sparsi</i>	CBS 480.65 <sup>T</sup> = NRRL 5074 = ATCC 16849 = IMI 232882 = QM 8882 = WB 5074	Forest soil, Costa Rica	EF661213	EF661114	EF661128	EF661034
<i>A. haitiensis</i>	<i>Sparsi</i>	CBS 464.91 <sup>T</sup>	Soil under sage and cactus, Haiti	FJ491657	FJ491670	FJ491645	KU866943
<i>A. implicatus</i>	<i>Sparsi</i>	CBS 484.95 <sup>T</sup>	Forest soil, Tai, Ivory Coast	FJ491656	FJ491667	FJ491650	–
<i>A. panamensis</i>	<i>Sparsi</i>	CBS 120.45 <sup>T</sup> = NRRL 1785 = ATCC 16797 = IMI 019393ii = IMI 019393iii = IMI 19393 = LSHBA .61 = NCTC 6974 = QM 6829 = QM 8897 = WB 1785	Soil, Panama	EF661177	EF661109	EF661135	EF661040
<i>A. sparsus</i>	<i>Sparsi</i>	CBS 139.61 <sup>T</sup> = NRRL 1933 = ATCC 16851 = IHEM 4377 = IMI 19394 = IMI 19394ii = MUCL 31314 = NCTC 6975 = QM 7470 = WB 1933	Soil, Costa Rica	EF661181	EF661125	EF661173	EF661071
<i>A. asper</i>	<i>Usti</i>	CBS 140842 <sup>T</sup> = NRRL 35910 = CCF 5174	House air in Pennsylvania, USA	KT698840	KT698838	KT698839	KT698842
<i>A. baeticus</i>	<i>Usti</i>	NRRL 62501 <sup>T</sup> = CMF ISB 2153 = CCF 4226	Cave sediment, Spain	HE615086	HE615092	HE615117	HE615124
<i>A. calidoustus</i>	<i>Usti</i>	CBS 121601 <sup>T</sup>	Bronchoalveolar lavage fluid, proven invasive aspergillosis; Nijmegen, The Netherlands	HE616558	FJ624456	HE616559	–
<i>A. carlsbadensis</i>	<i>Usti</i>	CBS 123894 <sup>T</sup> = IBT 14493	Soil, New Mexico, Carlsbad Caverns National Park, Lechuquilla Cave, USA	FJ531151	FJ531179	FJ531126	KU866973
<i>A. collinsii</i>	<i>Usti</i>	CBS 140843 <sup>T</sup> = NRRL 66196 = CCF 5175	From an air settle plate exposed in a domestic bathroom, Fair Oaks, California	KT698845	KT698843	KT698844	KT698848
<i>A. deflectus</i>	<i>Usti</i>	CBS 109.55 <sup>T</sup> = NRRL 2206 = ATCC 16807 = IMI 61448 = NRRL A-2700A = QM 1904 = UC4638 = WB 2206	Soil, Brazil	EF652437	EF652261	EF652349	EF652173
<i>A. elongatus</i>	<i>Usti</i>	CBS 387.75 <sup>T</sup> = NRRL 5176 = QM 9702 = WB 5495	Alkaline Usar soil, India	EF652502	EF652326	EF652414	EF652238
<i>A. germanicus</i>	<i>Usti</i>	CBS 123887 <sup>T</sup>	Indoor air, Germany	FJ531146	FJ531172	FJ531141	KU866944
<i>A. granulosis</i>	<i>Usti</i>	NRRL 1932 <sup>T</sup> = ATCC 16837 = IMI 17278 = QM 6846 = WB 1932	Soil, Fayetteville, Arkansas, USA	EF652430	EF652254	EF652342	EF652166
<i>A. heterothallicus</i>	<i>Usti</i>	CBS 488.65 <sup>T</sup> = NRRL 5096 = ATCC 16847 = IMI 139277 = QM 8916 = WB 5096	Soil, Costa Rica	EF652499	EF652323	EF652411	EF652235

Table 1. (Continued).

Species name	Section	Collection no.	Substrate and origin	GenBank accession nr.			
				ITS	<i>BenA</i>	<i>CaM</i>	<i>RPB2</i>
<i>A. insuetus</i>	<i>Usti</i>	CBS 107.25 <sup>T</sup> = NRRL 279 = NRRL 1726 = ATCC 1033 = IFO 4128	Unknown	EF652457	EF652281	EF652369	EF652193
<i>A. keveii</i>	<i>Usti</i>	CBS 209.92 <sup>T</sup>	Soil, Spain	EU076354	EU076376	EU076365	KU866938
<i>A. keveiooides</i>	<i>Usti</i>	CBS 132737 <sup>T</sup>	Soil, China	JN982704	JN982694	JN982684	KX423660
<i>A. lucknowensis</i>	<i>Usti</i>	CBS 449.75 <sup>T</sup> = NRRL 3491 = ATCC 18607 = IMI 278379 = PIL623 = QM 9271 = WB 5377	Alkaline Usar soil, India	EF652459	EF652283	EF652371	EF652195
<i>A. minutus</i>	<i>Usti</i>	NRRL 4876 <sup>T</sup>	Soil, Iowa, USA	EF652393	EF652481	EF652305	EF652217
<i>A. monodii</i>	<i>Usti</i>	CBS 435.93 <sup>T</sup>	Dung of sheep, Chad	FJ531150	FJ531171	FJ531142	–
<i>A. porphyrostipitatus</i>	<i>Usti</i>	CBS 138203 <sup>T</sup> = DTO 266-D9	House dust, Mexico	KJ775564	KJ775080	KJ775338	KU866987
<i>A. pseudodefectus</i>	<i>Usti</i>	CBS 756.74 <sup>T</sup> = NRRL 6135	Desert soil, Egypt	EF652507	EF652331	EF652419	EF652243
<i>A. pseudoustus</i>	<i>Usti</i>	CBS 123904 <sup>T</sup> = NRRL 5856 = IBT 28161	Stored maize, South Africa	FJ531147	FJ531168	FJ531129	KU866978
<i>A. puniceus</i>	<i>Usti</i>	CBS 495.65 <sup>T</sup> = NRRL 5077 = ATCC 16800 = IMI 126692 = QM 9812 = WB 5077	Soil, Costa Rica	EF652498	EF652322	EF652410	EF652234
<i>A. thesauroicus</i>	<i>Usti</i>	NRRL 62485 <sup>T</sup> = CMF ISB 2155 = 5CCF 4166	Indoor air, Spain	HE615088	HE615095	HE615120	HE615126
<i>A. turkensis</i>	<i>Usti</i>	CBS 504.65 <sup>T</sup> = NRRL A-3261 = NRRL 4993 = ATCC 16799 = IMI 135420	Soil, Turkey	FJ531160	FJ531191	FJ531145	EF652230
<i>A. ustus</i>	<i>Usti</i>	CBS 261.67 <sup>T</sup> = NRRL 275 = ATCC 1041 = ATCC 16818 = IMI 211805 = QM 7477 = WB 275	Culture contaminant, USA	EF652455	EF652279	EF652367	EF652191

were performed with MrBayes v. 3.1.2 (Ronquist & Huelsenbeck 2003). The sample frequency was set to 100 and the first 25 % of the trees removed as burn-in. Maximum likelihood analyses including 500 bootstrap replicates were run using RAxML (Gamma model of rate heterogeneity) (Stamatakis *et al.* 2008). *Aspergillus flavipes* (NRRL 302<sup>T</sup>) was used as outgroup in the *Aspergillus* subgenus *Nidulantes* phylogeny and *Aspergillus ustus* (CBS 261.67<sup>T</sup>) as outgroup in the section *Nidulantes* phylogeny. The resulting trees were visualized with FigTree v1.4.2 and annotated using Adobe Illustrator CS5. BI posterior probabilities (pp) values and bootstrap (bs) percentages of analysis are labelled at the nodes. Values less than 0.95 pp and less than 70 % bs are not shown. Branches with values more than 1 pp and 95 % bs are thickened. Newly obtained sequences were deposited in GenBank.

## Morphological analysis

Macroscopic characters were studied on the agar media Czapek Yeast Autolysate agar (CYA), CYA supplemented with 5 % NaCl (CYAS), yeast extract sucrose agar (YES), creatine sucrose agar (CREA), dichloran 18 % glycerol agar (DG18), oatmeal agar (OA) and malt extract agar (MEA; Oxoid CM0059), trace elements (0.1 g ZnSO<sub>4</sub>·7H<sub>2</sub>O and 0.5 g CuSO<sub>4</sub>·5H<sub>2</sub>O in 100 ml distilled water) were added to all media to obtain stable pigment production and consistent conidial colours (Samson *et al.* 2010). The isolates were inoculated at three points on 90 mm plates and incubated for 7 d at 25 °C in darkness. In addition, CYA plates were incubated at 37 and 40 °C (CYA 37 °C and CYA 40 °C, respectively), while additional MEA plates were incubated at 37 °C (MEA 37 °C). After 7 d of incubation, colony diameters were recorded. Colony texture, degree of sporulation, obverse

and reverse colony colours, production of soluble pigments, exudates and ascospores were determined. Acid production on CREA is indicated by a change in the pH sensitive bromocresole purple dye from purple to yellow around growing colonies. For ascospore production, OA, MEA and CYA plates were incubated at 25 °C for up to four wks.

Light microscope preparations were made from 1 wk old colonies grown on MEA, for species which do not sporulate on MEA, other media (YES, OA or DG 18) were used for preparations and were indicated in species descriptions. Ascospores, asci and ascospores were observed from OA. Lactic acid (60 %) was used as mounting fluid. Alcohol (96 %) was used to remove excess conidia and prevent air bubbles. A Zeiss Stereo Discovery V20 dissecting microscope and Zeiss AX10 Imager A2 light microscope both equipped with a Nikon DS-Ri2 camera and software NIS-Elements D v4.50 were used to capture digital images. The temperature growth profile of the strains was studied on CYA. Strains were inoculated at one point in the centre of the plates and incubated at 18, 21, 24, 27, 30, 33, 37, 40, 45 and 50 °C for 5 d in darkness. Species in the clade *Versicolores* were studied extensively by Jurjevic *et al.* (2012) and are not included here.

## Cryo Scanning Electron Microscopy (cryoSEM)

Mature ascospores were harvested from 30–50 day old cultures on OA. Ascospores were crushed and ascospores were picked using a dissecting needle and carefully transferred into distilled deionized water. A drop (5 µl) of this suspension was transferred to a polycarbonate membrane (1.0 Micron, 47 mm, GE Water and Process Technologies, Trevose, PA, USA). Polycarbonate membranes were placed on filter paper circles (0.7 mm, Schleicher & Schuell)

to ensure that fluid was quickly absorbed through the pores of the membranes. The quick removal of fluid resulted in an equal distribution of ascospores and also more ascospores that could be viewed from the equatorial side as compared with passive evaporation of a droplet. The polycarbonate membranes with ascospore depositions were carefully cut out with a surgical knife and transferred to an aluminium stub. After drying at room temperature for one wk, the stubs were sputter-coated with gold three times for 30 s in a JEOL JFC-1300 Auto-fine coater and then viewed using a JEOL 5600LV scanning electron microscope (JEOL, Tokyo, Japan). Electron micrographs were acquired with the F4 scan at an acceleration voltage of 10 kV.

## Extrolite analysis

Representatives of 48 section *Nidulantes* species were analysed for extrolite production using the method originally described by Frisvad & Thrane (1987, 1993) and modified by Smedsgaard (1997), and using the UHPLC-DAD method described in Kildgaard et al. (2014) and Klitgaard et al. (2014). Strains were inoculated and incubated on CYA and YES agar for 7 d at 25 °C in darkness and subsequently three plugs were extracted as described by Smedsgaard (1997). Species in clade *Versicolores* (= section *Versicolores*) and currently described *A. croceus* and *A. askiburgiensis* (Hubka et al. 2016) are not included.

## RESULTS

### Phylogeny

The phylogenetic relationships among *Aspergillus* subgenus *Nidulantes* species were studied using concatenated sequence data of four loci: ITS, *BenA*, *CaM* and *RPB2*. In total, 130 ex-type strains were included in the analysis and the total length of the aligned data set was 2483 characters, containing 498, 527, 537 and 921 bp for ITS, *BenA*, *CaM* and *RPB2* respectively. For Bayesian analyses, GTR+G model was used for ITS, *BenA*, *CaM* and *RPB2*. Fig. 1 shows the results of the analysis and reveals the presence of nine lineages in subgenus *Nidulantes*. These lineages are treated here as sections, namely *Aenei*, *Nidulantes*, *Usti*, *Raperi*, *Silvati*, *Bispori*, *Ochraceorosei*, *Sparsi* and the newly introduced section *Cavernicolus*. The members of sections *Nidulantes* and *Versicolores* form a well-supported group (1 pp, 100 % ML), which is in agreement with previous studies (Peterson 2008, Peterson et al. 2008). On the basis of the phylogenetic analysis we follow Hubka et al. (2016) and include *Versicolores* within section *Nidulantes*. Based on our results, 65 species are well resolved in section *Nidulantes*. Section *Cavernicolus* (1 pp, 85 % ML) contains five species previously assigned to section *Usti*, namely *A. californicus*, *A. cavernicola*, *A. egyptiacus*, *A. kassunensis* and *A. subsessilis*. Most of species in this section produce short conidiophores, except *A. californicus*, which produces long, light brown conidiophores, resembling typical section *Usti* species (Samson et al. 2011). *Aspergillus funiculosus* included in section *Sparsi* by Peterson (2008), clusters with *A. ochraceorosues* and *A. rambellii* with poor bootstrap and Bayesian statistics.

To define relationships within section *Nidulantes*, an aligned concatenated data set with a total length of 2,400 characters (ITS 533; *BenA* 472; *CaM* 505; *RPB2* 890 bp) was analysed. For

Bayesian analysis, GTR+G was used for *BenA*, *CaM* and ITS and K2P+G for *RPB2*. Members of section *Nidulantes* are resolved into seven well supported clades (Fig. 2). The *A. nidulans* clade contains 23 species including the type species of section *Nidulantes*-*A. nidulans*. *Aspergillus dentatus* is phylogenetically identical with *A. nidulans* and therefore considered a synonym. Similarly, four species (*A. parvathecicus*, *A. nidulans* var. *acristatus*, *A. floriformis* and *A. miyajii*) are synonymised with *A. quadrilineatus*. *Aspergillus sublatus* and *A. montenegroi* are synonymised with *A. latus*; *A. rugulosus* var. *lazulina* and *A. cleistominutus* are synonymised with *A. rugulosus*; *A. similis* is synonymised with *A. violaceus*. The relation between the clades *A. aurantiobrunneus*, *A. spelunceus* and *A. versicolor* are uncertain, *A. aurantiobrunneus* clade clusters outside clades *A. spelunceus* and *A. versicolor* in the subgenus phylogeny (Fig. 1), while it clusters with *A. spelunceus* clade in the section phylogeny (Fig. 2), both of the phylograms do not have bootstrap and Bayesian statistics. The *A. stellatus* clade contains species with either stellate or appendaged ascospores. *Aspergillus chinensis* is considered a synonym of *A. filifer* based on phylogenetic and morphological characters as suggested by Matsuzawa et al. (2012) and Hubka et al. (2016).

### Morphology

Morphological characters of *Aspergillus* section *Nidulantes* are summarised in Tables 2–4. Ascospores can be globose, subglobose, stellate or appendaged (Figs 3–6). The ornamentation on the ascospore convex is informative for species identification. For example in the *A. nidulans* clade, the ascospore ornamentation can be irregularly wrinkled (*A. corrugatus*), finely pitted (*A. foveolatus*), rugulose (*A. rugulosus*) or echinulate (*A. spinulosporus*). Ascospore crests are two in number in most species, four crests are only observed in *A. quadrilineatus*. Ascospore colour is also taxonomically informative, for example the violet ascospores can easily differentiate *A. violaceus* from other section *Nidulantes* species (Fig. 5). In *A. aurantiopurpureus*, orange ascospores can turn to violet in older cultures (Fig. 4), which is firstly observed in section *Nidulantes*. However, ascospore colour can be variable in some species. Peintner & Rainer (1999) reported an isolate of *A. nidulans* (CBS 100522) with blue ascospores; another example is *A. miraensis*, which was originally described with violet ascospores (Zhang et al. 2013), but shows orange to reddish brown ascospores in our study. Ascomata, when present, are mostly 200–600 µm, but it may be highly variable depending on the media, and in some species like *A. quadrilineatus* and *A. violaceus*, variable size of ascomata were observed in different strains even under same cultivation condition. Thus the ascoma size is not recommended as a distinguishing feature.

In general, species in *Aspergillus* section *Nidulantes* produce more or less brown-pigmented conidiophores, typically smooth but occasionally showing surface protuberances. Vesicles are usually globose, subglobose or subclavate, narrower than 30 µm. Conidia are typically globose and echinulate, green in mass, in some cases (*A. asperescens* and *A. varians*) conidia are ellipsoidal (Figs 7, 8). For non-ascosporic species, size and shape of conidiophores and conidia are taxonomically informative (Table 2).

Macromorphology including temperature growth profile, production of cleistothecia, mycelium colour, sporulation, soluble pigments, and exudate is also important distinguishing character. Species within the *A. nidulans* clade grow optimally at 37 °C but

ITS/*BenA*/*CaM*/*RBP2*

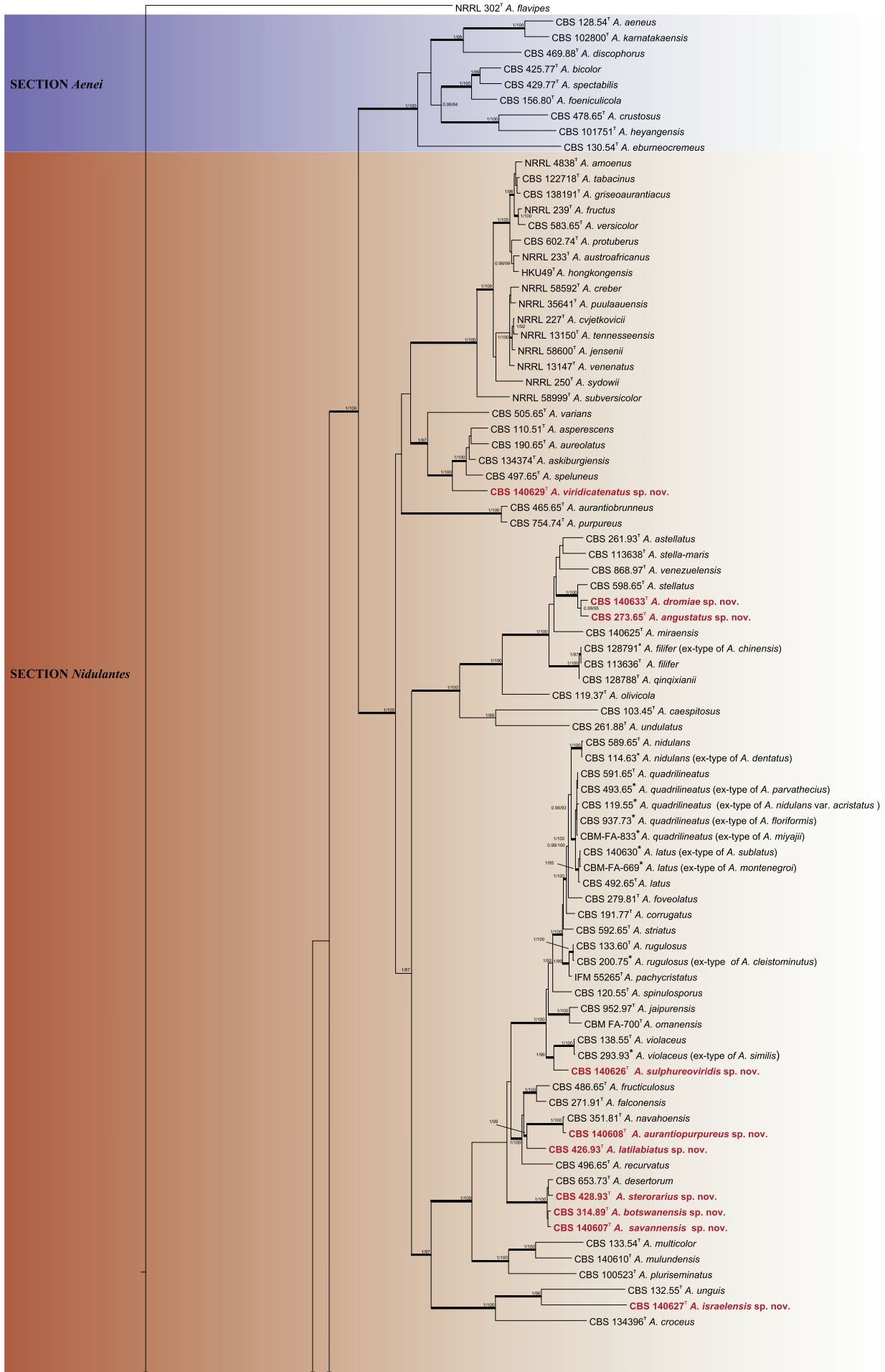


Fig. 1. Phylogenetic tree of subgenus *Nidulantes* inferred from concatenated 4 loci: ITS, *BenA*, *CaM* and *RBP2*. Branches with values more than 1 pp and 95% bs are thickened. The phylogram is rooted with *Aspergillus flavipes* (NRRL 302<sup>T</sup>).

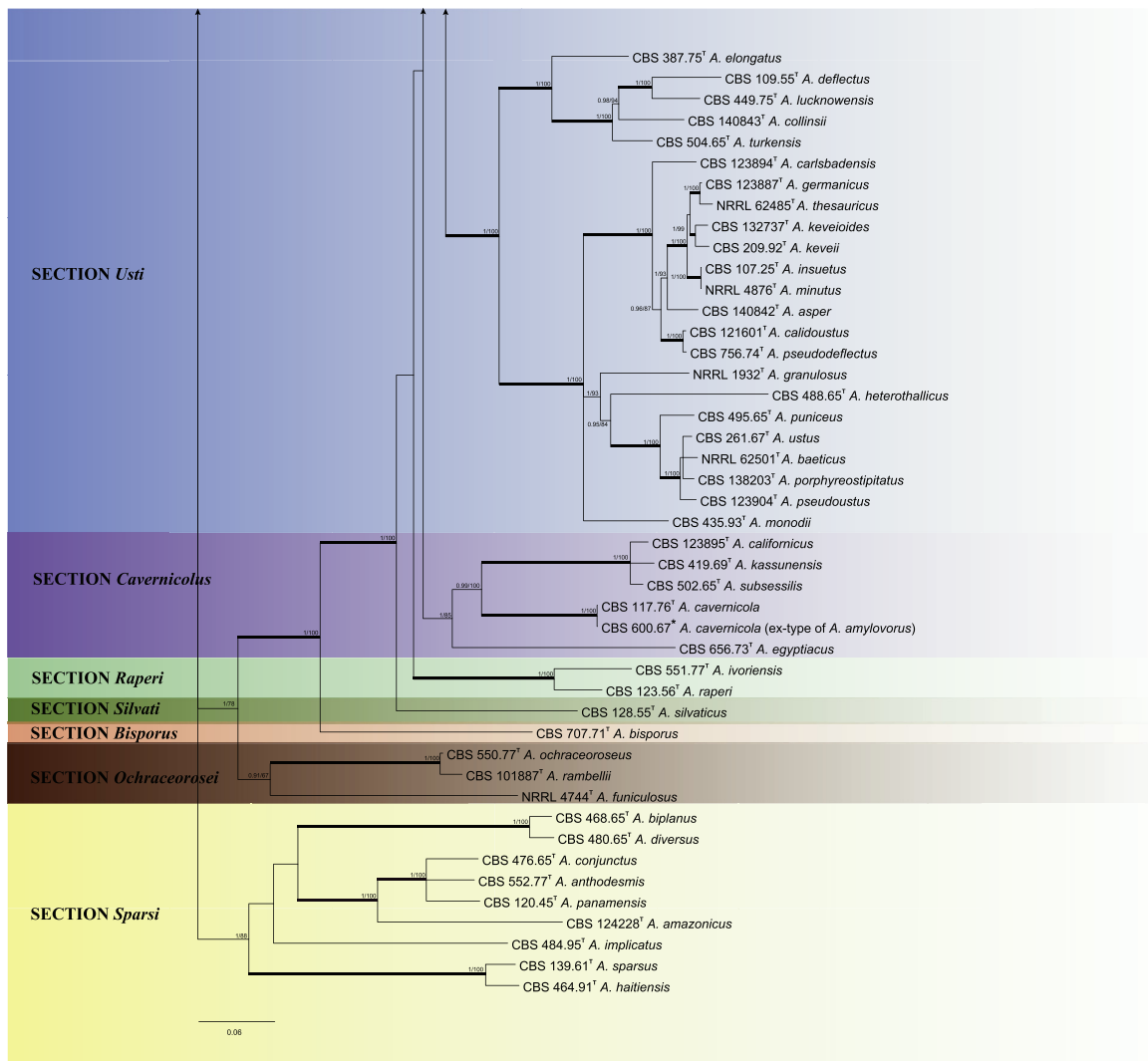


Fig. 1. (Continued).

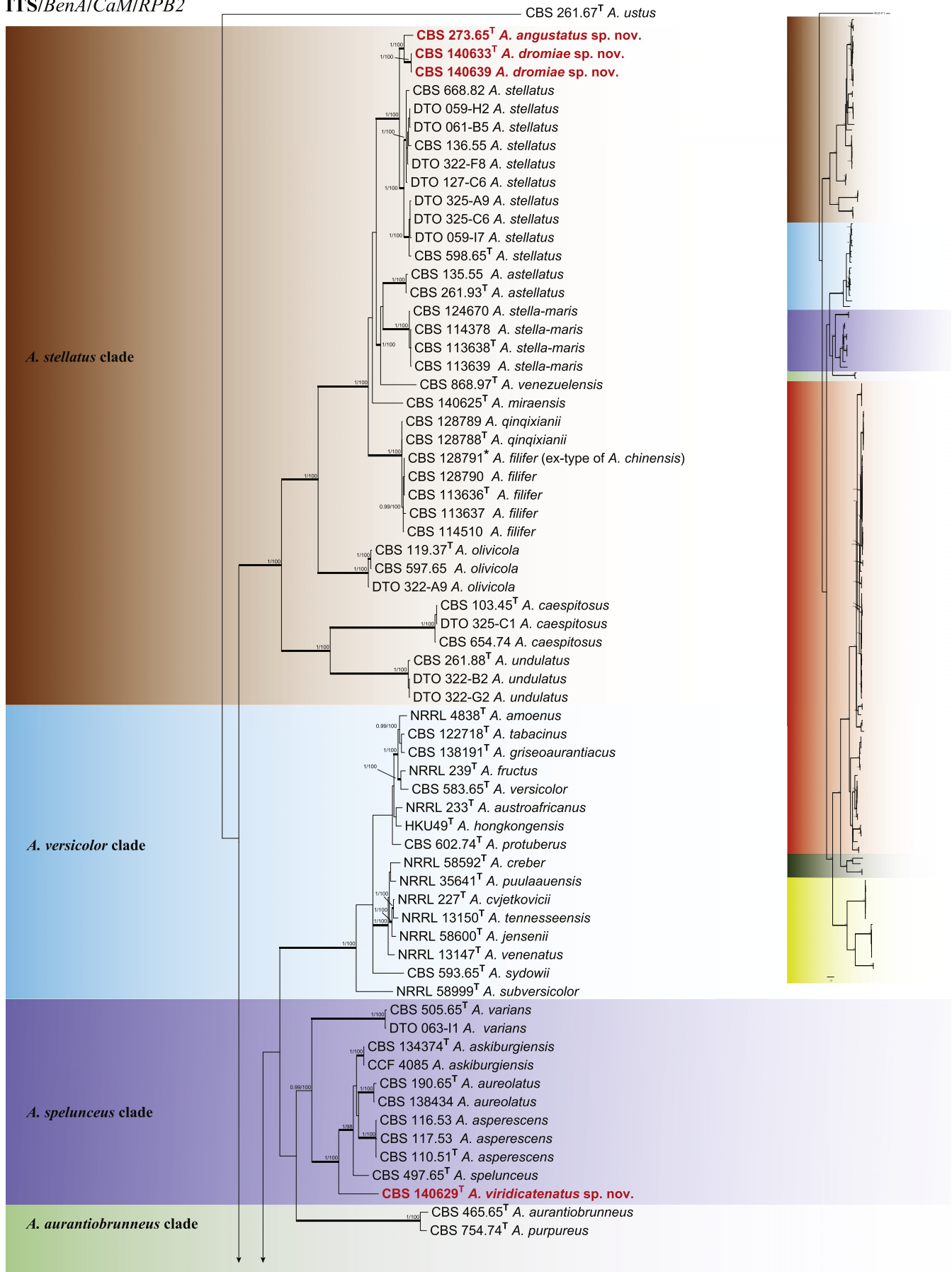
do not grow at 50 °C (Table 5, Figs 9, 10), while species in the other six clades cannot grow at 40 °C, some species such as *A. asperescens*, *A. aureolatus*, *A. pluriseminatus*, *A. spelunceus* and *A. varians* cannot grow at 36 °C (Table 5, Figs 11, 12).

## Extrolites

Forty eight species were analysed for extrolites and produced several shared or unique small molecule extrolites and often had species specific profiles (mentioned after each species description). An overview of reported extrolites from section *Nidulantes* species is shown in Table 6. Sterigmatocystins, shamixanthones, and violaceols are common to many species and are also found in some species from sections *Usti* and *Aenei* (Houbraken et al. 2007, Varga et al. 2010a, Samson et al. 2011). The shamixanthones are produced by 19 species in section *Nidulantes*. The ascospore / Hülle cell-associate metabolite asperthecin is produced by 20 species in the section. The desertorin polyketides are produced by 13 species, while violaceol polyketides are found in 19 species. The falconensins and falconensons are produced by the closely related species *A. aurantiopurpureus*, *A. falconensis*, *A. fruticulosus*, *A. navahoensis* and *A. revurvatus*. Emericellin is found in 18 species, asperugin polyketides is produced by 14 species and the shikimic derived emerins are formed by two

species. The dithiodiketopiparazine mycotoxin emestrin is produced by six closely related species: *A. foveolatus*, *A. jaipurensis*, *A. quadrilineatus*, *A. rugulosus*, *A. striatus* and *A. violaceus*. The important antibiotic echinocandin and mulundocandin producers include *A. mulundensis*, *A. navahoensis*, *A. pachyristatus*, *A. quadrilineatus*, and *A. rugulosus* (Bills et al. 2016, de la Cruz et al. 2012). One of the originally reported producers was first identified as *A. spinulosporus* (as *Emericella echinulata*), but was later re-identified as *A. rugulosus* (*Emericella rugulosa*) (Dreyfuss 1986).

The mycotoxin sterigmatocystin has not only been found in most species of sections *Nidulantes*, *Aenei* and *Usti*, but also in species of section *Ochraceorosei* (Table 7) (Frisvad 1985, Horie & Yamazaki 1985, Rank et al. 2011, Jurjevic et al. 2013). In *Aspergillus* section *Nidulantes* 35 species could produce sterigmatocystin, four additional species (*A. multicolor*, *A. purpureus*, *A. stellatus* and *A. violaceus*) have been reported to produce sterigmatocystin, but this could not be confirmed here, and two species remains to be examined for production of sterigmatocystin (*A. omanensis* and *A. sulphureoviridis*) (Table 7). Aflatoxin B1 is produced by four species: *A. stellatus*, *A. miraensis*, *A. olivicola*, and *A. venezuelensis*. This is the first report of aflatoxin production by *A. miraensis*. Other mycotoxins are also produced by a few species in section *Nidulantes*, such as verruculogen and fumitremorgins in *A. caespitosus* and asteltolxin produced by

ITS/*BenA*/*CaM*/*RPB2*

**Fig. 2.** Phylogenetic tree of section *Nidulantes* inferred from concatenated 4 loci: ITS, *BenA*, *CaM* and *RPB2*. Branches with values more than 1 pp and 95% bs are thickened. The phylogram is rooted with *Aspergillus ustus* (CBS 261.67<sup>T</sup>).

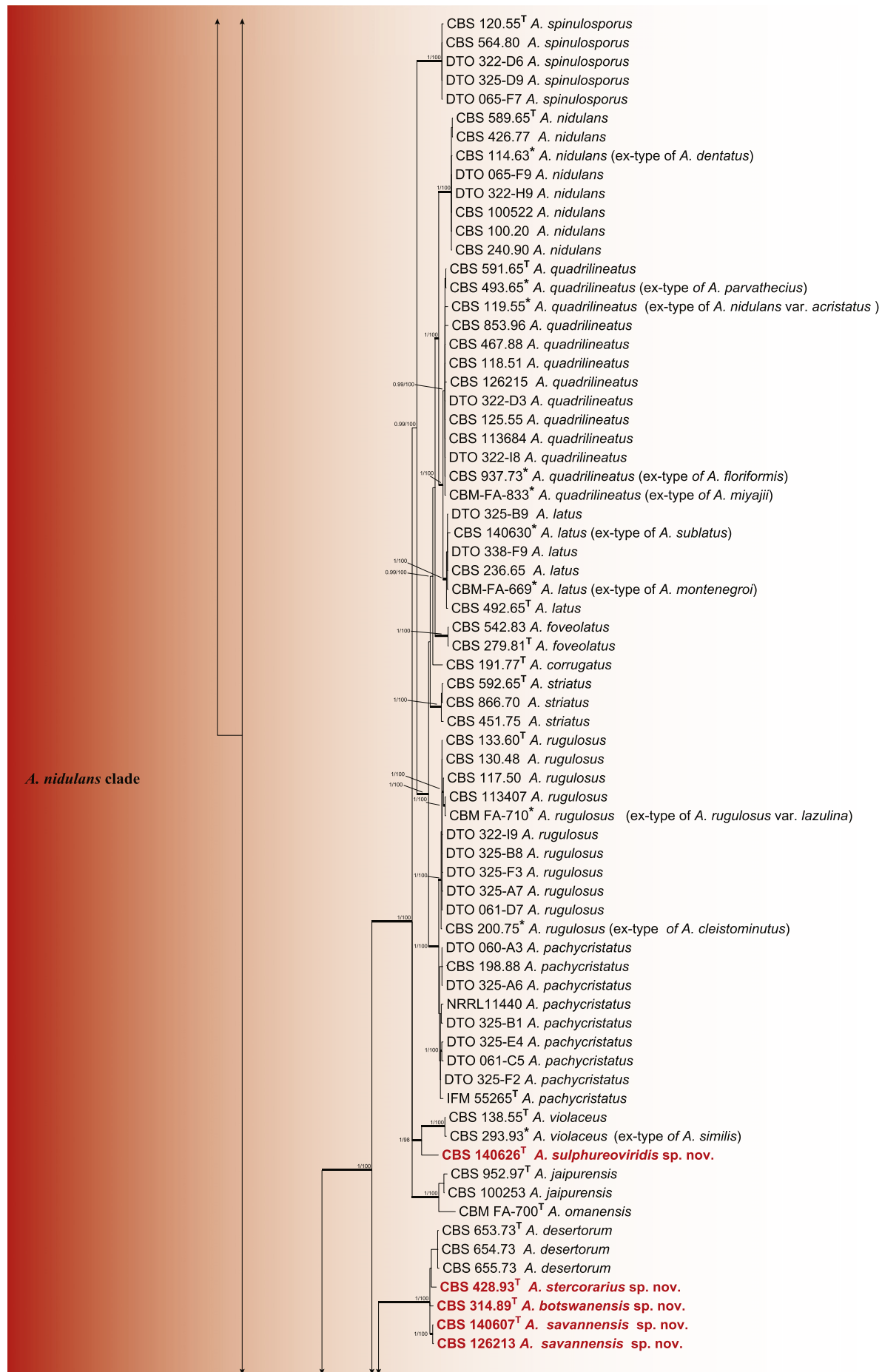


Fig. 2. (Continued).



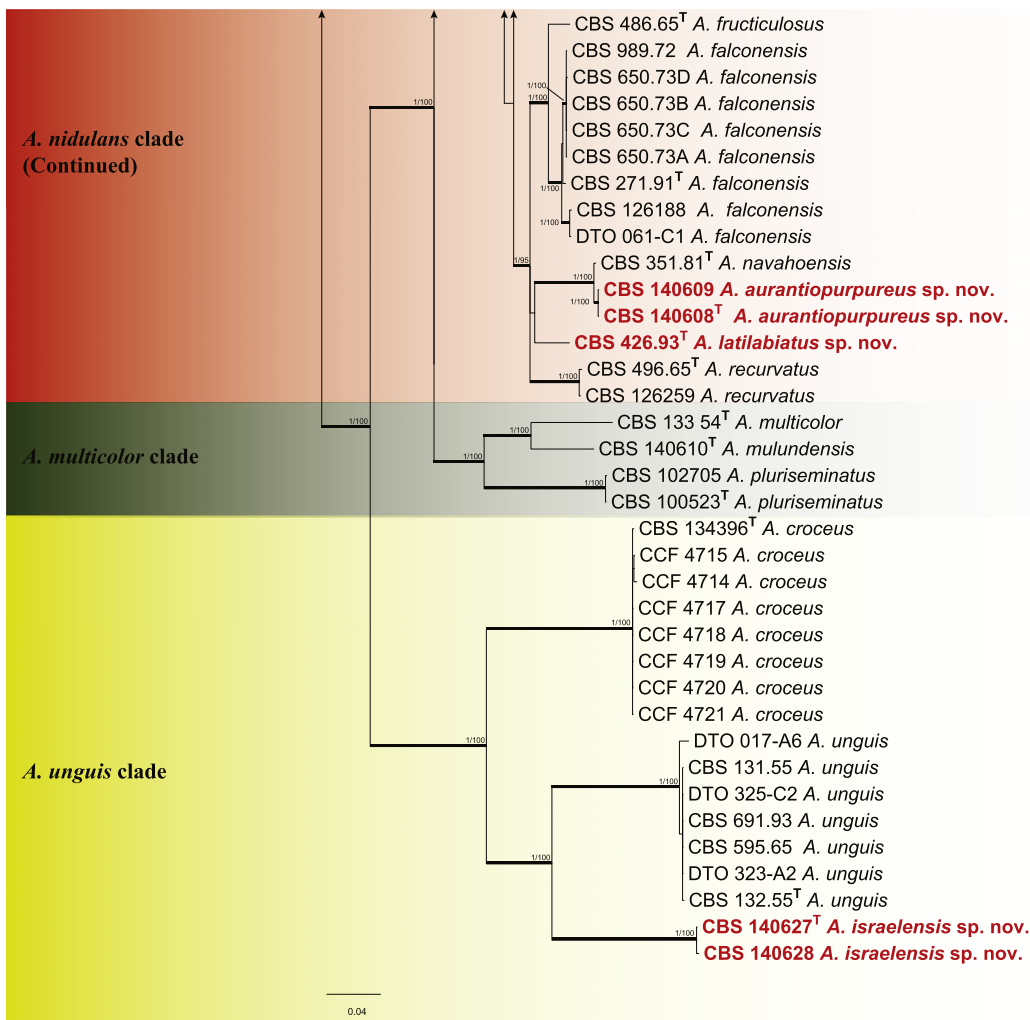


Fig. 2. (Continued).

*A. olivicola*, *A. qinqixianii*, *A. stellatus* and *A. filifer*. Thus the most important mycotoxins in *Aspergillus* section *Nidulantes* are aflatoxins, sterigmatocystin, emestrin, fumitremorgins, asteltoxins, and paxillin while other extrolites are useful drugs or drug lead candidates such as echinocandins, mulundocandins, calbistrins, varitriols, variecolins and terrein, and some can be regarded as both mycotoxins and drug lead candidates, for example viridicatumtoxin. It is interesting to note that many of these compounds are also produced by other *Aspergillus* species in phylogenetically different subgenera, showing that species in section *Nidulantes* are quite closely related to these other species in many features (Frisvad & Larsen 2015).

## DISCUSSION

### Sectional classification in subgenus *Nidulantes*

Based on a multigene phylogeny, nine sections are proposed within subgenus *Nidulantes*. Eight of them were introduced in previous studies (Peterson 2008, Peterson *et al.* 2008, Varga *et al.* 2010a, b). Five species previously assigned in section *Usti*, namely *A. californicus*, *A. cavernicola*, *A. egyptiacus*, *A. kassunensis* and *A. subsessilis* form a monophyletic clade outside section *Usti*. The bootstrap support of this distinct clade is low (Hubka *et al.* 2016), but the species within this clade do

share some phenotypic characters, most of them (except *A. californicus*) produce short conidiophores, which is not common in section *Usti*. Based on these observations, we propose *Aspergillus* section *Cavernicolus* to accommodate these species within subgenus *Nidulantes*. Section *Aenei* was included in section *Nidulantes* as *Aspergillus aeneus* clade (Hubka *et al.* 2016). However in our study, section *Aenei* locates outside section *Nidulantes* with full support, which agrees with Varga *et al.* (2010a). Phenotypically the homothallic species in section *Aenei* (*A. discophorus*, *A. bicolor*, *A. spectabilis* and *A. foeniculicola*) produce similar ascospores with *A. nidulans* clade, but none of them is able to grow at 40 °C. Based on these observations, section *Aenei* is kept to accommodate these species. The placement of *A. funiculosus* in a certain group is doubtful, Raper & Fennell (1965) accepted *A. funiculosus* as the only uniseriate species in section *Sparsi* (*Aspergillus sparsus* group), our phylogenetic results show that *A. funiculosus* is more closely to *A. ochraceoroseus*, however is not supported by bootstrap and Bayesian statistics as shown by Hubka *et al.* (2016), the belonging of this species needs further study.

### Clade classification in section *Nidulantes*

Matsuzawa *et al.* (2012) performed the first multilocus analysis based on *BenA*, *CaM* and *actin* in the genus *Emericella*, eight clades were introduced for 37 species, clades I, II, III, IV, V and VI

**Table 2.** Most important micromorphological characters for non-ascosporic *Aspergillus* section *Nidulantes* species ( $\mu\text{m}$ ).

Species name	Conidiophores	Vesicles	Metulae	Phialides	Conidia
<i>Aspergillus askurgiensis</i> <sup>1</sup>	40–180 × 3–8.5	5.5–18.5	4–6	5–8	2.5–4 (–4.5)
<i>A. asperescens</i>	200–400 × 6–8	8–15	6–9 × 3–4	7.5–9 × 3–4	4–7 × 3–5
<i>A. aureolatus</i>	80–200 × 4–5.5	9–12	5–8.5 × 2–4	5–7 × 2.5–3	3.5–5
<i>A. caespitosus</i>	200–300 × 3–6	10–15	5–8 × 3–3.5	6.5–8 × 3–4.5	3–4
<i>A. croceus</i> <sup>1</sup>	90–200 × 3.5–5	7–15	7.5–10.5	(6.5–) 7–9 (–9.5)	2–3 (–3.5)
<i>A. israelensis</i>	90–160 × 3.5–4.5	7–10	5–8 × 2.5–3.5	6–8 × 2–2.5	2.5–3.5
<i>A. multicolor</i>	300–350 × 5–7	16–20	6–10 × 3–4	8–9 × 2.5–3	3.5–5.5
<i>A. mulundensis</i>	33–70 × 2.5–4.5	5.5–15	5–7 × 2.5–4.5	6–7.5 × 2.5–4	2.5–3.5
<i>A. recurvatus</i>	40–150 × 3.5–4.5	8–10	5–6 × 2.5–3.5	4.5–5.5 × 2–3	3–4.5
<i>A. spelunceus</i>	130–300 × 4–6	7–11	4–6.5 × 2.5–3.5	5.5–7.5 × 2–2.5	2.5–3.5
<i>A. unguis</i>	50–100 × 3–5	8–10	5–7 × 2.5–3.5	5–9 × 2–2.5	2.5–4
<i>A. varians</i>	600–1200 × 7–12	20–30	7–10 × 3.5–4.5	8–12 × 3–4	4–6 × 3.5–4
<i>A. viridicatenatus</i>	120–270 × 5–6	10–15	6–9 × 2.5–3.5	6–9.5 × 2.5–3.5	3–5 × 2.5–4
<i>A. amoenus</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(35–) 100–600 (–1100) × (2.5–) 4–7 (–8)	(4–) 7–17 (–21)	3–6 (–8) × 2.5–4 (–5.5)	(5–) 6–8 (–11) × 2–3	2.5–3.5 (–5)
<i>A. austroafricanus</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(40–) 100–350 (–500) × 3–5 (–6)	(4–) 6–12 (–15)	3–7 (–9) × 2.5–4.5	(4–) 5–7 (–9) × (2–) 2.5–3 (–4)	2.5–3.5 (–4.5)
<i>A. creber</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(10–) 70–450 (–650) × (3–) 4–7 (–8)	(4–) 7–17 (–25)	(3–) 4–6 (–8) × 2.5–4.5	(4–) 5–8 (–10) × 2–3 (–4)	(2.5–) 3–4 (–9)
<i>A. cvjetkovicii</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(40–) 200–700 (–850) × (3–) 4–7 (–8)	(5–) 9–18 (–23)	3–6 (–8) × 2.5–4.5	5–8 (–10) × 2–3 (–4)	(2–) 2.5–3.5 (–5)
<i>A. fructus</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(50–) 150–400 (–500) × 4–7	(6–) 9–17 (–21)	(2–) 3–7 (–9) × 2.5–4.5 (–7)	(5–) 6–8 (–11) × 2–3 (–4)	(2–) 2.5–3.5 (–4.5)
<i>A. griseoaurantiacus</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	100–500 × 3.5–8	(3.5–) 9–18 (–26.5)	4–10 × 3–5.5	5.5–7 × 2.5–3.5	2.5–4 × 2–3
<i>A. hongkongensis</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	>100	15	–	–	2
<i>A. jensenii</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(45–) 200–700 (–1000) × (3–) 4–7 (–8)	(5–) 7–16 (–22)	3–8 × 2.5–4 (–5)	(4–) 5–8 (–11) × 2–3	(2.5–) 3–4.5 (–7)
<i>A. protuberus</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(120–) 300–800 (–1250) × 4–10	(6–) 10–24 (–27)	(3–) 4–7 (–8) × 2.5–4.5 (–5.5)	(4–) 5–8 (–11) × 2–3 (–3.5)	(2–) 2.5–3.5 (–5)
<i>A. puulaauensis</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(35–) 100–500 (–700) × (3–) 4–7	(5–) 8–18 (–21)	(3–) 4–7 (–9) × 2.5–4	5–7 (–10) × 2–3	(2.5–) 3–4 (–5.5)
<i>A. subversicolor</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(60–) 250–450 (–550) × 4–7 (–10)	(6–) 10–17 (–22)	(3–) 4–7 (–9) × (2–) 2.5–4	5–8 (–10) × 2–3	(2.5–) 3–4 (–7)
<i>A. sydowii</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	100–500 × 4–7	5–10 (–15)	6–7 × 2–3	7–10 × 2–2.5	2.5–3 (–5)
<i>A. tabacinus</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(70–) 300–700 (–900) × 4–8 (–9)	(5–) 8–15 (–22)	3–8 (–9) × 2.5–4.5 (–5.5)	5–8 (–11) × 2–3 (–3.5)	(2.5–) 3–4 (–7)
<i>A. tennesseensis</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(35–) 100–300 (–400) × 4–7	(7–) 10–16 (–18)	4–6 (–8) × 2.5–4	5–8 (–11) × 2–3	(2.5–) 3–4 (–8)
<i>A. venenatus</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(20–) 100–400 (–500) × 4–7	(6–) 9–17 (–21)	(3–) 4–7 (–9) × 2.5–4 (–5)	(5–) 6–8 (–11) × 2–3 (–3.5)	3–4 (–6)
<i>A. versicolor</i> <sup>1</sup> ( <i>A. versicolor</i> clade)	(45–) 200–750 (–1050) × (4–) 5–8 (–12)	(6–) 9–17 (–20)	3–6 (–9) × 2.5–4.5	(4–) 5–7 (–11) × 2–3	(2–) 2.5–3.5 (–6.5)

<sup>1</sup>Data derived from Jurjevic et al. 2012, Visagie et al. 2014, Hubka et al. 2016, Tsang et al. 2016.

are equal with our *A. nidulans* clade, clades VII and VIII are equal with our *A. stellatus* clade, anamorphic species were not included in their analysis. Hubka et al. (2016) constructed a phylogenetic analysis for section *Nidulantes*, six statistically supported clades were designated, namely clades *A. aeneus*, *A. spelunceus*, *A. versicolor*, *A. stellatus*, *A. nidulans* and *A. unguis*, five of them are confirmed in our study, while *Aspergillus aeneus* clade is treated as section *Aenei* as discussed above. Besides these clades, additional two clades are introduced here, namely clades *A. aurantiobrunneus* and *A. multicolor*. The *A. aurantiobrunneus*

clade contains *A. aurantiobrunneus* and *A. purpureus*. Hubka et al. (2016) included *A. aurantiobrunneus* in *A. spelunceus* clade although the grouping was not well supported (100/80/1 ML/MP/PP), *A. purpureus* was not included in their study. In our study, these two species form a full supported branch (1 pp, 100 % ML), morphologically they all produce globose and subglobose ascospores and grow restrictedly on all tested media. In contrast all species in *A. spelunceus* clade are anamorphic, and grow faster. Another newly introduced clade is *A. multicolor* clade, this clade contains *A. multicolor*, *A. mulundensis* and *A. pluriseminatus*, and

Table 3. Most important micromorphological characters for *Aspergillus* section *Nidulantes* species with stellate ascospores ( $\mu\text{m}$ ).

Species name	Teleomorphic characters				Anamorphic characters							
	Ascomata Hülle cells	Ascospore colour	Ascospore size	Ascospore bodies	Ornamentation of convex surfaces	Undissected part of crests	Extensions	Conidiophores	Vesicles	Metulae	Phialides	Conidia
<i>A. angustatus</i>	430–780	Orange to reddish brown	9–12	3–4 × 3–3.5	Smooth	0.5–1	1.5–3	200–400 × 4.5–6	8–12	6–8 × 3–4.5	7–8.5 × 2.5–3.5	3–4.5
<i>A. dromiae</i>	450–800	Orange to reddish brown	11–15	3–4.5 × 3.5–4.5	Smooth	1–1.5	2–3	300–410 × 4.5–6.5	12–17	6–8 × 3–4.5	6.5–10 × 3.5–4.5	3.5–4.5
<i>A. miraensis</i>	320–600	Orange to reddish brown or violet	8–10	2–4 × 2–3	Smooth or verrucose	0.7–1	1.5–2.5	300–500 × 5–6	12–15	5–8 × 3–4	6–8 × 2–3.5	2–3.5
<i>A. olivicola</i>	400–770	Orange to reddish brown	7.5–11	3–4.5 × 3–4	Smooth	0.4–0.7	1–3	150–340 × 4–5.5	8–15	7.5–10.5 × 2–3.5	7.5–12.5 × 1.5–3	2–3.5
<i>A. pluriseminatus</i> <sup>1</sup>	80–250	Violet brown	–	7–9 × 6–7	Tuberculate	–	–	–	–	–	–	–
<i>A. stella-maris</i>	370–770	Orange to reddish brown	13–16	3–4.5 × 2.5–4.5	Smooth	1–1.5	3–4.5	300–800 × 3.5–7	9–20	5–9 × 3–4	6–9 × 2–3.5	3–4
<i>A. stellatus</i>	300–600	Orange to reddish brown	10–14	3.5–4 × 3–4	Smooth	0.5–1	2.5–4	320–610 × 4.5–6.5	13.5–18.5	4–7.5 × 3.5–4	6–8.5 × 2.5–3.5	2.5–3
<i>A. venezuelensis</i>	400–1000	Orange to reddish brown	12.5–19.5	4–5 × 3.5–4.5	Covered with triangular flap	1–1.2	2.5–4	65–130 × 2–3	5.5–7	4–5 × 2.5–3.5	6–7 × 2.5–3.5	2.5–4

<sup>1</sup>Data derived from Stchigel & Guarro 1997.

is close related with *A. nidulans* clade. No species in this clade grow at 40 °C, *A. pluriseminatus*, the only homothallic species in this clade produces stellate ascospores, which show more similarity with species in *A. stellatus* clade.

### *Aspergillus* section *Nidulantes*

= *Emericella* Berk., Intr. Crypt. Bot. (London): 340. 1857

= *Thecospora* Harkn., Bulletin of the California Academy of Sciences 1: 41. 1884

= *Diplostephanus* Langeron, Crypt. Fr. Exs.: 344. 1922

Anamorph present or absent, if present conidiophores more or less brown-pigmented, typically smooth but occasionally showing protuberances, usually sinuous; vesicles usually globose, subglobose or subclavate, biseriolate, metulae and phialides usually about equal in length. Conidia globose to subglobose, ovate to ellipsoidal, echinulate or finely rough, less commonly smooth. Ascospores produced in most species, but lacking in others; emericella-like, cleistothecial, superficial, solitary or clustered, globose to subglobose, non-ostiolate, reddish brown, violet, dark brown or blackish, typically surrounded by a heavy to discontinuous layer of Hülle cells; Hülle cells hyaline, pale brown, orange brown or pink, globose, subglobose, pyriform or ovoid. Asci 8 spored, globose to subglobose or stellate, evanescent. Ascospores one-celled, orange, purplish, violet, reddish brown or brown, globose to subglobose or stellate, usually with equatorial crests, smooth or with different patterns of ornamentation, entire, dentate, defective or with filiform appendages.

*Typus*: *Aspergillus nidulans* (Eidam) G. Winter, Rabenh. Krypt.-Fl., ed. 2, 1: 62. 1884

### *Aspergillus nidulans* clade

*Description*: Conidiophores (if present) typically smooth but occasionally showing surface protuberances, hyaline to yellowish brown; vesicles globose to subclavate, fertile over the upper half to two thirds; Conidia echinulate, globose to subglobose. Ascospores (if present), cleistothecial, superficial, reddish brown, violet or dark brown, globose to subglobose, surrounded by numerous Hülle cells; Hülle cells hyaline to pale brown, globose, subglobose pyriform or ovoid. Asci 8 spored, globose to subglobose. Ascospores orange, reddish brown, brown or violet, in surface view globose to subglobose, spore bodies smooth or with verrucose, echinulate, reticulate or pitted ornamentation. Ascospore crests entire, dentate, defective or with irregular protuberance, inconspicuous in some species, mostly two in number, four crests are present in *A. quadrilineatus*. Most species grow optimally around 37 °C, do not grow at or above 50 °C, *A. botswanensis*, *A. fruticosus*, *A. latilabiatum* and *A. recurvatus* do not grow at 45 °C (Table 5). Twenty-three species are accepted in this clade, 22 of them are homothallic, *A. recurvatus* is the only anamorphic species.

Accepted species:

***Aspergillus botswanensis*** A.J. Chen, Frisvad & Samson, this study. [MB816095].

***Aspergillus corrugatus*** Udagawa & Y. Horie, Mycotaxon 4: 535. 1976. [MB309216].

***Aspergillus desertorum*** (Samson & Mouch) Samson, Visagie & Houbraken, Stud. Mycol. 78: 155. 2014. [MB809587].

**Table 4.** Most important micromorphological characters for *Aspergillus* section *Nidulantes* species with globose or appendaged ascospores ( $\mu\text{m}$ ).

Species name	Teleomorphic characters						Anamorphic characters				
	Ascomata	Hülle cells	Ascospore color	Spore bodies	Ornamentation of Crests convex surfaces		Conidiophores	Vesicles	Metulae	Phialides	Conidia
<i>Aspergillus stellatus</i>	330–500	15–27	Reddish brown	5.5–6 × 3.5–5	Smooth	2–3.5	80–200 × 3–4	5–7	4.5–5.5 × 2–3	4.5–5 × 2–4	2.5–6
<i>A. aurantiobrunneus</i>	60–300	14–25	Light orange	4–5 × 3.5–4.5	Smooth	0.8–1	50–200 × 3.5–4.5	7–12	4–6 × 2.5–3.5	6.5–7.5 × 2.5–3	2.5–3.5
<i>A. aurantiopurpureus</i>	200–320	11.5–20.5	Orange or reddish brown, later turns to violet	3.5–4.5 × 3–3.5	Smooth	0.8–1.2	130–260 × 3.5–5	8–11.5	5–6 × 2.5–4	5–6.5 × 3–3.5	3–3.5
<i>A. botswanensis</i>	90–180	12–16.5	Brown	5–6 × 3.5–5	Tuberculate to reticulate	0.4–0.8	–	–	–	–	–
<i>A. corrugatus</i>	200–360	16–23	Orange to reddish brown	3.5–4.5 × 3.5–4	Irregularly wrinkled	0.5–1	40–120 × 3.5–5.5	8–10	5–8 × 2.5–4	6–8 × 2.5–3.5	2.5–3.5
<i>A. desertorum</i>	100–300	10–25	Reddish brown	6.5–7.5 × 6–7.5	Tuberculate	0.5	–	–	–	–	–
<i>A. falconensis</i>	300–700	14–25	Orange to reddish brown	4–6 × 3–3.5	Smooth	1–2	75–240 × 4–6.5	8–10	6–10 × 2–3.5	6–9 × 2–4	2.5–4
<i>A. foveolatus</i>	100–280	7–21.5	Orange to reddish brown	4–5 × 3.5–4.5	Finely pitted	0.5–1	40–200 × 4.5–6.5	12–15	5–7 × 2–4	6–8 × 2–3	3–4.5
<i>A. fruticosus</i>	230–500	10–20	Orange to reddish brown	4.5–5.5 × 3–5	Smooth	0.8–1	40–200 × 4–6	8–12	5–6 × 3–4.5	6–9 × 2–3.5	3.5–4
<i>A. jaipurensis</i>	150–500	14–25	Purplish red	6–7.5 × 5.5–6	Smooth	0.8–1	30–100 × 4–6	7–9	5–6.5 × 2.5–3.5	5–7 × 2–3.5	4–6.5 × 3–4.5
<i>A. latilabiatus</i>	100–160	13–24	Brown	5.5–7 × 4.5–6	Smooth	0.5–1	–	–	–	–	–
<i>A. latus</i>	150–400	14–30	Light orange, orange or reddish brown	3.5–5 × 3–5	Smooth, incompletely reticulate or ribbed	1–1.5	150–300 × 4.5–5.6	10–12.5	3.5–8 × 3–4	6.5–11 × 2–3.5	2.5–5
<i>A. navahoensis</i>	140–400	13–23	Orange to reddish brown	3.5–4.5 × 3–3.5	Smooth	0.7–1	35–150 × 2.5–3	6–8	6–9.5 × 3–4.5	6–8 × 2.5–3	3.5–4.5
<i>A. nidulans</i>	150–420	12–20	Orange to reddish brown	3.5–5 × 3–4.5	Smooth	0.5–1 (entire or dentate)	70–220 × 5–8	8–14.5	5–8 × 2.5–4.5	6–8 × 2.5–3.5	3–4
<i>A. omanensis</i> <sup>1</sup>	180–370	10–35	Brownish red	4.5–5.5 × 4–4.5 including crests	Tuberculate or verruculose	1	50–120 × 4–7	10–14	4–7 × 2–3	5–8 × 2–4	4–5.5
<i>A. pachycristatus</i>	200–500	11–21	Orange to reddish brown	4–5 × 3.5–4	Smooth	0.7–1	150–260 × 5–6	8–12	5.5–7.5 × 2.5–4	6–9 × 2.5–3.5	3–4
<i>A. purpureus</i>	90–200	8–20	Brown	6–7 × 4.5–5	Smooth	0.3–0.6	40–50 × 2.5–5*	6–8*	3.5–6 × 2.5–3.5*	6–8 × 2.5–3*	3.5–5.5 × 1.5–2*
<i>A. quadrilineatus</i>	100–700	10–24	Orange to reddish brown	4–4.5 × 3–4.5	Smooth	0.5–1 (entire, defective or with irregular protuberance)	50–150 × 4–5.5	10–13	5–7 × 2–4.5	5–7 × 2–4	3–4
<i>A. rugulosus</i>	220–350	14–24	Orange, greyish violet, reddish purple or brownish red	4–4.5 × 3.5–4	Rugulose	0.5–0.6	50–200 × 5–6	8–12	7–8 × 3–3.5	6–7 × 2.5–3	3–4
<i>A. savannensis</i>	65–120	11–16.5	Orange to reddish brown	4–5 × 3.5–4	Smooth	0.5–1	85–190 × 5–7	8–15.5	4.5–8 × 3.5–4.5	7.5–9 × 3–4	3.5–5
<i>A. spinulosporus</i>	200–550	15–30	Orange to reddish brown	3.5–4.5 × 3–4.5	Echinulate	0.8–1	70–120 × 5–6	9–11	6–8 × 3–4	6–8.5 × 2–3	3–4
<i>A. stercorarius</i>	70–150	8–14.5	Brown	4.5–6 × 3.5–4.5	Smooth	0.3–0.4	–	–	–	–	–

<i>A. striatus</i>	180–500	14–23	Orange	6–7 × 5–5.5	With concentric thickenings	–	–	–	–	–	
<i>A. sulphureoviridis</i>	350–600	10–22.5	Orange to reddish brown	4.5–5.5 × 3.5–4.5	Smooth	0.8–1.2	30–80 × 3–5	7–10	6.5–8.5 × 2.5–3.5	6.5–7.5 × 3–4	3.5–5
<i>A. undulatus</i>	300–500	14–26	Brown	4–4.5 × 3.5–4	Tuberculate	Low part: 0.3–0.7; high part: 0.8–1.3	80–150 × 3–4.5	7–11	5.5–7.5 × 2.5–3	6.5–7.5 × 2–2.5	3–4
<i>A. violaceus</i>	25–190	6–26	Violet	4–6.5 × 3–5	Reticulate intertwined	<0.3	30–50 × 3–4 <sup>1</sup>	5–6 <sup>1</sup>	6–7.5 × 3–3.5 <sup>1</sup>	5–6 × 2–2.5 <sup>1</sup>	2.8–3.3 <sup>1</sup>
<i>A. filifer</i>	220–660	13–24	Brown	3.5–4.5 × 3–4	Tuberculate	0.5–1.2 (with filiform appendages)	120–250 × 3–5	7–13	7–10 × 3–5	7–11 × 2–4	3–4
<i>A. qinqianii</i>	200–510	16–24	Brown	3.5–4.5 × 3–4	Smooth	0.5 (with filiform appendages)	120–280 × 3–5	7–12	4–8 × 3–5	7–8 × 2–4	3–4

<sup>1</sup>Data derived from Fennell & Raper 1955, Samson & Mouchacca 1975, Horie & Udagawa 1995.

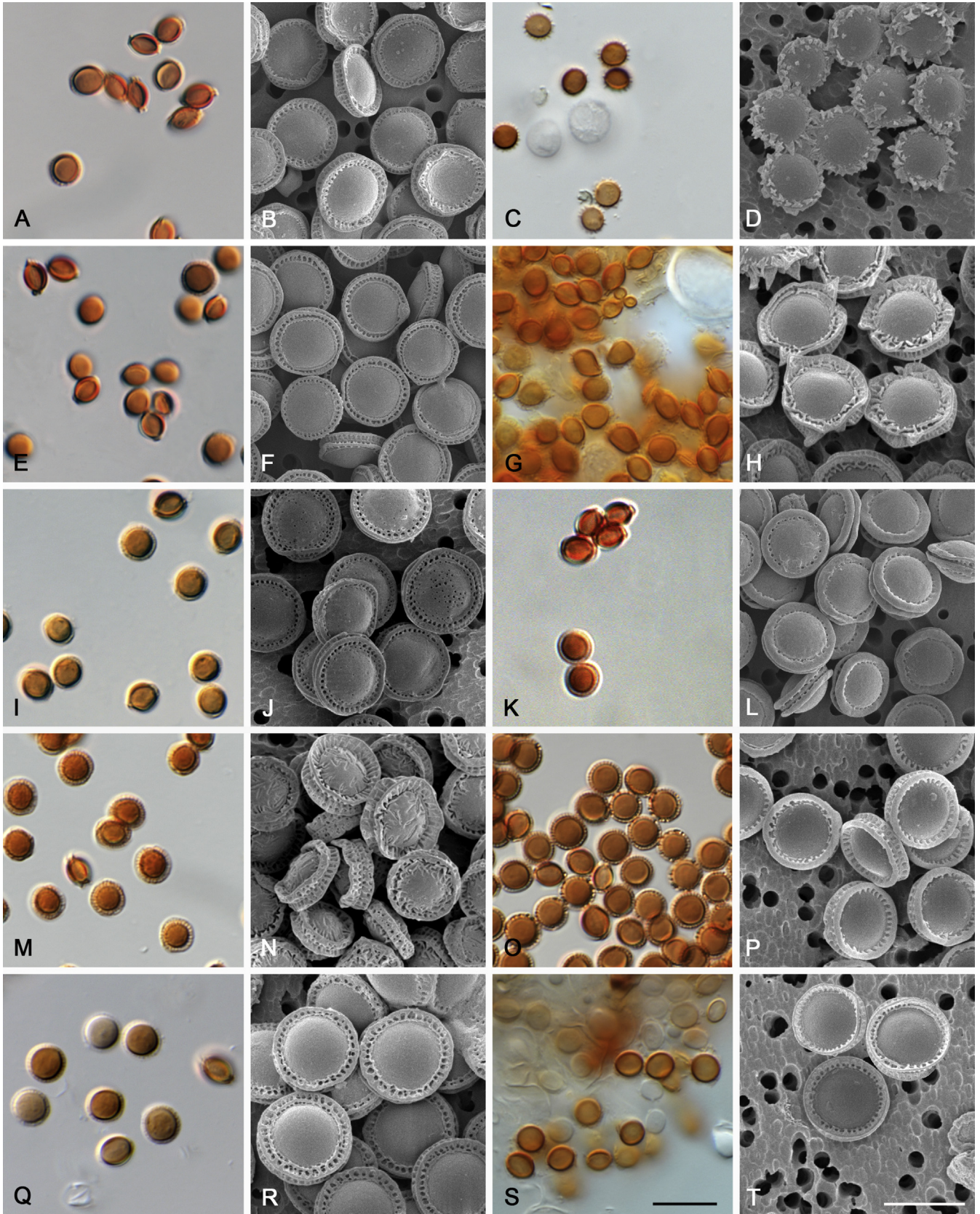
- Aspergillus falconensis* Y. Horie *et al.*, Trans. Mycol. Soc. Japan 30: 257. 1989. [MB127891].
- Aspergillus foveolatus* Y. Horie, Trans. Mycol. Soc. Japan 19: 313. 1978. [MB309221].
- Aspergillus fruticosus* Raper & Fennell, Gen. *Aspergillus*: 506. 1965. [MB326630].
- Aspergillus jaipurensis* Samson, Visagie & Houbraken, Stud. Mycol. 78: 155. 2014. [MB809592].
- Aspergillus latilabiatu*s A.J. Chen, Frisvad & Samson, this study. [MB816093].
- Aspergillus latus* (Thom & Raper) A.J. Chen, Frisvad & Samson, comb. nov., this study. [MB816100].
- Aspergillus navahoensis* M. Chr. & States, Mycologia 74: 226. 1982. [MB110496].
- Aspergillus nidulans* (Eidam) G. Winter, Rabenh. Krypt.-Fl., ed. 2, 1: 62. 1884. [MB182069].
- Aspergillus omanensis* Y. Horie & Udagawa, Mycoscience 36: 391. 1995. [MB414655].
- Aspergillus pachycristatus* Matsuzawa, Y. Horie & Yaguchi, Mycoscience 53: 439. 2012. [MB580944].
- Aspergillus quadrilineatus* Thom & Raper, Mycologia 31: 660. 1939. [MB275888].
- Aspergillus recurvatus* Raper & Fennell, Gen. *Aspergillus*: 529. 1965. [MB326653].
- Aspergillus rugulosus* Thom & Raper, Mycologia 31: 660. 1939. [MB277104].
- Aspergillus savannensis* A.J. Chen, Frisvad & Samson, this study. [MB816096].
- Aspergillus aurantiopurpureus* A.J. Chen, Frisvad & Samson, this study. [MB816087].
- Aspergillus stercorarius* A.J. Chen, Frisvad & Samson, this study. [MB816094].
- Aspergillus striatus* J.N. Rai, J.P. Tewari & Mukerji, Can. J. Bot. 42: 1521. 1964. [MB326659].
- Aspergillus spinulosporus* Hubka, S.W. Peterson & M. Kolařík, Plant Syst. Evol. 302: 1290. 2016. [MB816282].
- Aspergillus sulphureoviridis* A.J. Chen, Frisvad & Samson, this study. [MB816097].
- Aspergillus violaceus* Fennell & Raper, Mycologia 47: 75. 1955. [MB292863].

### *Aspergillus stellatus* clade

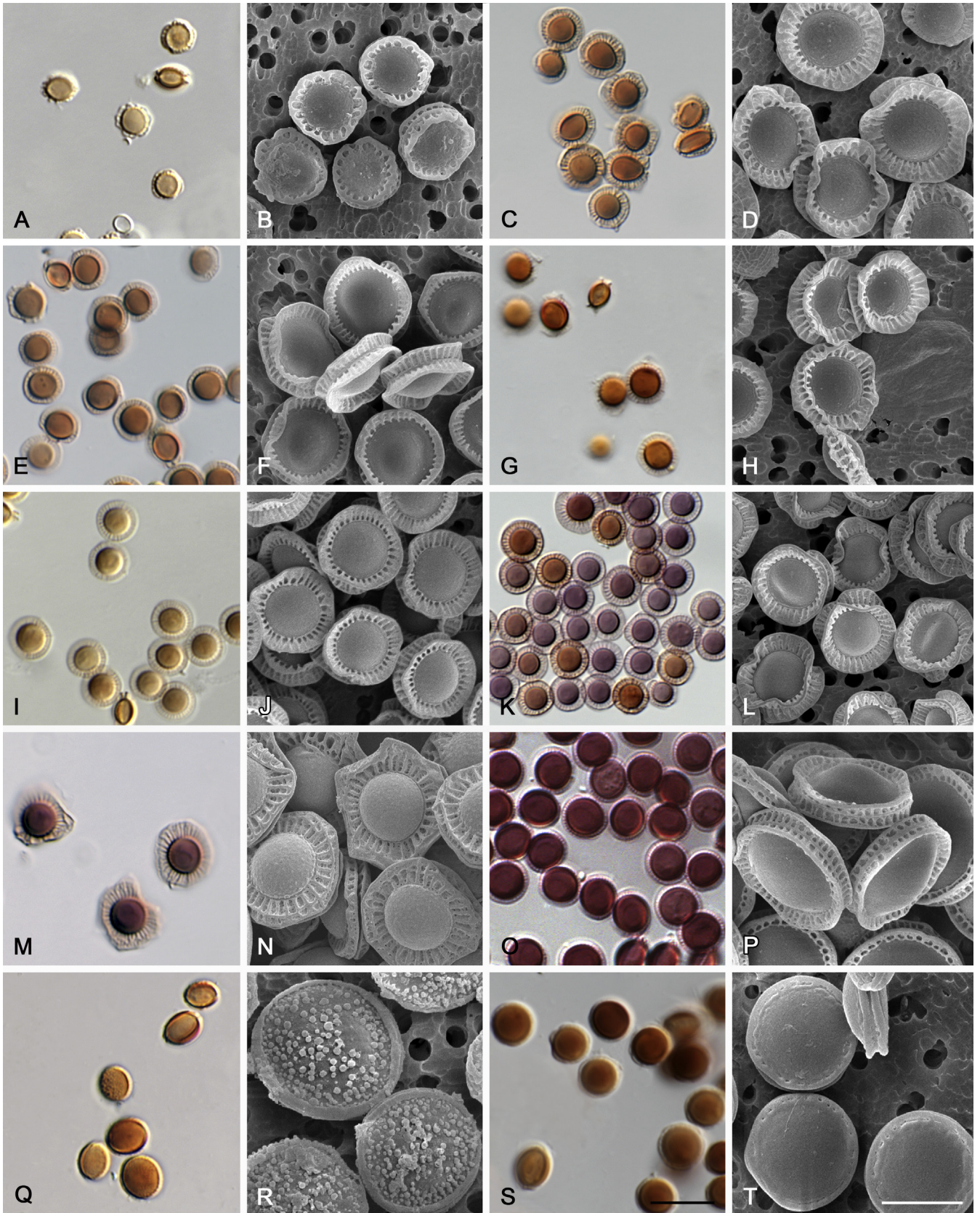
*Description*: Conidiophores (if present) smooth, hyaline to yellowish brown; vesicles globose to subclavate, fertile over the upper half to two thirds; Conidia echinulate, globose to subglobose. Ascomata (if present), cleistothecial, superficial, reddish brown, violet or dark brown, globose to subglobose, surrounded by numerous Hülle cells; Hülle cells hyaline to pale brown, globose, subglobose or ovoid. Asci 8 spored, subglobose to polygonal or stellate. Ascospores orange, reddish brown, brown or violet brown, globose, stellate or appendaged. Most species do not grow at 40 °C, three species (*A. astellatus*, *A. miraensis* and *A. stella-maris*) do not grow at 37 °C (Table 5). Twelve species are accepted in this clade, 11 of them are homothallic, *A. caespitosus* is the only anamorphic species.

Accepted species:

*Aspergillus angustatus* A.J. Chen, Frisvad & Samson, this study. [MB816090].



**Fig. 3.** Range of ascospore phenotypes. A,B. *Aspergillus nidulans* CBS 589.65<sup>T</sup>. C,D. *A. nidulans* CBS 114.63 (ex-type of *A. dentatus*). E,F. *A. quadrilineatus* CBS 591.65<sup>T</sup>. G,H. *A. quadrilineatus* CBS 853.96. I,J. *A. foveolatus* CBS 279.81<sup>T</sup>. K,L. *A. navahoensis* CBS 351.81<sup>T</sup>. M,N. *A. corrugatus* CBS 191.77<sup>T</sup>. O,P. *A. pachycristatus* NRRL 11440. Q,R. *A. sulphureoviridis* CBS 140626<sup>T</sup>. S,T. *A. savannensis* CBS 140607<sup>T</sup>. Scale bars: S = 10  $\mu$ m, applies to A,C,E,G,I,K,M,O,Q; T = 5  $\mu$ m, applies to B,D,F,H,J,L,N,P,R. Pictures were arranged according to ascospore colour, shape and ornamentation.



**Fig. 4.** Range of ascospore phenotypes. A,B. *Aspergillus aurantiobrunneus* CBS 465.65<sup>T</sup>. C,D. *A. falconensis* CBS 271.91<sup>T</sup>. E,F. *A. fruticosus* CBS 486.65<sup>T</sup>. G,H. *A. latus* CBS 492.65<sup>T</sup>. I,J. *A. latus* CBS 140630 (ex-type of *A. sublatus*). K,L. *A. aurantiopurpureus* CBS 140608<sup>T</sup>. M,N. *A. stellatus* CBS 261.93<sup>T</sup>. O,P. *A. jaipurensis* CBS 952.97<sup>T</sup>. Q,R. *A. desertorum* CBS 653.73<sup>T</sup>. S,T. *A. purpureus* CBS 754.74<sup>T</sup>. Scale bars: S = 10  $\mu$ m, applies to A,C,E,G,I,K,M,O,Q; T = 5  $\mu$ m, applies to B,D,F,H,J,L,N,P,R. Pictures were arranged according to ascospore colour, shape and ornamentation.

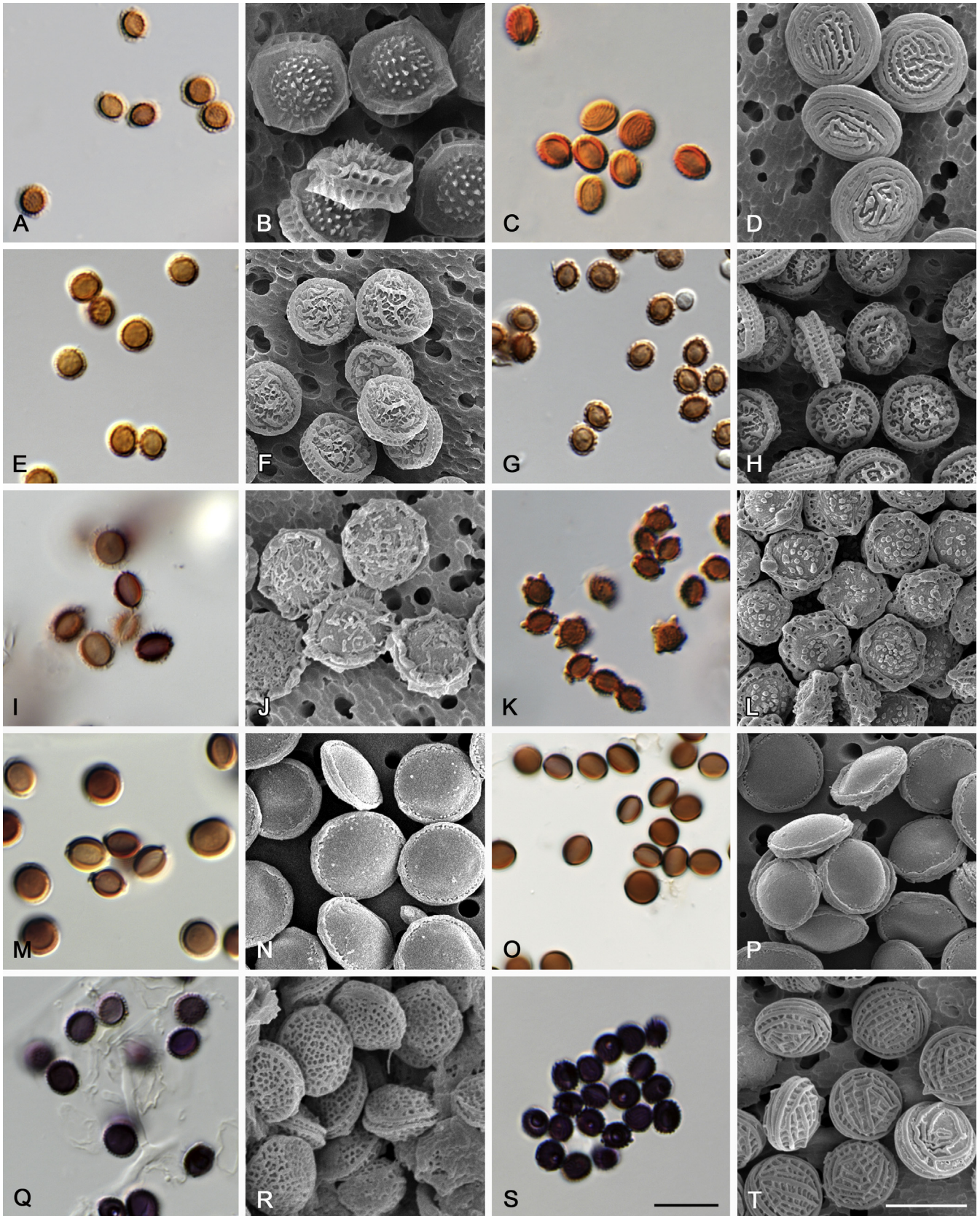
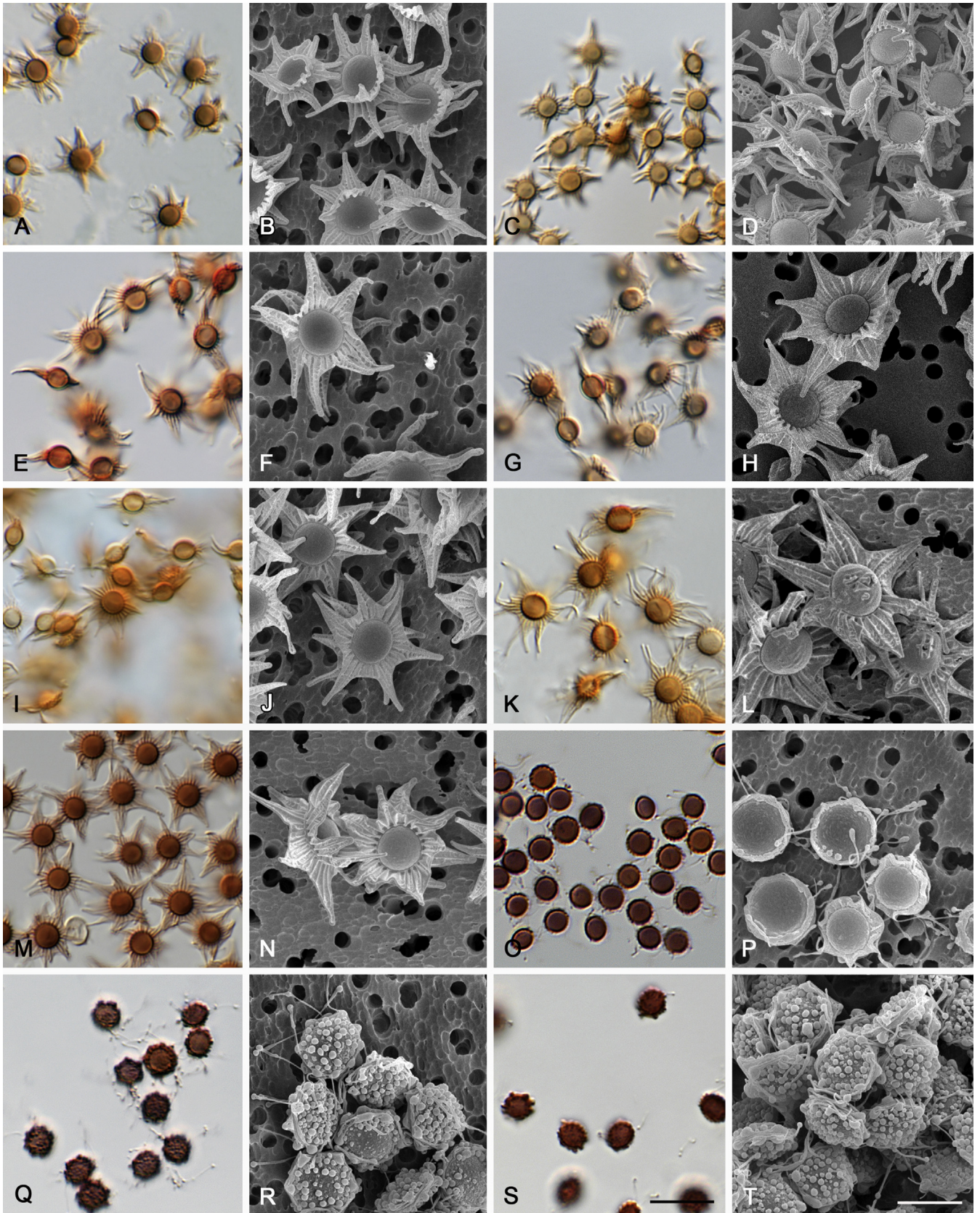
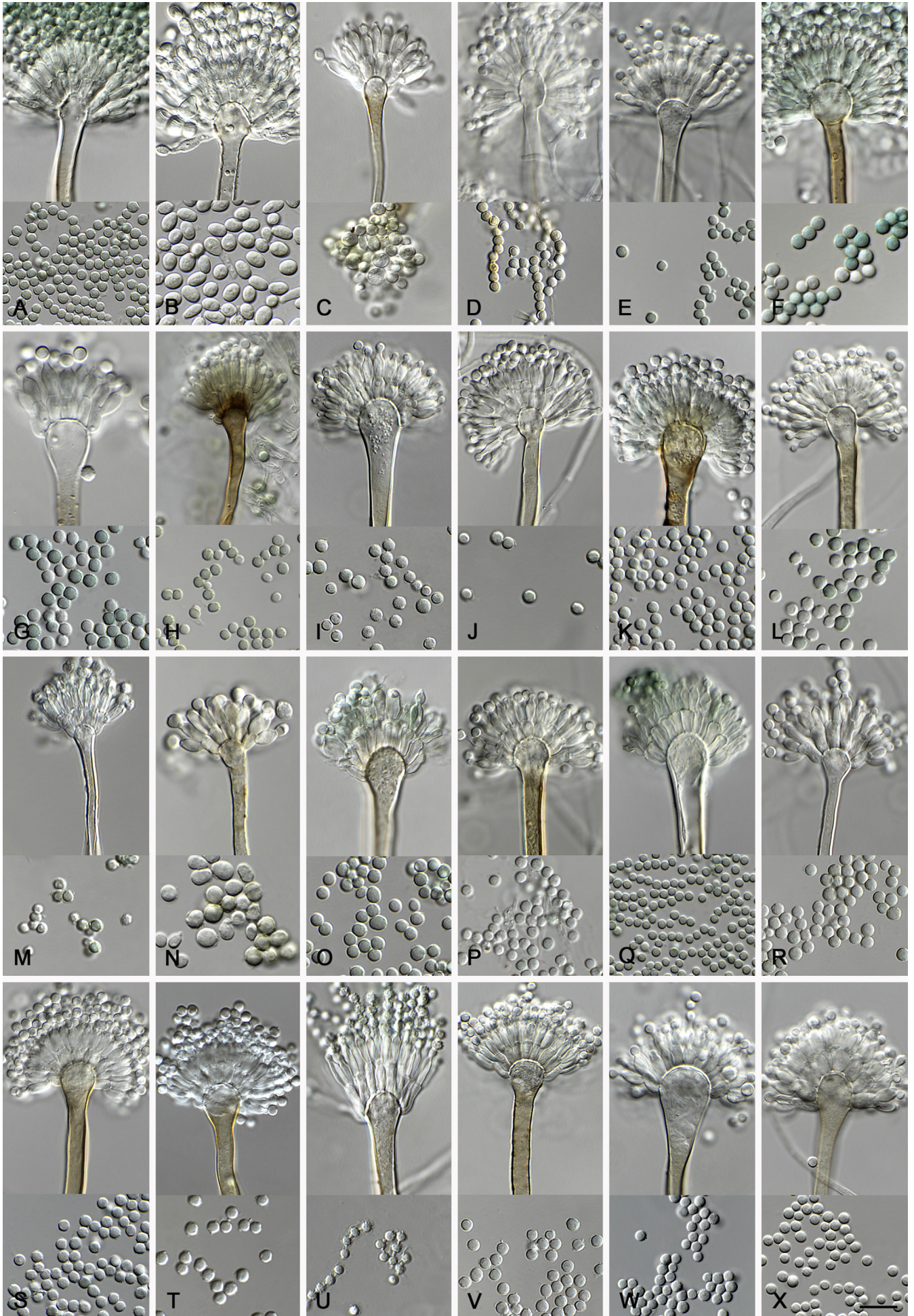


Fig. 5. Range of ascospore phenotypes. A,B. *Aspergillus spinulosporus* CBS 120.55<sup>T</sup>. C,D. *A. striatus* CBS 592.65<sup>T</sup>. E,F. *A. rugulosus* CBS 133.60<sup>T</sup>. G,H. *A. rugulosus* CBS 200.75 (ex-type of *A. cleistominutus*). I,J. *A. botswanensis* CBS 314.89<sup>T</sup>. K,L. *A. undulatus* CBS 261.88<sup>T</sup>. M,N. *A. latilabiatius* CBS 426.93<sup>T</sup>. O,P. *A. stercorarius* CBS 428.93<sup>T</sup>. Q,R. *A. violaceus* CBS 138.55<sup>T</sup>. S,T. *A. violaceus* CBS 293.93 (ex-type of *A. similis*). Scale bars: S = 10  $\mu$ m, applies to A,C,E,G,I,K,M,O,Q; T = 5  $\mu$ m, applies to B,D,F,H,J,L,N,P,R. Pictures were arranged according to ascospore colour, shape and ornamentation.





**Fig. 6.** Range of ascospore phenotypes. A,B. *Aspergillus miraensis* CBS 140625<sup>T</sup>. C,D. *A. olivicola* CBS 119.37<sup>T</sup>. E,F. *A. stella-maris* CBS 113638<sup>T</sup>. G,H. *A. dromiae* CBS 140633<sup>T</sup>. I,J. *A. angustatus* CBS 273.65<sup>T</sup>. K,L. *A. venezuelensis* CBS 868.97<sup>T</sup>. M,N. *A. stellatus* CBS 598.65<sup>T</sup>. O,P. *A. qinqixianii* CBS 128788<sup>T</sup>. Q,R. *A. filifer* CBS 113636<sup>T</sup>. S,T. *A. filifer* CBS 128791 (ex-type of *A. chinensis*). Scale bars: S = 10  $\mu$ m, applies to A,C,E,G,I,K,M,O,Q; T = 5  $\mu$ m, applies to B,D,F,H,J,L,N,P,R. Pictures were arranged according to ascospore colour, shape and ornamentation.



- Aspergillus astellatus*** (Fennell & Raper) Houbraken, Visagie & Samson, *Stud. Mycol.* 78: 154. 2014. [MB809577].
- Aspergillus caespitosus*** Raper & Thom, *Mycologia* 36: 563. 1944. [MB284298].
- Aspergillus dromiae*** A.J. Chen, Frisvad & Samson, this study. [MB816089].
- Aspergillus filifer*** Zalar, Frisvad & Samson, *Mycologia* 100: 787. 2008. [MB507357].
- Aspergillus miraensis*** (Zhang, Chen & Guo) Hubka, S.W. Peterson & M. Kolařík, *Plant Syst. Evol.* 302: 1288. 2016. [MB816283].
- Aspergillus olivicola*** Frisvad, Zalar & Samson, *Mycologia* 100: 781. 2008. [MB507362].
- Aspergillus qinqixianii*** Y. Horie, Abliz & R.Y. Li, *Mycoscience* 41: 183. 2000. [MB464660].
- Aspergillus stella-maris*** Zalar, Frisvad & Samson, *Mycologia* 100: 789. 2008. [MB507363].
- Aspergillus stellatus*** Curzi, *C.R. Accad. Lincei* 19: 428. 1934. [MB254841].
- Aspergillus undulatus*** H.Z. Kong & Z.T. Qi, *Acta Mycol. Sin.* 5: 211. 1986. [MB129004].
- Aspergillus venezuelensis*** Frisvad & Samson, *Syst. Appl. Microbiol.* 27: 678. 2004. [MB368544].

### ***Aspergillus versicolor* clade**

*Description:* Fide [Jurjevic et al. \(2012\)](#) conidiophores smooth to tuberoso, hyaline to yellow or brownish; vesicles pyriform, spatulate or subglobose, fertile over half, two thirds or entire vesicle; Conidia smooth, spinulose or finely roughened, globose, subglobose or ellipsoidal. Hülle cells present in six species: *A. cvjetkovicii*, *A. fructus*, *A. griseoaurantiacus*, *A. protuberus*, *A. puulaauensis* and *A. venenatus*, hyaline, globose, subglobose, ellipsoidal or pyriform. All species do not grow at 37 °C. Sixteen species are accepted, all of them are anamorphic species. ([Jurjevic et al. 2012](#), [Visagie et al. 2014](#), [Tsang et al. 2016](#)).

Accepted species:

- Aspergillus amoenus*** M. Roberg, 1931, *Hedwigia*. 70: 138. 1931. [MB250654].
- Aspergillus austroafricanus*** Jurjevic, S.W. Peterson & B. W. Horn, *IMA Fungus* 3: 67. 2012. [MB800597].
- Aspergillus creber*** Jurjevic, S.W. Peterson & B.W. Horn, *IMA Fungus* 3: 69. 2012. [MB800598].
- Aspergillus cvjetkovicii*** Jurjevic, S.W. Peterson & B.W. Horn, *IMA Fungus* 3: 69. 2012. [MB800599].
- Aspergillus fructus*** Jurjevic, S.W. Peterson & B.W. Horn, *IMA Fungus* 3: 70. 2012. [MB800600].
- Aspergillus griseoaurantiacus*** Visagie, Hirooka & Samson, *Stud. Mycol.* 78: 112. 2014. [MB809197].
- Aspergillus hongkongensis*** Tsang et al. *Diagn. Microbiol. Infect. Dis.* 84: 130. 2016. [MB810279].
- Aspergillus jensenii*** Jurjevic, S.W. Peterson & B.W. Horn, *IMA Fungus* 3: 70. 2012. [MB800601].
- Aspergillus protuberus*** Munt.-Cvetk., *Mikrobiologia*. 5: 119. 1968. [MB326650].

- Aspergillus puulaauensis*** Jurjevic, S.W. Peterson & B.W. Horn, *IMA Fungus* 3: 71. 2012. [MB800602].
- Aspergillus subversicolor*** Jurjevic, S.W. Peterson & B.W. Horn, *IMA Fungus* 3: 72. 2012. [MB800603].
- Aspergillus sydowii*** (Bainier & Sartory) Thom & Church, *The Aspergilli*: 147. 1926. [MB279636].
- Aspergillus tabacinus*** Nakazawa, Y. Takeda, Simo & A. Watanabe, *J. Agric. Chem. Soc. Japan* 10: 177. 1934. [MB539544].
- Aspergillus tennesseensis*** Jurjevic, S.W. Peterson & B.W. Horn, *IMA Fungus* 3: 73. 2012. [MB800604].
- Aspergillus venenatus*** Jurjevic, S.W. Peterson & B.W. Horn, *IMA Fungus* 3: 73. 2012. [MB800605].
- Aspergillus versicolor*** (Vuill.) Tirab., *Annali Bot.* 7: 9. 1908. [MB172159].

### ***Aspergillus spelunceus* clade**

*Description:* Conidiophores smooth, hyaline to yellowish brown; vesicles globose to subclavate, fertile over the upper half to whole surface; Conidia echinulate, globose, subglobose to ellipsoidal (in *A. asperescens*, conidia are smooth in young cultures but turn to rough in old cultures). Hülle cells present in three species: *A. askiburgiensis*, *A. asperescens*, and *A. spelunceus*, hyaline, globose, subglobose or ovoid. Most species do not grow at 37 °C ([Hubka et al. 2016](#) reported several *A. asperescens* strains with restrict growth at 37 °C). Six species are accepted, all of them are anamorphic species.

Accepted species

- Aspergillus askiburgiensis*** A. Nováková, Hubka, Frisvad, S.W. Peterson & M. Kolařík, *Plant Syst. Evol.* 302: 1285. 2016. [MB816280].
- Aspergillus asperescens*** Stolk, *Antonie van Leeuwenhoek* 20: 303. 1954. [MB809583].
- Aspergillus aureolatus*** Munt.-Cvetk. & Bata, *Bull. Inst. Jard. Bot. Univ. Beograd* 1: 196. 1964. [MB326614].
- Aspergillus spelunceus*** Raper & Fennell [as '*speluneus*'], *Gen. Aspergillus*: 457. 1965. [MB326656].
- Aspergillus varians*** Wehmer, *Bot. Centralbl.* 80: 460. 1899. [MB172782].
- Aspergillus viridicatenatus*** A.J. Chen, Frisvad & Samson, this study [MB816088].

### ***Aspergillus multicolor* clade**

*Description:* Conidiophores smooth, hyaline to yellowish brown; vesicles globose to subclavate, fertile over the two thirds; Conidia echinulate, globose to subglobose. Ascospores (only reported in *A. pluriseminatus*), superficial, globose, nonostiolate, blackish, produced very late, appearing after 2–3 months, surrounded by hyphae and Hülle cells; Hülle cells present in two species: *A. pluriseminatus* and *A. multicolor*, pale yellowish brown, orange brown to pink, globose, subglobose or ovoid. Ascospores violet-brown, stellate. Most species do not grow at 40 °C, *A. pluriseminatus* does not grow at 37 °C. Three species are

**Fig. 7.** Range of conidiophore and conidia phenotypes. A. *A. angustatus* CBS 273.65<sup>T</sup>. B. *A. asperescens* CBS 110.51<sup>T</sup>. C. *A. astellatus* CBS 261.93<sup>T</sup>. D. *A. aurantiobrunneus* CBS 465.65<sup>T</sup>. E. *A. aurantiopurpureus* CBS 140608<sup>T</sup>. F. *A. aureolatus* CBS 190.65<sup>T</sup>. G. *A. caespitosus* CBS 103.45<sup>T</sup>. H. *A. corrugatus* CBS 191.77<sup>T</sup>. I. *A. dromiae* CBS 140633<sup>T</sup>. J. *A. falconensis* CBS 271.91<sup>T</sup>. K. *A. foveolatus* CBS 279.81<sup>T</sup>. L. *A. fruticulosus* CBS 486.65<sup>T</sup>. M. *A. israelensis* CBS 140627<sup>T</sup>. N. *A. jaipurensis* CBS 952.97<sup>T</sup>. O. *A. latus* CBS 492.65<sup>T</sup>. P. *A. latus* CBS 140630 (extype of *A. sublatus*). Q. *A. miraensis* CBS 140625<sup>T</sup>. R. *A. navahoensis* CBS 351.81<sup>T</sup>. S. *A. nidulans* CBS 589.65<sup>T</sup>. T. *A. nidulans* CBS 114.63 (ex-type of *A. dentatus*). U. *A. olivicola* CBS 119.37<sup>T</sup>. V. *A. pachycristatus* NRRL 11440. W. *A. qinqixianii* CBS 128788<sup>T</sup>. X. *A. filifer* CBS 113636<sup>T</sup>. Scale bar: X = 10 µm, applies to A–W.

accepted, *A. pluriseminatus* is homothallic, *A. multicolor* and *A. mulundensis* are anamorphic species.

Accepted species

*Aspergillus multicolor* Sappa, Allionia 2: 87. 1954.  
[MB292849].

*Aspergillus mulundensis* Bills & Frisvad, J Antibiot. 69: 143.  
2016. [MB813062].

*Aspergillus pluriseminatus* (Stchigel & Guarro) Samson,  
Visagie & Houbraken, Stud. Mycol. 78: 155. 2014.  
[MB809595].

### *Aspergillus unguis* clade

**Description:** Conidiophores smooth, hyaline to yellowish brown; vesicles globose to subclavate, fertile over the upper half to one third; Conidia smooth to echinulate, globose to subglobose. Most species do not grow at 40 °C (Hubka et al. 2016 reported several *A. unguis* strains with restrict growth at 40 °C), two species: *A. croceus* and *A. israelensis* do not grow at 37 °C. Three species are accepted, *A. croceus* and *A. israelensis* are anamorphic, all *A. unguis* strains observed in this study



**Fig. 8.** Range of conidiophore and conidia phenotypes. A. *A. quadrilineatus* CBS 591.65<sup>T</sup>. B. *A. quadrilineatus* CBS 853.96. C. *A. recurvatus* CBS 496.65<sup>T</sup>. D. *A. rugulosus* CBS 133.60<sup>T</sup>. E. *A. savannensis* CBS 140607<sup>T</sup>. F. *A. spelunceus* CBS 497.65<sup>T</sup>. G. *A. spinulosporus* CBS 120.55<sup>T</sup>. H. *A. stellatus* CBS 598.65<sup>T</sup>. I. *A. sulphureoviridis* CBS 140626<sup>T</sup>. J. *A. stella-maris* CBS 113638<sup>T</sup>. K. *A. undulatus* CBS 261.88<sup>T</sup>. L. *A. unguis* CBS 132.55<sup>T</sup>. M. *A. venezuelensis* CBS 868.97<sup>T</sup>. N. *A. viridicatenatus* CBS 140629<sup>T</sup>. O. *A. mulundensis* CBS 140610<sup>T</sup>. P. *A. multicolor* CBS 133.54<sup>T</sup>. Q. *A. varians* CBS 505.65<sup>T</sup>. Scale bar: Q = 10 µm, applies to A–P.

**Table 5.** Temperature profiles (5 days, in mm) on CYA for *Aspergillus* section *Nidulantes* species<sup>1</sup>.

Species name	Temperature									
	18 °C	21 °C	24 °C	27 °C	30 °C	33 °C	37 °C	40 °C	45 °C	50 °C
<i>A. asperescens</i>	13	17	19	15	7	0	0	–	–	–
<i>A. stellatus</i>	7	10	12	12	8	0	0	–	–	–
<i>A. aurantiobrunneus</i>	0	0	3	7	6	2	0	–	–	–
<i>A. aureolatus</i>	7	10	12	13	12	0	0	–	–	–
<i>A. israelensis</i>	6	8	9	9	8	0.5	0	–	–	–
<i>A. miraensis</i>	15	21	30	33	30	16	0	–	–	–
<i>A. pluriseminatus</i>	0	5	10	17	20	16	0	–	–	–
<i>A. purpureus</i>	0	0	2	1	0	0	0	–	–	–
<i>A. spelunceus</i>	4	9	11	12	11	8	0	–	–	–
<i>A. stella-maris</i>	17	21	25	28	26	14	0	–	–	–
<i>A. varians</i>	12	13	16	18	17	4	0	–	–	–
<i>A. viridicatenatus</i>	7	10	11	11	9	0	0	–	–	–
<i>A. angustatus</i>	–	22	27	33	31	25	9	0	–	–
<i>A. caespitosus</i>	–	26	31	39	37	27	12	0	–	–
<i>A. dromiae</i>	–	15	26	33	36	23	5	0	–	–
<i>A. filifer</i>	–	17	27	33	33	26	16	0	–	–
<i>A. filifer</i> (ex-type of <i>A. chinensis</i> )	–	16	26	29	32	27	19	0	–	–
<i>A. multicolor</i>	–	19	25	32	32	20	7	0	–	–
<i>A. mulundensis</i>	–	11	18	24	24	20	2	0	–	–
<i>A. olivicola</i>	–	19	25	29	30	26	14	0	–	–
<i>A. qinqixianii</i>	–	18	24	33	35	28	17	0	–	–
<i>A. stellatus</i>	–	19	23	28	29	29	21	0	–	–
<i>A. undulatus</i>	–	11	15	15	15	12	9	0	–	–
<i>A. unguis</i>	–	18	21	23	25	21	14	0	–	–
<i>A. venezuelensis</i>	–	12	22	26	26	20	6	0	–	–
<i>A. aurantiopurpureus</i>	–	–	–	–	18	19	19	25	16	0
<i>A. botswanensis</i>	–	–	–	–	19	25	31	30	0	0
<i>A. corrugatus</i>	–	–	–	–	32	41	46	39	35	5
<i>A. desertorum</i>	–	–	–	–	22	26	31	23	2	0
<i>A. falconensis</i>	–	–	–	–	37	46	45	33	13	0
<i>A. foveolatus</i>	–	–	–	–	50	55	62	54	31	0
<i>A. fruticulosus</i>	–	–	–	–	24	28	31	23	0	0
<i>A. jaipurensis</i>	–	–	–	–	32	35	35	29	5	0
<i>A. latilabiatu</i>	–	–	–	–	11	22	22	9	0	0
<i>A. latus</i>	–	–	–	–	46	46	58	50	41	3
<i>A. latus</i> (ex-type of <i>A. sublatus</i> )	–	–	–	–	51	57	62	48	35	0
<i>A. navahoensis</i>	–	–	–	–	36	39	35	20	2	0
<i>A. nidulans</i>	–	–	–	–	38	37	50	46	28	5
<i>A. nidulans</i> (ex-type of <i>A. dentatus</i> )	–	–	–	–	40	48	47	46	26	0
<i>A. pachyristatus</i>	–	–	–	–	22	36	45	40	32	0
<i>A. quadrilineatus</i>	–	–	–	–	32	52	58	47	29	0
<i>A. quadrilineatus</i> (ex-type of <i>A. floriformis</i> )	–	–	–	–	52	56	56	38	16	0
<i>A. quadrilineatus</i> (ex-type of <i>A. nidulans</i> var. <i>acristatus</i> )	–	–	–	–	56	63	62	43	30	0
<i>A. quadrilineatus</i> (ex-type of <i>A. parvathecus</i> )	–	–	–	–	60	61	72	53	32	0
<i>A. recurvatus</i>	–	–	–	–	25	30	33	20	0	0
<i>A. rugulosus</i>	–	–	–	–	21	30	38	40	26	0
<i>A. rugulosus</i> (ex-type of <i>A. cleistominutus</i> )	–	–	–	–	22	25	42	37	30	0
<i>A. savannensis</i>	–	–	–	–	37	43	48	50	35	0
<i>A. spinulosporus</i>	–	–	–	–	45	52	60	60	47	13
<i>A. stercorarius</i>	–	–	–	–	35	40	40	36	8	0
<i>A. striatus</i>	–	–	–	–	41	48	49	34	22	0
<i>A. sulphureoviridis</i>	–	–	–	–	36	39	40	32	18	0
<i>A. violaceus</i>	–	–	–	–	27	32	40	39	22	0
<i>A. violaceus</i> (ex-type of <i>A. similis</i> )	–	–	–	–	35	38	41	33	20	0

<sup>1</sup> Species marked in green have optimal temperature around 27 °C, and do not grow at 37 °C; species marked in yellow have optimal temperature around 30 °C, and do not grow at 40 °C; species marked in orange have optimal temperature around 37 °C, and do not grow at 50 °C (four species do not grow at 45 °C).

are anamorphic, but *A. unguis* NRRL 2393 was reported to tardily produce ascospores (Fennell & Raper 1955, Hubka *et al.* 2016).

Accepted species

***Aspergillus croceus*** Hubka, A. Nováková, Frisvad, S.W. Peterson & M. Kolařík, Plant Syst. Evol. 302: 1291. [MB816281].

***Aspergillus israelensis*** A.J. Chen, Frisvad & Samson, this study [MB816091].

***Aspergillus unguis*** (Emile-Weill & L. Gaudin) Thom & Raper, Mycologia 31: 667. 1939. [MB255264].

### ***Aspergillus aurantiobrunneus* clade**

**Description:** Grow restrictedly on all tested media, anamorphic structures are hardly produced. Conidiophores smooth, hyaline to pale brown; vesicles globose to subclavate, fertile over two thirds to whole surface; Conidia echinulate, globose, subglobose, ellipsoidal to cylindrical. Ascomata cleistothecial, superficial, reddish brown, globose to subglobose, surrounded by numerous Hülle cells; Hülle cells hyaline to pale brown, globose, subglobose or ovoid. Asci 8 spored, globose to subglobose. Ascospores light orange to brown, globose to subglobose. All species do not grow at 37 °C. Two homothallic species are accepted in this clade.

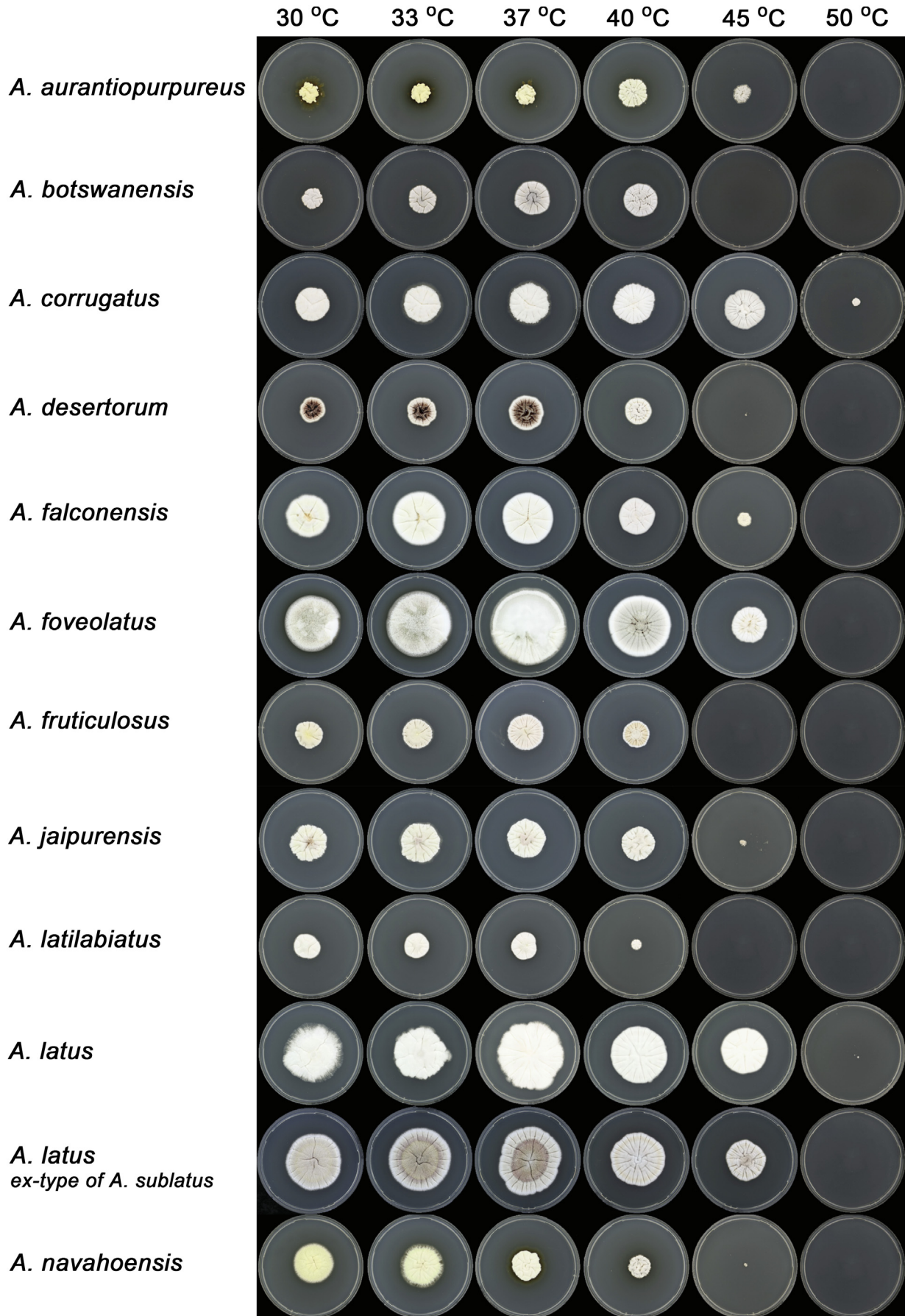


Fig. 9. Temperature growth profile of *Aspergillus* sect. *Nidulantes* species on CYA, from left to right 30, 33, 37, 40, 45, 50 °C.

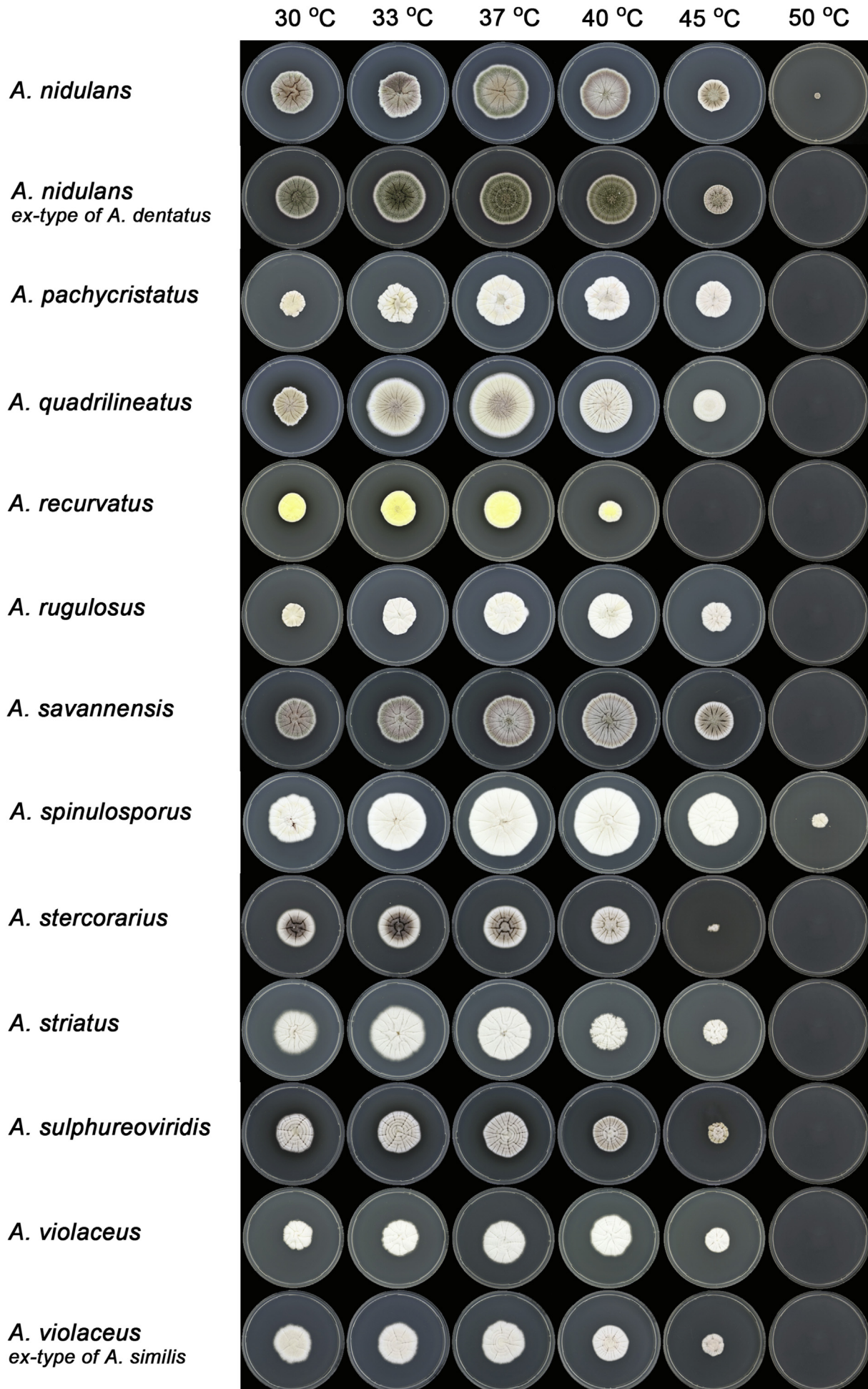


Fig. 10. Temperature growth profile of *Aspergillus* sect. *Nidulantes* species on CYA, from left to right 30, 33, 37, 40, 45, 50 °C.

**Table 6.** Extrolites reported from species of *Aspergillus* section *Nidulantes*.

Species	Extrolites reported	Reference
<i>Aspergillus askiburgiensis</i>	Sterigmatocystin, versicolorins, cf. monascorubramin	Hubka <i>et al.</i> 2016
<i>A. stellatus</i>	Aflatoxin B <sub>1</sub>	Frisvad <i>et al.</i> 2004
	Asperthecin	Frisvad 1985
	Austin, dehydroaustin	Simpson <i>et al.</i> 1982 (as "variant" of " <i>Aspergillus varicolor</i> ")
	2-(3,4-dihydroxyhepta-1,5-dienyl)-6-methoxybenzyl alcohol & terrein	Dunn & Johnstone 1979
	Desferriacetylfulsigen	de la Cruz <i>et al.</i> 2012
	Sterigmatocystin	Frisvad <i>et al.</i> 2004
	Tajixanthone, shamixanthone	Ahmed <i>et al.</i> 1992
<i>A. aurantiobrunneus</i>	Emeremophilin	Fujimoto <i>et al.</i> 2000
	Emericolin A-D, variecolin, variecolol	Yoganathan <i>et al.</i> 2004
	Desferriacetylfulsigen	de la Cruz <i>et al.</i> 2012
	Sterigmatocystin	Rabie <i>et al.</i> 1977
	Variecoacetal A & B	Yoganathan <i>et al.</i> 2004
	Variecolactone, variecolin, variecolol	Fujimoto <i>et al.</i> 2000, Yoganathan <i>et al.</i> 2004
<i>A. caespitosus</i>	Asperline, (5S,6S)-5,6-dihydro-5-acetoxy-6-(1,2-trans-propenyl)-2H-pyran-2-one, (5S,6S)-5,6-dihydro-5-acetoxy-6-(1,2-trans-epoxy-propyl)-2H-pyran-2-one	Mizuba <i>et al.</i> 1975
	Fumitremorgin B, C, verruculogen	Schroeder <i>et al.</i> 1975, Steyn <i>et al.</i> 1981
	Penicillin G	Dulaney <i>et al.</i> 1947b, Gill-Carey 1949
	Cyclopiamine B	Steyn <i>et al.</i> 1981
	6-methoxymellein	Dunn <i>et al.</i> 1979
	Trisdechloronormidulin	Steyn <i>et al.</i> 1981
<i>A. corrugatus</i>	Asperthecin	Frisvad 1985
	Emecorrugatin A & B	Fujimoto <i>et al.</i> 1998
	Sterigmatocystin	Frisvad 1985, Horie & Yamazaki 1985, Fujimoto <i>et al.</i> 1998
	Norsolorinic acid	Fujimoto <i>et al.</i> 1998
<i>A. croceus</i>	Kotanins, norsolorinic acid, orlandin, siderin, sterigmatocystin, versicolorins	Hubka <i>et al.</i> 2016
<i>A. desertorum</i>	Desertorin A-C, 4,7-dihydroxy-5-methylcoumarin, 7-demethylsiderin	Nozawa <i>et al.</i> 1987a, Rizzacasa & Sargent 1988, Mazzaferro <i>et al.</i> 2015
	Desferriacetylfulsigen	de la Cruz <i>et al.</i> 2012
	Emindol DA, Emindol DB, Emindol SA	Nozawa <i>et al.</i> 1987b, 1988a, 1989
	Nidulol	Nozawa <i>et al.</i> 1987a
	Paxillin	Nozawa <i>et al.</i> 1987b
	Silvaticol	Nozawa <i>et al.</i> 1987a
<i>A. falconensis</i>	3,3'-Dihydroxy-5,5'-dimethyldiphenyl ether	Itabashi <i>et al.</i> 1993
	Falconensin A-N	Itabashi <i>et al.</i> 1992, 1993, 1996; Ogasawara & Kawai 1998
	Falconenson A-B	Ogasawara <i>et al.</i> 1997
	Hopane-6 $\alpha$ ,7 $\beta$ ,22-triol, hopane-7 $\beta$ ,22-diol	Itabashi <i>et al.</i> 1996
	Mitorubrin, monomethyldihydromitorubrin, monomethylmitorubrin	Ogasawara & Kawai 1998
	Zeorin	Itabashi <i>et al.</i> 1996
<i>A. foveolatus</i>	Asperthecin	Frisvad 1985
	Dethiosecoemestrin, emestrin, emestrin B, secoemestrin C	Seya <i>et al.</i> 1986a,b, Ooike <i>et al.</i> 1997
	Secoemestrin D, emericellenes A-E	Xu <i>et al.</i> 2013, identity of producer was <i>Emericella</i> sp.
	Desferriacetylfulsigen	de la Cruz <i>et al.</i> 2012
	Paxillin	Nozawa <i>et al.</i> 1989
	Violaceic acid	Ooike <i>et al.</i> 1997



Table 6. (Continued).

Species	Extrolites reported	Reference
<i>A. fruticosus</i>	Sterigmatocystin	Frisvad 1985
<i>A. latus</i>	Asperthecin	Frisvad 1985
	Nidulalin A & B	Kawahara <i>et al.</i> 1994
	Sterigmatocystin	El-Khady & Hafez 1981, Frisvad 1985, Horie & Yamazaki 1985
<i>A. multicolor</i>	Asticolourin A-C; averufin, 5,6-dimethoxydihydrosterigmatocystin, 5,6-dimethoxysterigmatocystin, sterigmatocystin, versicolourin C	Rabie <i>et al.</i> 1984, Hamasaki <i>et al.</i> 1977, 1980 (from IFO 8133, we could not confirm sterigmatocystin production by <i>A. multicolor</i> )
<i>A. mulundensis</i>	Dexoymulundocandin, mulundocandin	Roy <i>et al.</i> 1987, Mukhopadhyay <i>et al.</i> 1987, 1992
<i>A. navahoensis</i>	Averufin, norsolorinic acid, 6,7,8-trihydroxy-3-methylisocoumarin	Yamazaki <i>et al.</i> 1988
	Desferriacetylufusigen	de la Cruz <i>et al.</i> 2012
	Echinocandin B	de la Cruz <i>et al.</i> 2012
	Sterigmatocystin	Frisvad 1985
<i>A. nidulans</i>	Aloe-emodin, chrysophanol, cichorine, 2- $\omega$ -dihydroxyemodin, 3-(2,6-dihydroxyphenyl)-4-hydroxy-6-methyl-1(3H)-isobenzofuranone, emodic acid, emodin, emodin anthrone, endocrocin, endocrocin anthrone, $\omega$ -hydroxyemodin	Ahmed <i>et al.</i> 1987, Sanchez <i>et al.</i> 2011, Schroeckh <i>et al.</i> 2009
	Arugosin A	See under <i>A. rugulosus</i>
	Arugosin H	Nielsen <i>et al.</i> 2011
	Ascoquinone A & B, Interasco A-C	Brown & Salvo 1994
	Asperfuranone, preasperfuranone	Chiang <i>et al.</i> 2009
	Asperline	Argoudelis & Zieserl 1966, Argoudelis <i>et al.</i> 1965, Hamasaki <i>et al.</i> 1983
	Aspernidine A & B	Scherlach <i>et al.</i> 2010
	Asperthecin, preasperthecin	Howard & Raistrick 1955, Frisvad 1985, Brown & Salvo 1994, Szewczyk <i>et al.</i> 2008, Chiang <i>et al.</i> 2010, Yin <i>et al.</i> 2013
	Asperugin A & B	Ballantine <i>et al.</i> 1965, 1967
	Aspoquinolone A-D, aniquinazoline A-D, aflaquinolone A, aniduquinolone A-C, 6-dexoyafloquinolone E, isoafloquinolone E, 14-hydroxyafloquinolone F	Scherlach & Hertweck 2006, An <i>et al.</i> 2013a,b, Neff <i>et al.</i> 2012. These quinolones and quinazolins were isolated from strains that may be misidentified, the strains are not available
	Aspyridone A & B, preaspyridone	Bergmann <i>et al.</i> 2007
	Atrochryson, atrochryson carboxylic acid	Klejnstrup <i>et al.</i> 2012
	Austinol, dehydroaustinol, austinolide, austinoneol, 11 $\beta$ -hydroxyisoaustinone, isoaustinone, (5'-R)-isoaustinone, neo-austinone; preaustinoid A3, A4, A5, protoaustinoid A	Fukuyama <i>et al.</i> 1980, Maebayashi <i>et al.</i> 1982, Sanchez <i>et al.</i> 2011, Lo <i>et al.</i> 2012
	Averufin	Ishida <i>et al.</i> 1972
	3-Benzyl-4-phenyl-2,5-furandione, 3-Carboxy-2,4-diphenyl-but-2-enoic anhydride	Hamasaki <i>et al.</i> 1983
	Citreoisocoumarin	Watanabe <i>et al.</i> 1998, 1999
	Cordycepin	Kodama <i>et al.</i> 1979, Yoshino 1979
	Cordylol C, C-10-deoxygerfelin	Sanchez <i>et al.</i> 2010, Nahlik <i>et al.</i> 2010
	2'-Deoxycoforycin = co-viderabin = pentostatin, 3-deoxyadenosine	Kaczka <i>et al.</i> 1964, Woo & Dion 1974, Kodama <i>et al.</i> 1979
	Desferriacetylufusigen	Middleton <i>et al.</i> 1978, de la Cruz <i>et al.</i> 2012
	Diorcinol, orcinol, orsellinaldehyde, orsellinic acid, violeceol I & II	Sanchez <i>et al.</i> 2010, Nahlik <i>et al.</i> 2010

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Table 6. (Continued).

Species	Extrolites reported	Reference
<i>A. olivicola</i>	Echinocandin B (only in CBS 240.90)	de la Cruz <i>et al.</i> 2012
	Emericellamide A-F	Oh <i>et al.</i> 2007, Chiang <i>et al.</i> 2008
	Emericellin = varicoxanthone B	Ishida <i>et al.</i> 1975a,b, Sanchez <i>et al.</i> 2011
	Emeridine A-B, emeriphenolicin A-D, aspernidine A-B, austin, austinol, dehydroaustin, acetoxyldehydroaustin	Zhang <i>et al.</i> 2011, identity of producer is questionable
	Emerin	Ishida <i>et al.</i> 1972, 1975b
	Epishamixanthone	Sanchez <i>et al.</i> 2011
	F-9775A, F-9775B, paeciloxanthone	Sanchez <i>et al.</i> 2010
	Ferricrocin	Eisendle <i>et al.</i> 2003
	Ferrirhodin	Fidelis <i>et al.</i> 1990
	Gerfelin	Sanchez <i>et al.</i> 2010, Nahlik <i>et al.</i> 2010, Klejnstrup <i>et al.</i> 2012
	8-Hydroxy-1-(hydroxymethyl)-3-methyl-9H-xanthen-9-one	Sanchez <i>et al.</i> 2011
	Hydroxypreaspyridone	Bringmann <i>et al.</i> 2003
	Koningin A, E, trichodermatide B, citranfidiol, (4S,5R)-4-hydroxy-5-methylfuran-2-one, gingerglycolipid B, flavuside B, (2S)-bis[9Z]-1-O,2-O-dilinoleoyl-3-O-[ $\alpha$ -D-galactopyranosyl-(1''->6')] $\beta$ -D-galactopyranosyl-glycerol, (2S)-bis[9Z,12Z]-1-O,2-O-dilinoleoyl-3-O- $\beta$ -D-galactopyranosylglycerol	Tarawneh <i>et al.</i> 2013, identity of the producing strain is dubious
	Lecanoric acid	Schroeckh <i>et al.</i> 2009
	Methyl-(2E,6E)-10,11-dihydroxy-3,7,11-trimethyl-2,6-dodecadienoate, methyl (2E,6E)-10,11-epoxid-3,7,11-trimethyl-2,6-dodecadienoate, methyl-(2E,6E)-10-hydroxy-11-formyl-3,7,11-trimethyl-2,6-dodecadienoate, methyl (2,6,10)-3,7,11-trimethyl-2,6-dodecadienoate	Nielsen <i>et al.</i> 2013
	Monodictyphenone	Sanchez <i>et al.</i> 2011
	Nidulol	Aucamp & Holzapfel 1968
	Nidulotoxin <sup>2</sup>	Lafont <i>et al.</i> 1970, Lafont & Lafont 1970
	Nidurufin, versicolourin A-C	Aucamp & Holzapfel 1970
	Penicillin G	Dulaney 1947a,b, Holt & MacDonald 1968
	Sanghaspirodin A-B	Scherlach <i>et al.</i> 2011
	Sporogenic fatty acids	Mazur <i>et al.</i> 1990
	Sterigmatocystin	Aucamp & Holzapfel 1970, Pachler <i>et al.</i> 1976, Cox & Cole 1977, El-Khady & Abdel Hafez 1981, Frisvad 1985, Horie & Yamazaki 1985, Hajjar <i>et al.</i> 1989
	Terrequinone A	Bok <i>et al.</i> 2006
	6,7,9-Trihydroxy-3-methylcyclohepta(c)-pyran-8(1H)-one = antibiotic C	Turner & Aldridge 1983
	Triacetylfulvarinine	Eisendle <i>et al.</i> 2003
	YWA1 & 2	Watanabe <i>et al.</i> 1999, Fujii <i>et al.</i> 2001
	Aflatoxin B <sub>1</sub>	Zalar <i>et al.</i> 2008
	Emericellin (as arugosin E)	Zalar <i>et al.</i> 2008
	Shamixanthone	Zalar <i>et al.</i> 2008
Siderin	Zalar <i>et al.</i> 2008	
Sterigmatocystin	Zalar <i>et al.</i> 2008	
Terrein	Zalar <i>et al.</i> 2008	
Varitriol	Zalar <i>et al.</i> 2008	

Table 6. (Continued).

Species	Extrolites reported	Reference
<i>A. pachycristatus</i> (also as <i>A. nidulans</i> var. <i>roseus</i> or <i>Emericella rugulosa</i> )	Echinocandins	Dreyfuss (1986) as <i>Emericella nidulans</i> , Klich <i>et al.</i> 2001, Cacho <i>et al.</i> 2012, Matsuzawa <i>et al.</i> 2012, Tóth <i>et al.</i> 2011, 2012
<i>A. pluriseminatus</i>	Desferritriacetylufusigen	de la Cruz <i>et al.</i> 2012
<i>A. purpureus</i>	Emindol SA, emindol SB, emindol SC	Kawai <i>et al.</i> 1994, Hosoe <i>et al.</i> 2006
	Epurpurin A-C	Takahashi <i>et al.</i> 1996
	Sterigmatocystin	Horie & Yamazaki 1985
	Variocolactone	Takahashi <i>et al.</i> 1999
	Variocolin, variocolol	Kawai <i>et al.</i> 1994, Takahashi <i>et al.</i> 1999, Hosoe <i>et al.</i> 2006
<i>A. quadrilineatus</i>	Asperthecin	Howard & Raistrick 1955, Neelakantan <i>et al.</i> 1957, Birkinshaw & Gourlay 1961, Frisvad 1985
	Averufin, 7-methoxyaverufin, sterigmatocystin, versicolourin	Ahmad & Sultana 1985
	Desferritriacetylufusigen	de la Cruz <i>et al.</i> 2012
	Echinocandin B & E	de la Cruz <i>et al.</i> 2012
	Emericellin = variacoxanthone B	Krajc <i>et al.</i> 2006 (as <i>Emericella nidulans</i> var. <i>acristata</i> )
	Emestrin, aurantioemestrin, dethiosecoemestrin	Ooike <i>et al.</i> 1997
	Emindol DA	Krajc <i>et al.</i> 2006
	Microperfuraneone	Krajc <i>et al.</i> 2006, Yeh <i>et al.</i> 2012
	Penicillin G	Dulaney 1947b, Gill-Carey 1949
	Quadrilineatin	Birkinshaw <i>et al.</i> 1957
	Sterigmatocystin	Rabie <i>et al.</i> 1977, El-Khady & Hafez 1981, Frisvad 1985, Horie & Yamazaki 1985, de la Cruz <i>et al.</i> 2012
	Violaceic acid	Ooike <i>et al.</i> 1997
<i>A. filifer</i>	Shamixanthones	Zalar <i>et al.</i> 2008
	Varitriol	Zalar <i>et al.</i> 2008
<i>A. rugulosus</i>	Arugosin A, B, C	Ballantine <i>et al.</i> 1970, 1973, Chexal <i>et al.</i> 1975a, Krajc <i>et al.</i> 2006, Nielsen <i>et al.</i> 2011
	Asperthecin	Howard & Raistrick 1955, Frisvad 1985
	Aspertetronin A & B	Ballantine <i>et al.</i> 1969
	Cyclo-L-isoleucyl-L-proline, cyclo-L-leucyl-L-proline, cyclo-L-valyl-L-proline	Trigos <i>et al.</i> 2005
	Desferritriacetylufusigen	de la Cruz <i>et al.</i> 2012
	3,3'-Dihydroxy-5,5'-dimethyldiphenyl ether, 2,4-dihydroxy-6-(hydroxymethyl)-benzaldehyde, 2,4-dihydroxy-6-methylbenzaldehyde, 2,4-dihydroxy-6-(hydroxymethyl)-benzaldehyde	Ballantine <i>et al.</i> 1968
	Echinocandin B, C & D	Nyfelner & Keller 1974 (as <i>Emericella nidulans</i> var. <i>echinulata</i> = <i>A. spinulosporus</i> = <i>A. delacroixii</i> ); Traber <i>et al.</i> 1979, Dreyfuss 1986, Hodges <i>et al.</i> 2000, Bills <i>et al.</i> 2008, de la Cruz <i>et al.</i> 2012, Yue <i>et al.</i> 2015
	Epishamixanthone, shamixanthone	Ishida <i>et al.</i> 1976, 1978, Fukuyama <i>et al.</i> 1978, Malmstrøm <i>et al.</i> 2002a,b
	14-Hydroxytjixanthone 25-O-acetate, 14-Methoxytjixanthone 25-O-acetate	Chexal <i>et al.</i> 1975b
	14-Methoxytjixanthone	Figuerola <i>et al.</i> 2009, Moosophon <i>et al.</i> 2009
	Orsellinaldehyde	Ballantine <i>et al.</i> 1968
	Penicillin G	Dulaney <i>et al.</i> 1947b
	Ruguloxanthone	Moosophon <i>et al.</i> 2009

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Table 6. (Continued).

Species	Extrolites reported	Reference
	Sterigmatocystin	Rabie <i>et al.</i> 1977, El-Khady & Hafez 1981, Frisvad 1985, Horie & Yamazaki 1985
<i>A. spinulosporus</i> = <i>A. delacroxii</i>	Asperthecin	Frisvad 1985
	Echinocandin B <sup>1</sup>	Benz <i>et al.</i> 1974 <sup>1</sup>
	Desferritriacetylfusigen	de la Cruz <i>et al.</i> 2012
	Sterigmatocystin	Frisvad 1985
<i>A. stella-maris</i>	Emericellin (as arugosin E)	Zalar <i>et al.</i> 2008
	Shamixanthone	Zalar <i>et al.</i> 2008
<i>A. stellatus</i>	Ajamxanthone, shamixanthone, tajixanthone, tajixanthone hydrate, tajixanthone methanoate, 19-O-methyl-22-methoxypre-shamixanthone, pre-shamixanthone, 15-acetyltajixanthone hydrate	Kamal <i>et al.</i> 1970c, 1971a,b, Holker <i>et al.</i> 1974, Chexal <i>et al.</i> 1974, 1975b, Malmstrøm <i>et al.</i> 2002a,b, Pornpakakul <i>et al.</i> 2006, Fredimoses <i>et al.</i> 2014, Wu <i>et al.</i> 2015
	Altamashin <sup>2</sup> , aminin <sup>2</sup> , nasrin <sup>2</sup> , nazirin <sup>2</sup>	Kamal <i>et al.</i> 1970b
	Andibenin A, B & C, andelesin A & B	Dunn <i>et al.</i> 1976, 1978, 1979, Simpson 1979, Simpson <i>et al.</i> 1997
	Anditomin	Bardshiri <i>et al.</i> 1980, Bartlett <i>et al.</i> 1981, Simpson 1981, Simpson & Walkinshaw 1981, Matsuda <i>et al.</i> 2014
	Arugosin A, B	See under <i>A. rugulosus</i>
	Arugosin D	Chexal <i>et al.</i> 1975b
	Asperthecin	Frisvad 1985
	Astellatol	Sadler & Simpson 1989, 1992, Simpson 1994
	Astellolide A = parasiticolide A, astelloide B	Hamasaki <i>et al.</i> 1975, Gould <i>et al.</i> 1981
	Asteltoxin	Kruger <i>et al.</i> 1979, Tadano <i>et al.</i> 1988
	Desferritriacetylfusigen	de la Cruz <i>et al.</i> 2012
	Dihydroterrein	Malmstrøm <i>et al.</i> 2002a,b
	Emericellin = variacoxanthone B, variacoxanthone A, C	Chexal <i>et al.</i> 1974, 1975a, Sanchez <i>et al.</i> 2011
	Emerixanthone A-D	Fredimoses <i>et al.</i> 2014
	Emervaridione, varioxiranediol	Liangsakul <i>et al.</i> 2011
	Epiioshamixanthone	Kamal <i>et al.</i> 1971b
	6-epiophiobolin C, G, K, N, ophiobolin C, G, H & K	Wei <i>et al.</i> 2004
	Evariquinone	Bringmann <i>et al.</i> 2003
	2-Furanoic acid	Hicks & Feather 1977, Bringmann <i>et al.</i> 2003
	Islandicin	Ahmed <i>et al.</i> 1987
	Isomericellin	Bringmann <i>et al.</i> 2003
	Kojic acid	Qureshi <i>et al.</i> 1968
	2-Methoxy-6-(3,4-dihydroxy-hepta-1,5-dienyl)benzyl alcohol	Dunn & Johnstone 1979
	Najamxanthone, radixanthone, shahenxanthone	Kamal <i>et al.</i> 1972
	Penicillin G	Dulaney 1947b
	Shimalactone A	Wei <i>et al.</i> 2005
	Siderin	Chexal <i>et al.</i> 1975c, Dunn <i>et al.</i> 1979
	Stellatic acid	Qureshi <i>et al.</i> 1980, Matsuda <i>et al.</i> 2015
	Stellatin	Simpson 1978
	Stromemycin	Hopmann <i>et al.</i> 2001, Bringmann <i>et al.</i> 2003
	Terrein	Qureshi <i>et al.</i> 1968, Malmstrøm <i>et al.</i> 2002a,b
	Variecoacetal A & B	Fujimoto <i>et al.</i> 2000
	Variocolactone	Tezuka <i>et al.</i> 1998
	Variocolin	Hensens <i>et al.</i> 1991, Yoganathan <i>et al.</i> 2004
	Varioxirane, varixanthone, varitriol	Malmstrøm <i>et al.</i> 2002a,b, Wu <i>et al.</i> 2015

Table 6. (Continued).

Species	Extrolites reported	Reference	
<i>A. striatus</i>	Varioxiranol A-G	Wu <i>et al.</i> 2015	
	Asperthecin	Frisvad 1985	
	Aurantioemestrin	Kawai <i>et al.</i> 1987	
	Cycloisoemericellin	Kawahara <i>et al.</i> 1988a	
	Desferritriacetylufusigen	de la Cruz <i>et al.</i> 2012	
	Dithiosilvatin	Kawahara <i>et al.</i> 1987	
	Emericellin = variecoxanthone B	Nozawa <i>et al.</i> 1987c, Kawahara <i>et al.</i> 1988a	
	Emestrin = striatin = EQ-1, dethiosecoemestrin, aurantioemestrin	Seya <i>et al.</i> 1985, 1986a,b, Ooike <i>et al.</i> 1997	
	Emindol SA, emindol SB	Nozawa <i>et al.</i> 1987a,b, 1988b	
	7-Hydroxyemodin	Bringmann <i>et al.</i> 2003	
	Paxillin, 1-O-acetylpaxillin	Nozawa <i>et al.</i> 1987b, 1989	
	Penicillin G	Dulaney 1947b	
	Sterigmatocystin	Horie & Yamazaki 1985	
	Violaceic acid, violaceol I & II	Ooike <i>et al.</i> 1997	
	<i>A. unguis</i>	Agonodepside A & B	Cao <i>et al.</i> 2002
Aspergillusether, aspergillusidone A-G, aspergillusphenol A & B, 2,4-dichlorounguinol		Sureram <i>et al.</i> 2012	
3-Chlorounguinol		Kawahara <i>et al.</i> 1988b	
Dechloronidulin		Dean <i>et al.</i> 1954, 1960, Beach & Richards 1963	
Desferritriacetylufusigen		de la Cruz <i>et al.</i> 2012	
3,5-Dibromo-2,4-dihydroxy-6-methyl benzoic acid methylester		Nicollier <i>et al.</i> 1978	
Emeguisin A-C		Kawahara <i>et al.</i> 1988c	
3-ethyl-5,7-dihydroxy-3,6-dimethylphthalide		Kawahara <i>et al.</i> 1988b,c, Nielsen <i>et al.</i> 1999	
Folipastatin		Hamano <i>et al.</i> 1992	
Guisinol		Nielsen <i>et al.</i> 1999	
Haiderin, khahilin <sup>2</sup> , sarwin <sup>2</sup> , shahidin <sup>2</sup> , yazidin <sup>2</sup>		Kamal <i>et al.</i> 1970b	
Nidulin, normidulin = ustin, dihydronormidulin = shirin		Dean <i>et al.</i> 1954, 1960, Beach & Richards 1963, Kamal <i>et al.</i> 1970a, Kawahara <i>et al.</i> 1988b	
Penicillin G		Dulaney 1947b	
Rubinin		Kamal <i>et al.</i> 1972	
Trisdechloronormidulin		Sierankiewicz & Gatenbeck 1972	
Unguinol = yasminin = trisdechloronidulin		Stodola <i>et al.</i> 1972, Kawahara <i>et al.</i> 1988b	
Unguisin A-E		Malmstrøm 1999, Malmstrøm <i>et al.</i> 2002a,b, Liu & Shen 2011	
Unguispyrone		Sureram <i>et al.</i> 2012	
<i>A. venezuelensis</i>		Aflatoxin B <sub>1</sub> , sterigmatocystin	Frisvad & Samson 2004
<i>A. violaceus</i>		Aspermutarubrol = ethericin A = violaceol I	Shibata <i>et al.</i> 1978 (for <i>A. sydowii</i> ), Taniguchi <i>et al.</i> 1978 (for <i>A. sydowii</i> ), König <i>et al.</i> 1978, Yamazaki & Maebayashi 1982b
		Asperthecin	Frisvad 1985
		Desferritriacetylufusigen	de la Cruz <i>et al.</i> 2012
	Sterigmatocystin	El-Khady & Hafez 1981	
	Violaceol I & II, violaceic acid	Yamazaki & Maebayashi 1982a,b, Asami <i>et al.</i> 2012	

<sup>1</sup>The strain of *Emericella echinulata* = *A. spinulosporus* = *A. delacroixii* of Benz *et al.* 1974 was claimed to be an *A. rugulosus* (*Emericella rugulosa*) by Dreyfuss 1986.<sup>2</sup>Not structure elucidated.

**Table 7.** Sterigmatocystin producers in *Aspergillus* subgenus *Nidulantes* (Frisvad 1985, Frisvad & Samson 2004, Frisvad et al. 2004, 2005, Horie & Yamazaki 1985, Hubka et al. 2016, Jurjevic et al. 2013, Rabie et al. 1977, Rank et al. 2011, Varga et al. 2009, 2010a,b).

### Species name

#### Section *Aenei*:

*Aspergillus bicolor*

*A. discophorus*

*A. eburneocremeus*

*A. foeniculicola*

*A. spectabilis*

#### Section *Nidulantes*:

*A. askiburgiensis*

*A. spelunceus*

*A. amoenus*

*A. asperescens* (reported here)

*A. astellatus*

*A. aurantiobrunneus*

*A. aurantiopurpureus* (reported here)

*A. aureolatus* (reported here)

*A. corrugatus*

*A. creber*

*A. croceus*

*A. cvjetkovicii*

*A. falconensis*

*A. foveolatus*

*A. fruticosus*

*A. fructus*

*A. jensenii*

*A. latus*

*A. miraensis* (reported here)

*A. multicolor* (not confirmed)

*A. navahoensis*

*A. nidulans*

*A. olivicola*

*A. pachycristatus*

*A. protuberus*

*A. purpureus* (not confirmed)

*A. puulaauensis*

*A. quadrilineatus*

*A. rugulosus*

*A. spinulosporus*

*A. stella-maris*

*A. stellatus* (not confirmed)

*A. striatus*

*A. subversicolor*

*A. tennesseensis*

*A. venenatus*

*A. venezuelensis*

*A. versicolor*

*A. violaceus* (not confirmed)

**Table 7.** (Continued).

### Species name

#### Section *Ochraceorosei*:

*A. ochraceoroseus*

*A. rambellii*

#### Section *Usti*:

*A. heterothallicus*

*A. ustus* (trace; not confirmed in later studies)

#### Accepted species

***Aspergillus aurantiobrunneus*** (G.A. Atkins, Hindson & A.B. Russell) Raper & Fennell, Gen. *Aspergillus*: 511. 1965. [MB326612].

***Aspergillus purpureus*** Samson & Mouch., Antonie van Leeuwenhoek 41: 350. 1975. [MB309237].

### Phylogenetic species recognition

Based on a concatenated sequence analysis, 65 species are well resolved in section *Nidulantes*. ITS, the recommended official DNA barcode for fungi (Schoch et al. 2012), performs well in recognizing species in clades *A. unguis*, *A. spelunceus* and *A. multicolor*. However it is not variable sufficiently for recognizing species in other clades. *BenA*, *CaM* and *RPB2* can identify 63 species respectively, with *A. quadrilineatus* sharing identical *BenA* with *A. latus*, *A. qinqixianii* and *A. filifer* sharing identical *CaM* and *A. rugulosus* and *A. pachycristatus* sharing identical *RPB2* sequences. Matsuzawa et al. (2012) stated that *A. nidulans* (= *E. nidulans*), *A. dentatus* (= *E. dentata*), *A. latus* (= *E. nidulans* var. *lata*), *A. sublatus* (= *E. sublata*), *A. montenegroi* (= *E. montenegroi*), *A. acristatus* (= *E. acristata*), *A. miyajii* (= *E. miyajii*), *A. quadrilineatus* (= *E. quadrilineata*) and *A. parvathecicus* (= *E. parvathecica*) were undistinguishable by phylogenetic analysis alone. These are confirmed in this study, to follow the genealogical concordance phylogenetic species recognition concept (GCPSR), several species are considered as synonyms here: *A. dentatus* is synonymised with *A. nidulans*; *A. sublatus* and *A. montenegroi* are synonymised with *A. latus*; *A. acristatus*, *A. miyajii* and *A. parvathecicus* are synonymised with *A. quadrilineatus* as did Hubka et al. 2016. Overall species in *A. nidulans* clade are phylogenetically similar, both phylogenetic and morphological data are important to define the species boundary. Species in other six clades are more divergent phylogenetically, the only exceptions are *A. qinqixianii* and *A. filifer*, they share identical *CaM* sequences, only small differences are present in *BenA* (99.7 % similarity, 344/345 bp), *actin* (98.9 % similarity, 366/370 bp) (Matsuzawa et al. 2012, Hubka et al. 2016) and *RPB2* (99.7 % similarity, 912/914 bp).

### Morphological species recognition

For homothallic species in section *Nidulantes*, the ascospore shape, ornamentation, color and size are of particular importance for differentiating species (Thom & Raper 1939, Christensen & Raper 1978, Horie 1980, Christensen & States 1982, Ismail et al. 1995, Zalar et al. 2008, Matsuzawa et al. 2012, Guarro et al. 2012). In *A. nidulans* clade, most species have unique ascospore morphology (Figs 3–5). However in some species, ascospore morphology shows a range of diversity. For example most of *A. nidulans* strains have entire

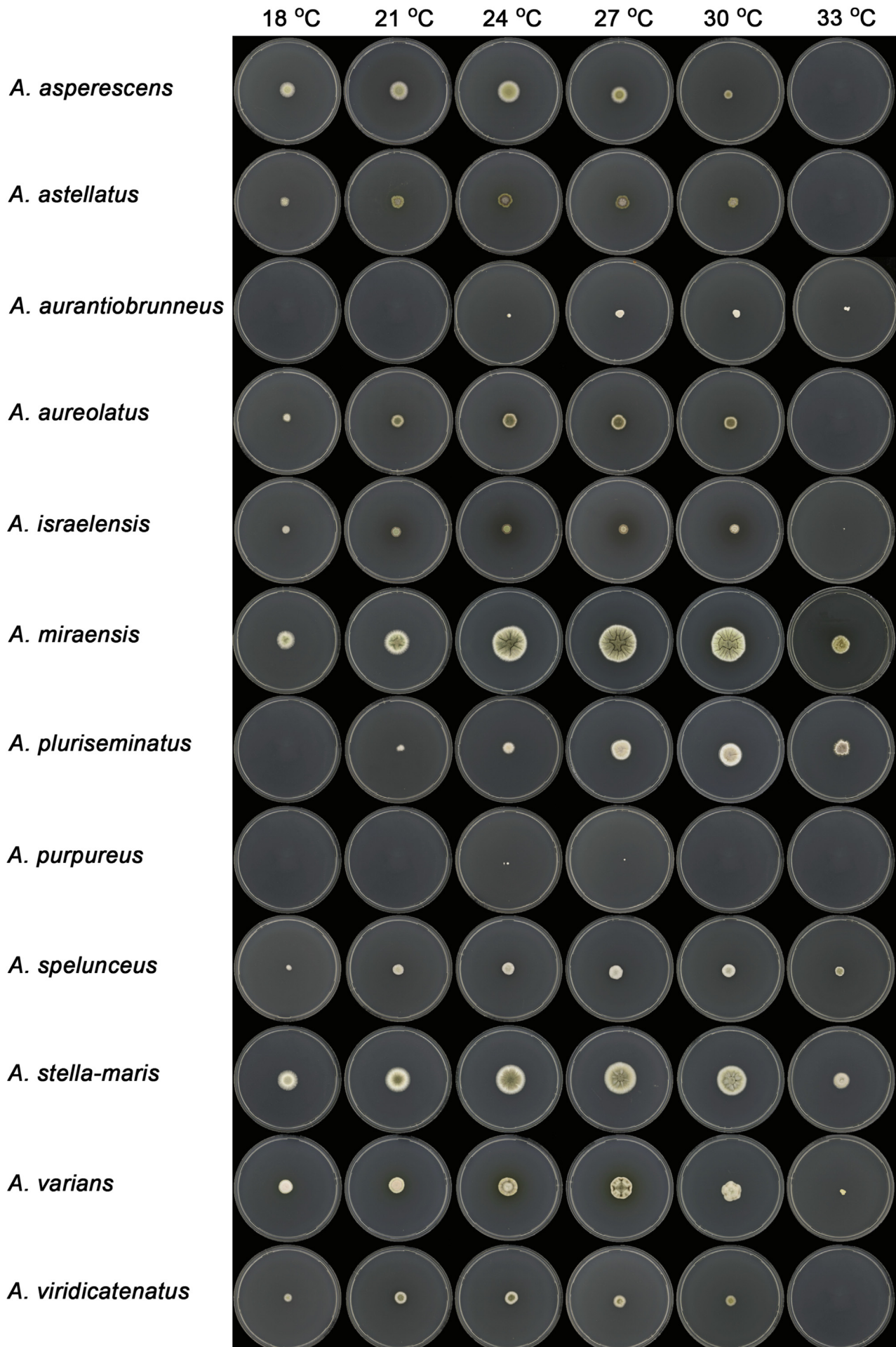


Fig. 11. Temperature growth profile of *Aspergillus* sect. *Nidulantes* species on CYA, from left to right 18, 21, 24, 27, 30, 33 °C.

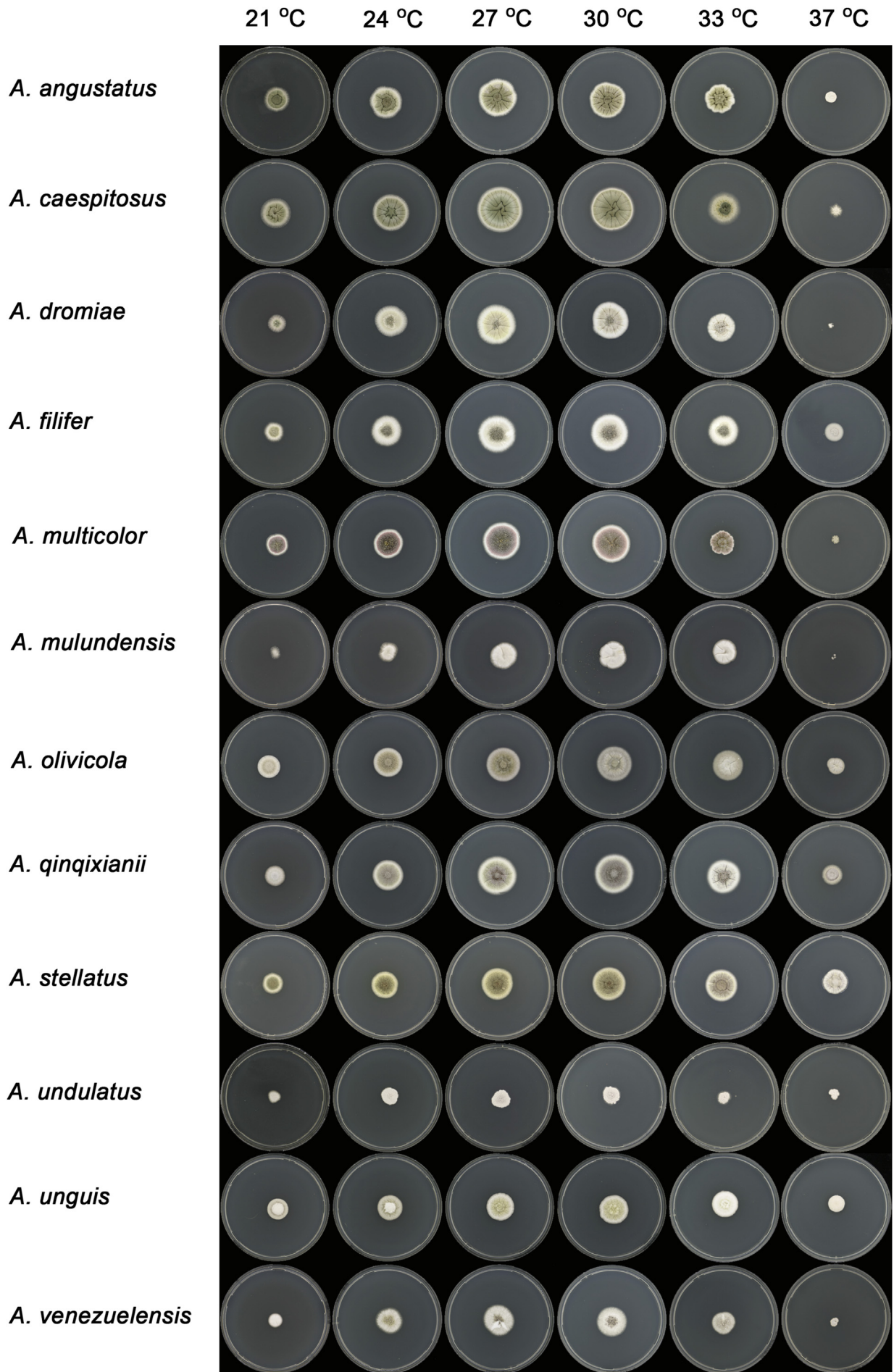


Fig. 12. Temperature growth profile of *Aspergillus* sect. *Nidulantes* species on CYA, from left to right 21, 24, 27, 30, 33, 37 °C.



crests, but atypical dentate crests are presented in one strain (CBS 114.63), similarly in *A. quadrilineatus*, the crests in ascospores can be entire, defective or with irregular protuberance. In *A. stellatus* clade, species with stellate ascospores are morphologically very similar, molecular identification is recommended for distinguishing these species. Anamorphic structures are also important for species recognition, especially for anamorphic species. But the anamorphic structures can be affected by media and incubation conditions, here we follow the standardized method for laboratories working with *Aspergillus* (Samson *et al.* 2014), MEA is recommended for anamorphic description and OA is recommended for teleomorphic description in section *Nidulantes*.

## SPECIES DESCRIPTIONS

***Aspergillus angustatus*** A.J. Chen, Frisvad & Samson, **sp. nov.** MycoBank MB816090. Fig. 13.

*Etymology*: The name refers to the narrow vesicles of the aspergilla.

*Diagnosis*: Moderately dense or dense sporulation on CYA, MEA and YES, stellate ascospores and narrow vesicles measuring 8–12 µm.

*Typus*: **Mali**, *Mangifera indica* root, isolated by I.F.C. (holotype CBS H-22487, culture ex-type CBS 273.65 = DTO 319-H8).

*ITS barcode*: EU448283. (Alternative markers: *BenA* = AY339993; *CaM* = EU443984; *RPB2* = KU867013).

*Colony diam*, 7 d (mm): CYA 37–38; CYA 37 °C 16–17; CYA 40 °C No growth; MEA 48–50; MEA 37 °C 1–2; OA 42–44; YES 52–53; CREA 13–15; CYAS 33–34; DG18 27–28.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white to light yellow; texture velvety to granular due to ascomata production; sporulation moderately dense, conidia *en masse* olive green; soluble pigments absent; exudates clear droplets; reverse dark brown at centre, light buff at edge; ascomata present after 1 wk. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* dark green; soluble pigments absent; exudates clear to light yellow droplets; reverse dark brown at centre, cream yellow at edge; ascomata present after 1 wk. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white to light yellow; texture granular due to ascomata production; sporulation moderately dense, conidia *en masse* olive green; soluble pigments absent; exudates absent; reverse dark brown at centre, cream yellow at edge; ascomata present after 1 wk. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse pale green. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture velvety; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates clear droplets; reverse pale brownish green; ascomata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascumata cleistothecial, superficial, reddish brown, globose to subglobose, 430–780 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale brown, globose to ovoid, 17–35 µm. Asci 8 spored, stellate. Ascospores orange to reddish brown, in surface view stellate, 9–12 µm; spore bodies smooth, globose to subglobose, 3–4 × 3–3.5 µm; in side view broadly lenticular, with two stellate equatorial crests; undissected part of crests 0.5–1 µm broad, with 1.5–3 µm long extensions; crests ornamented with longitudinal, 0.3–0.4 µm wide pleats. Conidiophores with smooth stipes, pale brown, 200–400 × 4.5–6 µm; vesicles hyaline to pale brown, subglobose to subclavate, 8–12 µm wide, fertile over the upper half; metulae hyaline, 6–8 × 3–4.5 µm; phialides hyaline, flask-shaped, 7–8.5 × 2.5–3.5 µm. Conidia echinulate, globose to subglobose, 3–4.5 µm, green in mass.

*Extrolites*: asperthecin, a desertorin, emericellin, 2-ω-hydroxyemodin, shamixanthones.

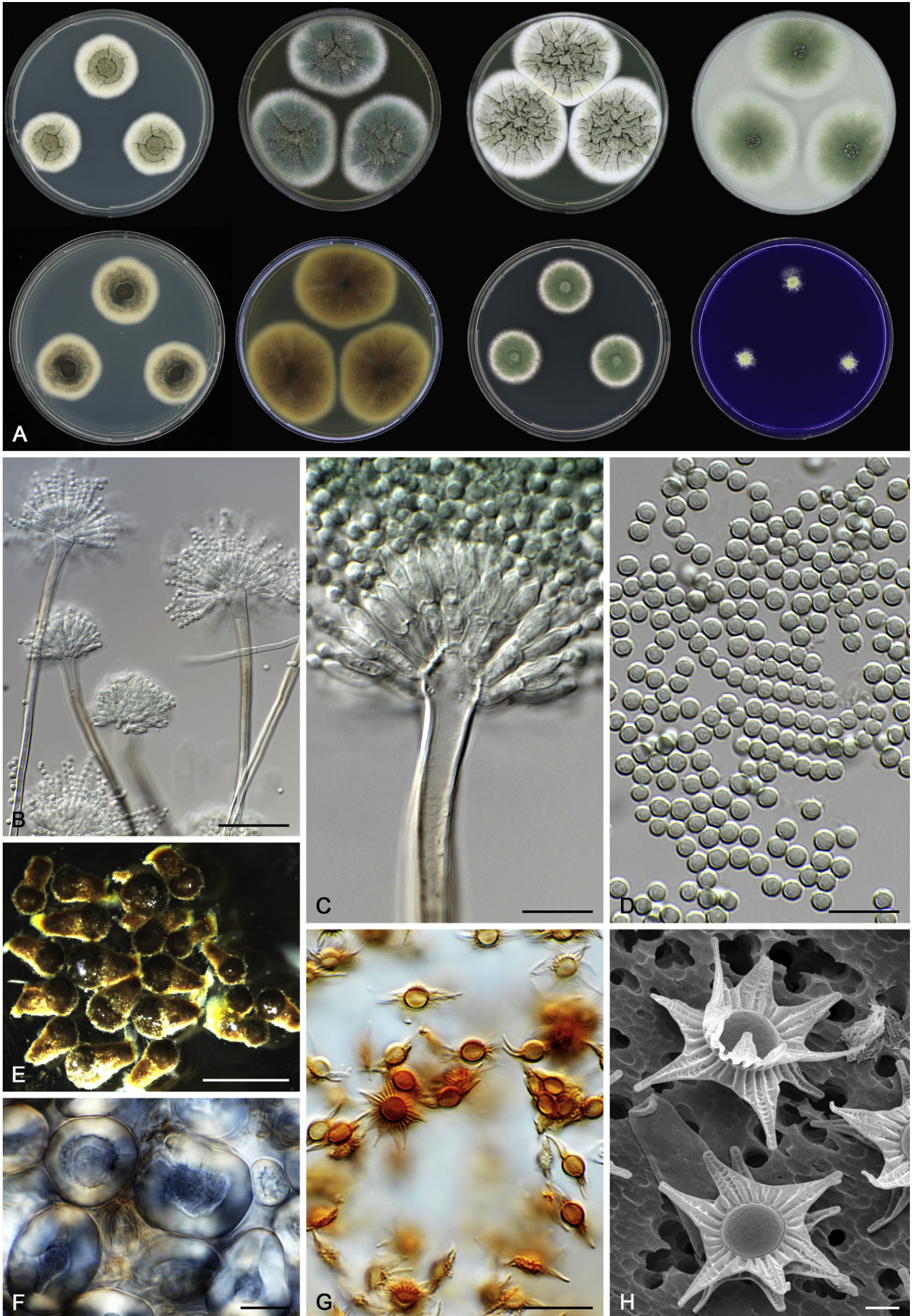
*Distinguishing characters*: *Aspergillus angustatus* is morphologically and phylogenetically closely related to *A. dromiae*; however, *A. angustatus* sporulates well on CYA, MEA and YES, compared to the absent sporulation in *A. dromiae*. Furthermore, *A. dromiae* has wider vesicles (12–17 µm) than *A. angustatus*.

***Aspergillus askiburgiensis*** A. Nováková, Hubka, Frisvad, S.W. Peterson & M. Kolařík, *Plant Syst. Evol.* 302: 1285. MycoBank MB816280.

*Typus*: Holotype PRM 924055; isotype 924056. Culture ex-type: CBS 134374 = CCF 4716 = CCF 4428 = NRRL 62818 = DSM 871 = IBT 33114 = IBT 32911.

*ITS barcode*: LN873939. (Alternative markers: *BenA* = LN873952; *CaM* = LN873965; *RPB2* = LN873984).

*Colony characters*: *Fide* Hubka *et al.* (2016) colonies of both isolates assigned to *A. askiburgiensis* show numerous differences, and they are described separately. Colonies of CCF 4716<sup>T</sup> on CYA at 25 °C attained 24–35 mm diam in 14 days (19–20 mm in 7 days), velutinous, irregularly wrinkled with margin submerged 2–3 mm, pale orange yellow (ISCC–NBS No. 73) with olive-gray (113) marginal parts, sporulation visible, olive-gray, no exudate, dark orange yellow (72) soluble pigment, reverse strong brown (55) to dark brown (59) with strong orange yellow margin (68). Colonies of CCF 4085 attained 18–19 mm diam in 14 days (12–13 mm in 7 days), floccose, plane to irregularly wrinkled, moderate yellow (87) with greyish olive (110) to dark olive (108) tint in central part (sporulation), 1 mm broad marginal zone yellowish white (92), no exudate or small brownish orange (54) droplets, reverse moderate yellowish brown (77) with light orange yellow 2–3 mm margin, no soluble pigment. No growth on CYA at 37 °C. Colonies of CCF 4716<sup>T</sup> on MEA at 25 °C attained 23–28 mm diam in 14 days (15–18 mm in 7 days), plane to very slightly furrowed, velutinous, yellowish white (92) to pale yellow (89), no exudate, no soluble pigment, reverse deep orange yellow (69) with vivid yellow margin (82). Colonies of CCF 4085 attained 14–15 mm diam in 14 days (10–11 mm in 7 days), plane, with 2 mm broad colorless leather-like marginal zone, colony centre velutinous (good sporulation), moderate olive brown (95) to moderate olive (107), no exudate, no soluble



**Fig. 13.** *Aspergillus angustatus* CBS 273.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–D. Conidiophores and conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.

pigment, reverse light greyish olive (109) with moderate yellow colony centre and colorless margin. Colonies of CCF 4716<sup>T</sup> on CZA at 25 °C attained 15–16 mm diam in 14 days (9–10 mm in 7 days), effuse, plane, yellowish white (92) with dark greyish yellowish brown (81) colored ring (sporulation) in the colony centre (6–8 mm diam), no exudate, brilliant yellow orange (67) soluble pigment, reverse deep yellowish brown (75) with dark yellowish brown (78) colony centre. Colonies of CCF 4085 attained 19–20 mm diam in 14 days (10–11 mm in 7 days), submerged, plane, moderate olive (107) to dark olive (108) sporulation, no exudate, no soluble pigment, reverse colorless. Colonies of CCF 4716<sup>T</sup> on CREA at 25 °C attained 15–17 mm diam in 14 days (10–11 mm in 7 days), effuse, yellowish white (92) to greyish greenish yellow (105), no acid production. Colonies of CCF 4085 attained 17–18 mm diam in 14 days (11–12 mm in 7 days), submerged, plane, good sporulation in colony centre, no exudate, no soluble pigment, no acid production.

**Micromorphology:** Fide Hubka *et al.* (2016) stipes on MEA brown, smooth, non-septate or occasionally with septum, most commonly 40–180 × 3–8.5 µm diam, diminutive conidiophores occasionally present; vesicles pyriform, subglobose, less frequently globose, 5.5–18.5 µm diam; biseriate; metulae cylindrical, 4–6 µm long, covering 1/2–3/4 of the vesicles; phialides ampulliform, 5–8 µm long; conidia subglobose or globose, green in mass, 2.5–4 (–4.5) µm diam, first almost smooth or finely roughened but later definitely spinulose. Hülle cells arranged in clusters, ellipsoidal or pyriform, 16–24 × 10–16.5 µm, or subglobose to globose, 11–20 µm diam, produced after 14 or more days of cultivation at 25 °C. Sexual state not observed.

**Extrrolites:** Fide Hubka *et al.* (2016) sterigmatocystin, versicolins, cf. monascorubramin.

**Distinguishing characters:** This species is closely related to *A. spelunceus*, *A. asperescens* and *A. aureolatus*, but *A. spelunceus* produces longer conidiophores (130–300 µm), *A. asperescens* produces larger ellipsoidal conidia (4–7 × 3–5 µm) and *A. aureolatus* is characterized by orange marginal zone of colonies.

**Notes:** *Aspergillus askiburgiensis* was described from European caves. For an illustration of the species, readers are referred to Hubka *et al.* (2016).

***Aspergillus asperescens*** Stolk, Antonie van Leeuwenhoek 20: 303. 1954. MycoBank MB809583. Fig. 14.

**Typus:** IMI 46813. Culture ex-type: CBS 110.51 = NRRL 2252 = NRRL 4770 = ATCC 11079 = DSM 871 = IMI 046813 = QM 1946 = WB 2252 = WB 4770 = WB 5038 = IBT 19363 = DTO 021-F4.

**ITS barcode:** EF652475. (Alternative markers: *BenA* = EF652299; *CaM* = EF652387; *RPB2* = EF652211).

**Colony diam, 7 d (mm):** CYA 23–29; CYA 37 °C No growth; CYA 40 °C No growth; MEA 22–29; MEA 37 °C No growth; OA 23–27; YES 27–30; CREA 11–14; CYAS 17–20; DG18 10–15.

**Colony characters:** CYA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white and light yellow; texture velvety; sporulation moderately dense, conidia *en masse* olive; soluble pigments absent; exudates absent; reverse buff. MEA 25 °C, 7 d: Colonies moderately deep, plane to slightly sulcate; margins entire; mycelium white; texture velvety to floccose; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse pale brown to brown. YES 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white and light yellow; texture velvety; sporulation dense, conidia *en masse* olive; soluble pigments absent; exudates absent; reverse pale brown. DG18 25 °C, 7 d: Colonies moderately deep, plane to slightly sulcate; margins entire; mycelium white; texture velvety to floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse yellow green at centre, cream white at edge. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture velvety; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse pale yellow green. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata not observed. Conidiophores with smooth stipes, yellowish brown, 200–400 × 6–8 µm; vesicles hyaline to pale yellowish brown, hemispherical to globose, 8–15 µm wide, fertile over the upper half; metulae hyaline to pale yellowish brown, 6–9 × 3–4 µm; phialides hyaline to pale yellowish brown, flask-shaped, 7.5–9 × 3–4 µm. Conidia in young cultures subglobose to ellipsoidal, smooth, 4–7 × 3–5 µm, in cultures older than two wks, rough conidia are formed.

**Extrrolites:** a calbistrin, dehydroaustin, sterigmatocystin, versicolins, violaceols.

**Distinguishing characters:** *Aspergillus asperescens* can be distinguished from other species by large, subglobose to ellipsoidal conidia that turn distinctly roughened with age.

**Notes:** *Aspergillus asperescens* was assigned in the *A. nidulans* series because of its yellow-green radiate conidial heads, brown conidiophores and Hülle cells (Stolk 1954). During our study, Hülle cells were not observed in the type culture; however, the characteristic asexual morphology and phylogeny prove its position in section *Nidulantes*.

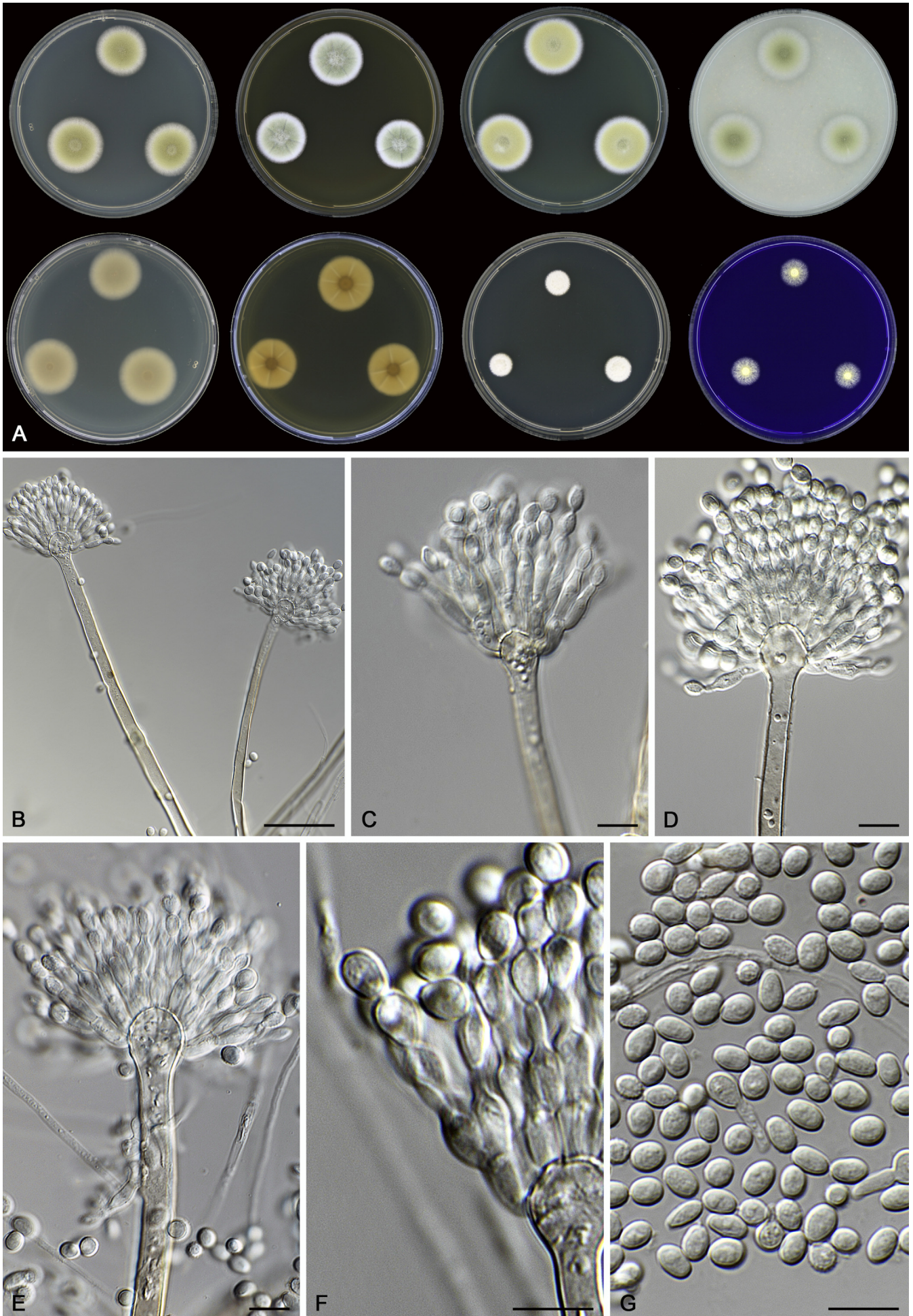
***Aspergillus astellatus*** (Fennell & Raper) Houbraken, Visagie & Samson, Stud. Mycol. 78: 154. 2014. MycoBank MB809577. Fig. 15.

≡ *Aspergillus variecolor* var. *astellatus* Fennell & Raper, Mycologia 47: 81. 1955. ≡ *Aspergillus stellatus* var. *astellatus* (Fennell & Raper) Subram., Curr. Sci. 41: 759. 1972. ≡ *Emericella astellata* (Fennell & Raper) Y. Horie, Trans. Mycol. Soc. Japan 21: 491. 1980.

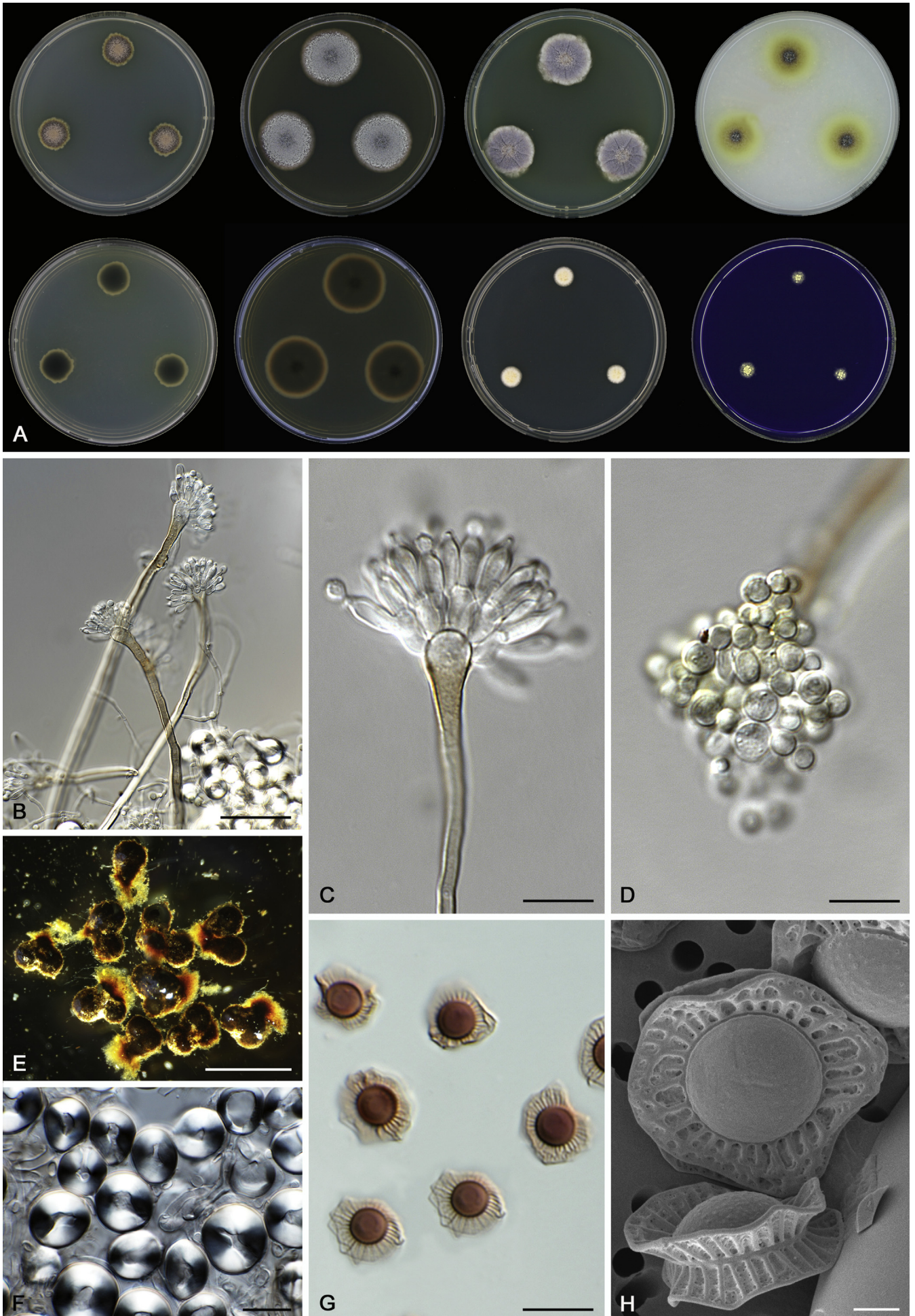
**Typus:** IMI 061455. Culture ex-type: CBS 261.93 = CBS 134.55 = NRRL 2396 = ATCC 16817 = IMI 61455 = IMI 61455ii = NRRL A-1634 = QM 1910 = WB 2396 = IBT 21902 = IBT 22589 = DTO 010-I7.

**ITS barcode:** EF652446. (Alternative markers: *BenA* = EF652270; *CaM* = EF652358; *RPB2* = EF652182).

**Colony diam, 7 d (mm):** CYA 12–16; CYA 37 °C No growth; CYA 40 °C No growth; MEA 25–27; MEA 37 °C No growth; OA 20–23; YES 20–23; CREA 3–5; CYAS 12–13; DG18 13–18.



**Fig. 14.** *Aspergillus asperescens* CBS 110.51<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–F. Conidiophores. G. Conidia. Scale bars: B = 30  $\mu$ m; C–E, G = 10  $\mu$ m; F = 8  $\mu$ m.



**Fig. 15.** *Aspergillus stellatus* CBS 261.93<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascospores. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.

*Colony characters:* CYA 25 °C, 7 d: Colonies moderately deep, plane; margins entire to slightly irregular; mycelium brown; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse dark brown to black. MEA 25 °C, 7 d: Colonies moderately deep, plane to sulcate; margins entire; mycelium white to blue violet; texture granular due to ascomata production; sporulation absent to sparse; soluble pigments absent; exudates clear to light brown droplets; reverse dark brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium violet; texture floccose to granular due to ascomata production; sporulation absent to sparse; soluble pigments absent; exudates absent; reverse dark brown to dark gray. DG18 25 °C, 7 d: Colonies moderately deep, plane to slightly sulcate; margins entire; mycelium white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse cream white to yellowish brown. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white and light yellow; texture floccose; sporulation absent; soluble pigments absent; exudates clear droplets; reverse light brown to greyish olive. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology:* Ascomata cleistothecial, superficial, violet to brown, globose to subglobose, 330–500 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 15–27 µm. Asci 8 spored, globose to subglobose. Ascospores reddish brown, in surface view globose, spore bodies smooth, 5.5–6 × 3.5–5 µm; in side view lenticular, with two equatorial crests measuring 2–3.5 µm wide; crests ornamented with longitudinal, 0.3–0.4 µm wide pleats. Conidiophores with smooth stipes, light brown, 80–200 × 3–4 µm; vesicles hyaline to pale brown, subclavate to subglobose, 5–7 µm wide, fertile over the upper half; metulae hyaline, 4.5–5.5 × 2–3 µm; phialides hyaline, flask-shaped, 4.5–5 × 2–4 µm. Conidia echinulate, globose to subglobose, 2.5–6 µm.

*Extrolites:* aflatoxin B1 and B2, asperthecin, 2- $\omega$ -hydroxyemodin, shamixanthones, sterigmatocystin and versicolorins.

*Distinguishing characters:* *Aspergillus stellatus* is characterized by ascospores with two wide undissected crests up to 3.5 µm wide. Phylogenetically it is close to *A. venezuelensis* and *A. stella-maris*, but the latter two produce stellate ascospores. All three species can produce sterigmatocystin and shamoxanthones. Only *A. venezuelensis* and *A. stellatus* produce aflatoxin B1, and *A. venezuelensis* and *A. stella-maris* produce emericellin (Table 6).

***Aspergillus aurantiobrunneus*** (G.A. Atkins, Hindson & A.B. Russell) Raper & Fennell, Gen. *Aspergillus*: 511. 1965. MycoBank MB326612. Fig. 16.

≡ *Emericella nidulans* var. *aurantio-brunnea* G.A. Atkins, Hindson & A.B. Russell, Trans. Brit. Mycol. Soc. 41: 504. 1958. ≡ *Emericella aurantiobrunnea* (G.A. Atkins, Hindson & A.B. Russell) Malloch, Can. J. Bot. 50: 61. 1972. ≡ *Aspergillus aurantiobrunneullus* Ismail, Abdel-Sater & Zohri, Mycotaxon 53: 397. 1995.

*Typus:* IMI 074897. Culture ex-type: CBS 465.65 = NRRL 4545 = NRRL 2775 = IMI 074897 = LCP 84.2354 = ATCC 16821 = WB 4545 = DSL 48 = IMI 139821 = IBT 22880 = DTO 047-G7.

*ITS barcode:* EF652465. (Alternative markers: *BenA* = EF652289; *CaM* = EF652377; *RPB2* = EF652201).

*Colony diam, 7 d (mm):* CYA 9–12; CYA 37 °C No growth; CYA 40 °C No growth; MEA 10–11; MEA 37 °C No growth; OA 9–10; YES 11–12; CREA No growth; CYAS 11–13; DG18 15–16.

*Colony characters:* CYA 25 °C, 7 d: Colonies deep, plane; margins entire; mycelium white and orange; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse wood brown. MEA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse yellowish brown. YES 25 °C, 7 d: Colonies deep, sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse cream yellow. DG18 25 °C, 7 d: Colonies deep, plane; margins entire; mycelium white and orange; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse light yellow. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse white. CREA 25 °C, 7 d: No growth.

*Micromorphology:* Ascomata cleistothecial, superficial, reddish brown, globose to subglobose, 60–300 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale brown, globose to ovoid, 14–25 µm. Asci 8 spored, globose to subglobose. Ascospores light orange, in surface view globose to subglobose, spore bodies smooth, 4–5 × 3.5–4.5 µm; in side view lenticular, with two equatorial crests measuring 0.8–1 µm. Conidiophores with smooth stipes, light brown, 50–200 × 3.5–4.5 µm; vesicles hyaline to pale brown, globose to subclavate, 7–12 µm wide, fertile over the two thirds to whole surface; metulae hyaline to pale brown, 4–6 × 2.5–3.5 µm; phialides hyaline to pale brown, flask-shaped, 6.5–7.5 × 2.5–3 µm. Conidia echinulate, globose to subglobose, 2.5–3.5 µm (Anamorphic structures were observed from YES).

*Extrolites:* emerin, an emindol, emericolin A-D, epurpurin A-C, eremophilin, stellatic acid, sterigmatocystin, variecoacetal A, B, variecolactone, variecolin, variecolol, versicolorins.

*Distinguishing characters:* *Aspergillus aurantiobrunneus* grows restrictedly on CYA, MEA, YES and OA, which differs from other morphologically similar species such as *A. fruticosus* and *A. pachycristatus*. Phylogenetically it is close to *A. purpureus*, but *A. purpureus* produces larger ascospores (6–7 × 4.5–5 µm) and narrower ascospore crests (0.3–0.6 µm).

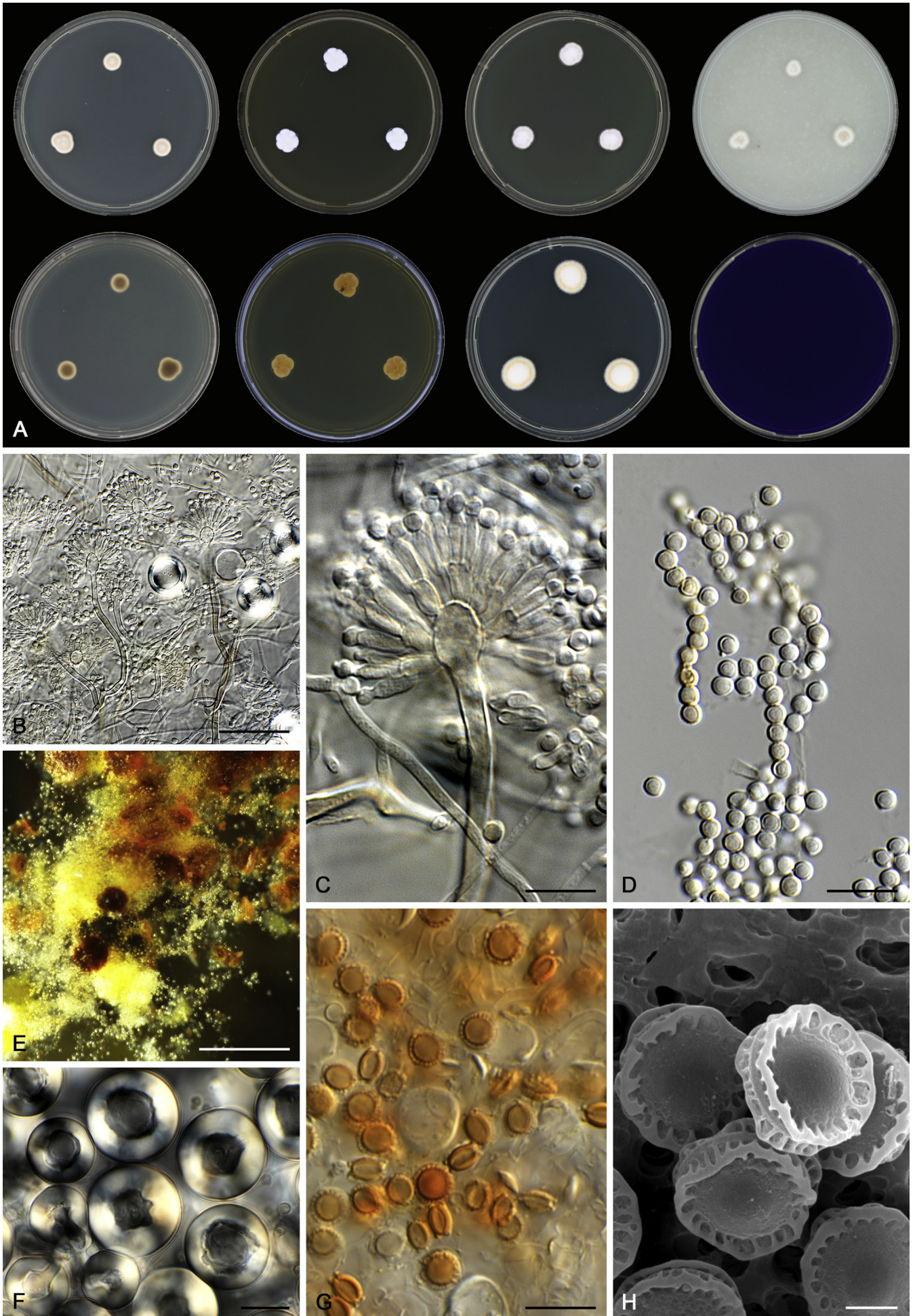
***Aspergillus aurantiopurpureus*** A.J. Chen, Frisvad & Samson, sp. nov. MycoBank MB816087. Fig. 17.

*Etymology:* Name refers to its ascospore colour, which is orange or reddish brown, later turns to violet.

*Diagnosis:* Yellow mycelium, smooth ascospores with crests measuring 0.8–1.2 µm wide, ascospores are first orange later turn to violet.

*Typus:* USA, New Mexico, Sevilette national wildlife refuge, kangaroo rat cheek pouch, 1989, isolated by L. Hawkins (holotype CBS H-22488, culture ex-type: CBS 140608 = IBT 12601 = DTO 060-A7).

*ITS barcode:* KU866588. (Alternative markers: *BenA* = KU866824; *CaM* = KU866711; *RPB2* = KU866966).



**Fig. 16.** *Aspergillus aurantiobrunneus* CBS 465.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–D. Conidiophores and conidia. E. Ascogonia. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30 µm; C,D,F,G = 10 µm; E = 1000 µm; H = 2 µm.

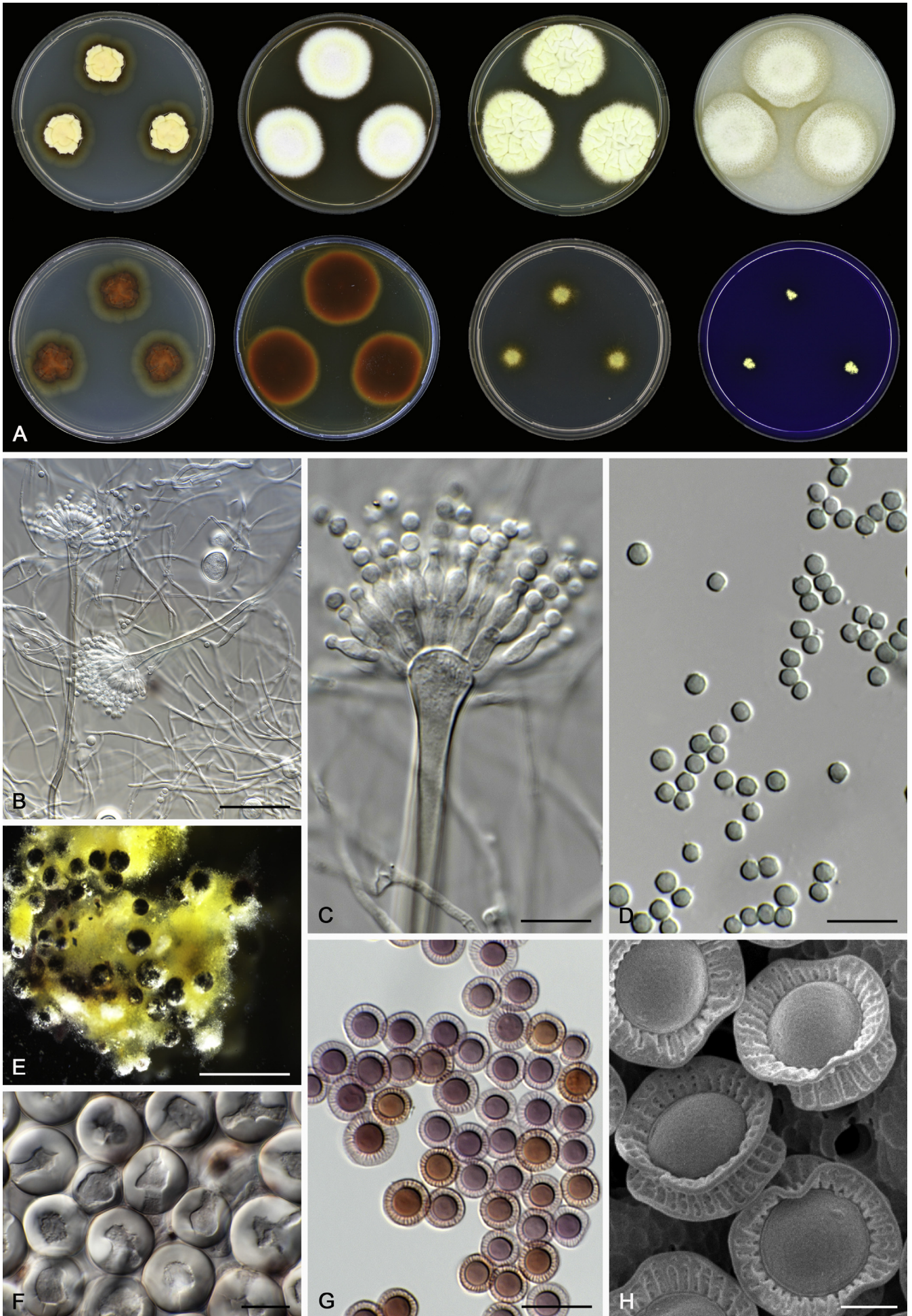


Fig. 17. *Aspergillus aurantiopurpureus* CBS 140608<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



*Colony diam*, 7 d (mm): CYA 32–35; CYA 37 °C 23–30; CYA 40 °C 28–30; MEA 38–41; MEA 37 °C 33–35; OA 25 °C 40–45; YES 42–49; CREA 6–7; CYAS 20–22; DG18 14–17.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins slightly irregular; mycelium yellow; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse reddish brown. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium light yellow and white; texture floccose; sporulation sparse; soluble pigments absent; exudates clear droplets; reverse reddish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium light yellow and white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse orange red. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium light yellow to yellowish green; texture floccose; sporulation moderately dense; conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse dark brown. OA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white to light yellow; texture floccose; sporulation sparse; soluble pigments light brown; exudates clear droplets; reverse yellowish brown. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata cleistothecial, enveloped by interwoven hyphae, blackish to dark brown, globose to subglobose, 200–320 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 11.5–20.5 µm. Asci 8 spored, globose to subglobose. Ascospores first orange to reddish brown, later turn to violet, in surface view globose, spore bodies smooth, 3.5–4.5 × 3–3.5 µm; in side view lenticular, with two equatorial crests measuring 0.8–1.2 µm wide; crests ornamented with longitudinal, 0.3–0.4 µm wide pleats. Conidiophores with smooth stipes, light brown, 130–260 × 3.5–5 µm; vesicles hyaline, subclavate to subglobose, 8–11.5 µm wide, fertile over the upper half; metulae hyaline, 5–6 × 2.5–4 µm; phialides hyaline, flask-shaped, 5–6.5 × 3–3.5 µm. Conidia echinulate, globose to subglobose, 3–3.5 µm, green in mass.

*Extrolites*: cyclopaldic acid, desertorins, falconensins, cf. falconensons, shamixanthones, sterigmatocystin.

*Distinguishing characters*: Phylogenetically it is close to *A. navahoensis*, but can be easily distinguished by wider pleated crests and ascospore colour.

***Aspergillus aureolatus*** Munt.-Cvetk. & Bata, Bull. Inst. Jard. Bot. Univ. Beograd 1: 196. 1964. MycoBank MB326614. Fig. 18.

*Typus*: CBS H-6738. Culture ex-type: CBS 190.65 = NRRL 5126 = ATCC 16810 = IMI 136527 = IMI 136527ii = WB5126 = IBT 18471 = IBT 22670 = DTO 053-C1.

*ITS barcode*: EF652501. (Alternative markers: *BenA* = EF652325; *CaM* = EF652413; *RPB2* = EF652237).

*Colony diam*, 7 d (mm): CYA 19–25; CYA 37 °C No growth; CYA 40 °C No growth; MEA 17–24; MEA 37 °C No growth; OA 16–19; YES 21–25; CREA 11–16; CYAS 18–21; DG18 11–17.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, plane; margins slightly irregular, surrounded by an orange halo; mycelium white; texture velvety; sporulation dense, conidia *en masse* greyish green to olive green; soluble pigments absent; exudates absent; reverse orange to reddish brown. MEA 25 °C, 7 d: Colonies deep, slightly sulcate; margins slightly irregular, surrounded by an orange halo; mycelium white; texture velvety; sporulation dense, conidia *en masse* yellow green to blue green; soluble pigments absent; exudates clear droplets; reverse orange to reddish brown. YES 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins slightly irregular, surrounded by an golden to orange halo; mycelium white; texture velvety; sporulation dense, conidia *en masse* greyish green; soluble pigments absent; exudates absent; reverse orange. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium yellow; texture velvety; sporulation dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse orange. OA 25 °C, 7 d: Colonies low, plane; margins slightly irregular, surrounded by an orange halo; mycelium white; texture velvety; sporulation dense, conidia *en masse* dark green; soluble pigments light brown; exudates clear droplets; reverse yellowish brown. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata not observed. Conidiophores with smooth stipes, yellowish brown, 80–200 × 4–5.5 µm, reduced conidial heads are formed, sometimes clusters of sterigmata appear along the ascending conidiophores; typical vesicles hyaline to pale yellowish brown, globose, 9–12 µm wide, fertile over the upper half to two thirds; metulae hyaline to pale green, 5–8.5 × 2–4 µm; phialides hyaline to pale green, flask-shaped, 5–7 × 2.5–3 µm. Conidia globose to subglobose, echinulate, 3.5–5 µm, green in mass.

*Extrolites*: austalides (tentatively identified), a desertorin, an emerin, sterigmatocystin, versicolorins.

*Distinguishing characters*: The striking orange halo surrounding the colony and globose vesicles can distinguish *Aspergillus aureolatus* from related non-ascosporic species.

***Aspergillus botswanensis*** A.J. Chen, Frisvad & Samson, sp. nov. MycoBank MB816095. Fig. 19.

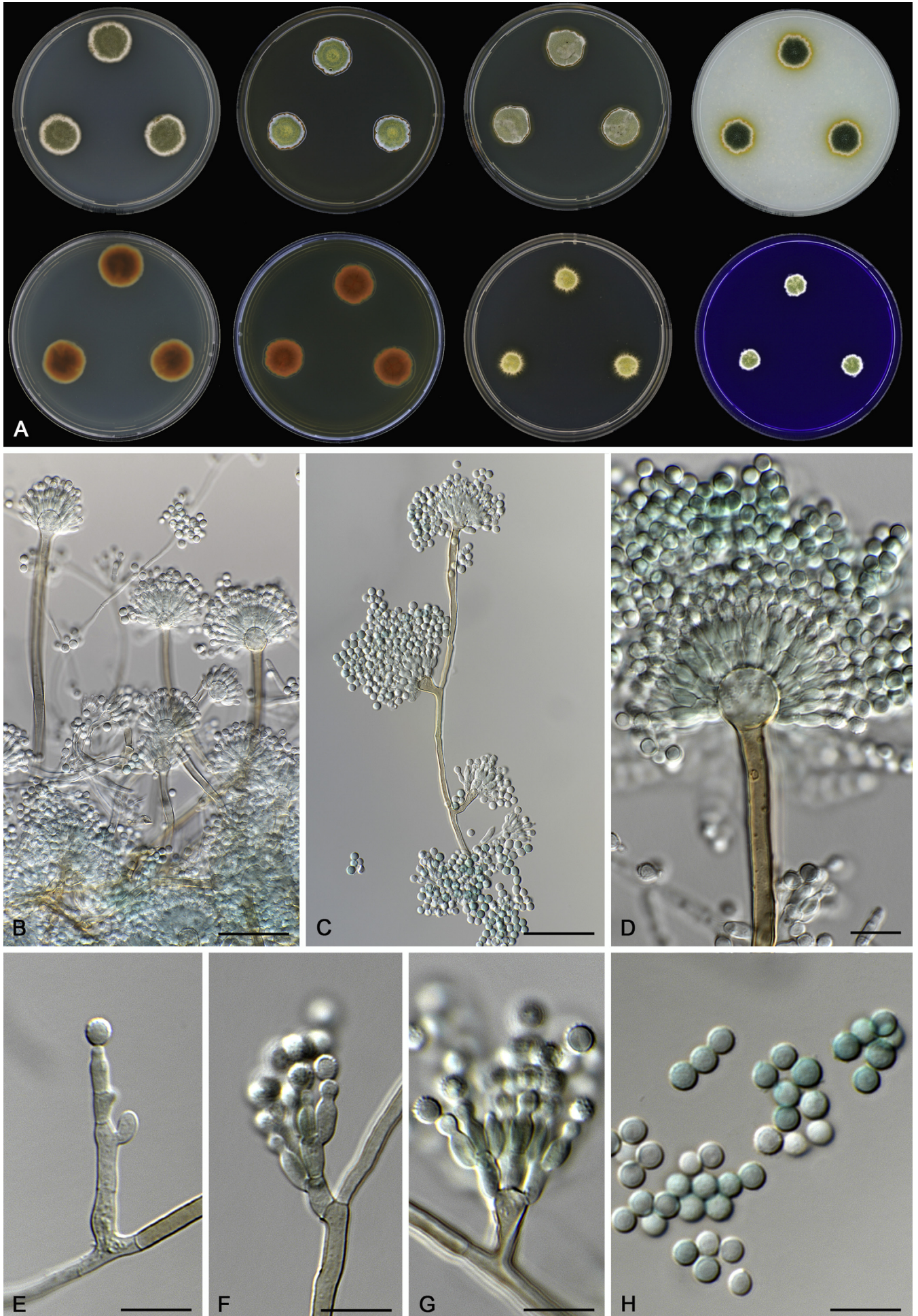
*Etymology*: Name refers to its origin, isolated from forest soil from Botswana.

*Diagnosis*: Brown ascospores ornamented with tuberculate to irregular reticulate ornamentation.

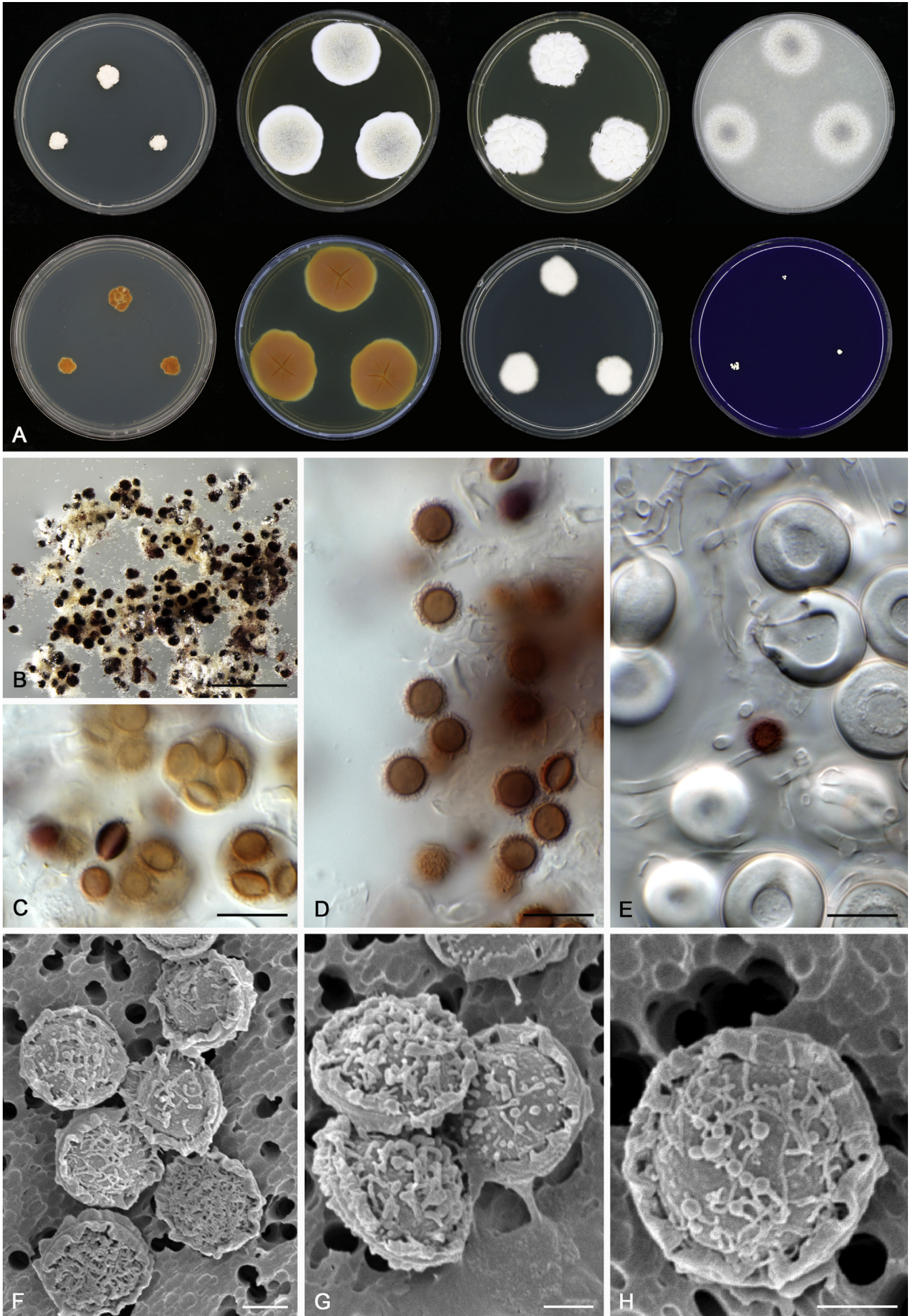
*Typus*: **Botswana**, Okavango Delta, Island Forest Area, at base of *Diospyros mespiliformis* (ebony tree), forest soil, 1986, collected by D. Pearce (holotype CBS H-22494, culture ex-type CBS 314.89 = DTO 047-I4).

*ITS barcode*: KU866572. (Alternative markers: *BenA* = KU866812; *CaM* = KU866695; *RPB2* = KU866949).

*Colony diam*, 7 d (mm): CYA 8–10; CYA 37 °C 45–46; CYA 40 °C 38–39; MEA 33–34; MEA 37 °C >60; OA 30–31; YES 32–33; CREA 2–5; CYAS 8–10; DG18 18–21.



**Fig. 18.** *Aspergillus aureolatus* CBS 190.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–G. Conidiophores. H. Conidia. Scale bars: B–C = 30 µm; D–H = 10 µm.



**Fig. 19.** *Aspergillus botswanensis* CBS 314.89<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B. Ascomata. C. Asci. D,F–H. Ascospores. E. Hülle cells. Scale bars: B = 1000 µm; C–E = 10 µm; F–H = 2 µm.

*Colony characters:* CYA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium light yellow to white; texture floccose; sporulation absent; soluble pigments absent; exudates clear droplets; reverse orange brown. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium light yellow and white; texture floccose; sporulation absent; soluble pigments absent; exudates clear droplets; reverse orange brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium white; texture velvety; sporulation absent; soluble pigments absent; exudates absent; reverse buff yellow. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse yellow. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture granular due to ascospores production; sporulation absent; soluble pigments absent; exudates absent; reverse pale olive. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology:* Ascospores cleistothecial, enveloped by interwoven mycelium, dark brown, globose, 90–180 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 12–16.5 µm. Asci 8 spored, globose to ovoid. Ascospores brown, in surface view globose to subglobose; spore bodies first tuberculate, later the extended protrusion melting into irregular reticulate ornamentation, 5–6 × 3.5–5 µm; in side view broadly lenticular, with two low equatorial crests, 0.4–0.8 wide. Anamorph absent.

*Extrolites:* asperthecin, desertorins, emericellin, an emindol, 2- $\omega$ -hydroxyemodin, paxillin, terrequinone A.

*Distinguishing characters:* The ascospores of *Aspergillus botswanensis* resemble those of *A. violaceus*, but *A. violaceus* produces constantly violet ascospores with regular reticulate ornamentation. Phylogenetically, *A. botswanensis* is close to *A. desertorum*, *A. stercorarius* and *A. savannensis*, but can be differed by its unique ascospore ornamentation.

***Aspergillus caespitosus*** Raper & Thom, *Mycologia* 36: 563. 1944. MycoBank MB284298. Fig. 20.

*Typus:* IMI 16034ii. Culture ex-type: CBS 103.45 = NRRL 1929 = ATCC 11256 = IMI 16034 = MUCL 13587 = NCTC 6972 = NCTC 6973 = QM 7399 = WB 1929 = IBT 10624 = DTO 053-D1.

*ITS barcode:* EF652428. (Alternative markers: *BenA* = EF652252; *CaM* = EF652340; *RPB2* = EF652164).

*Colony diam, 7 d (mm):* CYA 42–46; CYA 37 °C 7–30; CYA 40 °C No growth; MEA 46–54; MEA 37 °C 12–34; OA 45–55; YES 51–60; CREA 9–12; CYAS 25–35; DG18 32–35.

*Colony characters:* CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture velvety; sporulation sparse to moderately dense, conidia *en masse* graysish green; soluble pigments absent; exudates clear droplets; reverse vinaceous buff to grey olivaceous. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate to sulcate; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* yellow green to olive green; soluble pigments absent; exudates absent or clear droplets; reverse yellowish

brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture velvety; sporulation moderately dense, conidia *en masse* yellow green to blue green; dark brown soluble pigments present after 2 wks; exudates absent; reverse olive to yellowish brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* dark green; soluble pigments absent; exudates absent; reverse pale yellow green. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* yellow green; soluble pigments absent to pale yellow; exudates absent; reverse greenish yellow to yellow. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology:* Ascospores not observed. Conidiophores with smooth stipes, pale brown, 200–300 × 3–6 µm; vesicles hyaline to pale brown, hemisphere to subclavate, 10–15 µm wide, fertile over the upper half; metulae hyaline to pale brown, 5–8 × 3–3.5 µm; phialides hyaline, flask-shaped, 6.5–8 × 3–4.5 µm. Conidia globose, echinulate, 3–4 µm, green in mass.

*Extrolites:* asperlicine, emodin, fischerin, fumitremorgin B, 2- $\omega$ -hydroxyemodin, 6-methoxymellein, mollicin (tentatively identified), secalonic acid D, TR-2, verruculogen.

*Distinguishing characters:* *Aspergillus caespitosus* is close to *A. asperescens* and *A. unguis*, but can be distinguished from *A. asperescens* by its globose conidia; from *A. unguis* by its longer conidiophores and wider vesicles. These three species share no extrolites, and can be easily distinguished chemically. *A. caespitosus* is the only species in section *Nidulantes* that produces fumitremorgins.

*Notes:* Abundant, thick walled, irregularly globose, ovoid or elliptical Hülle cells were mentioned in the original descriptions (Raper & Thom 1944); however, they are not confirmed in this study. Only some degenerated terminal or intercalary cells resembling Hülle cells are observed on CYA plates, measuring 7–16 × 5–10 µm.

***Aspergillus corrugatus*** Udagawa & Y. Horie, *Mycotaxon* 4: 535. 1976. MycoBank MB309216. Fig. 21.

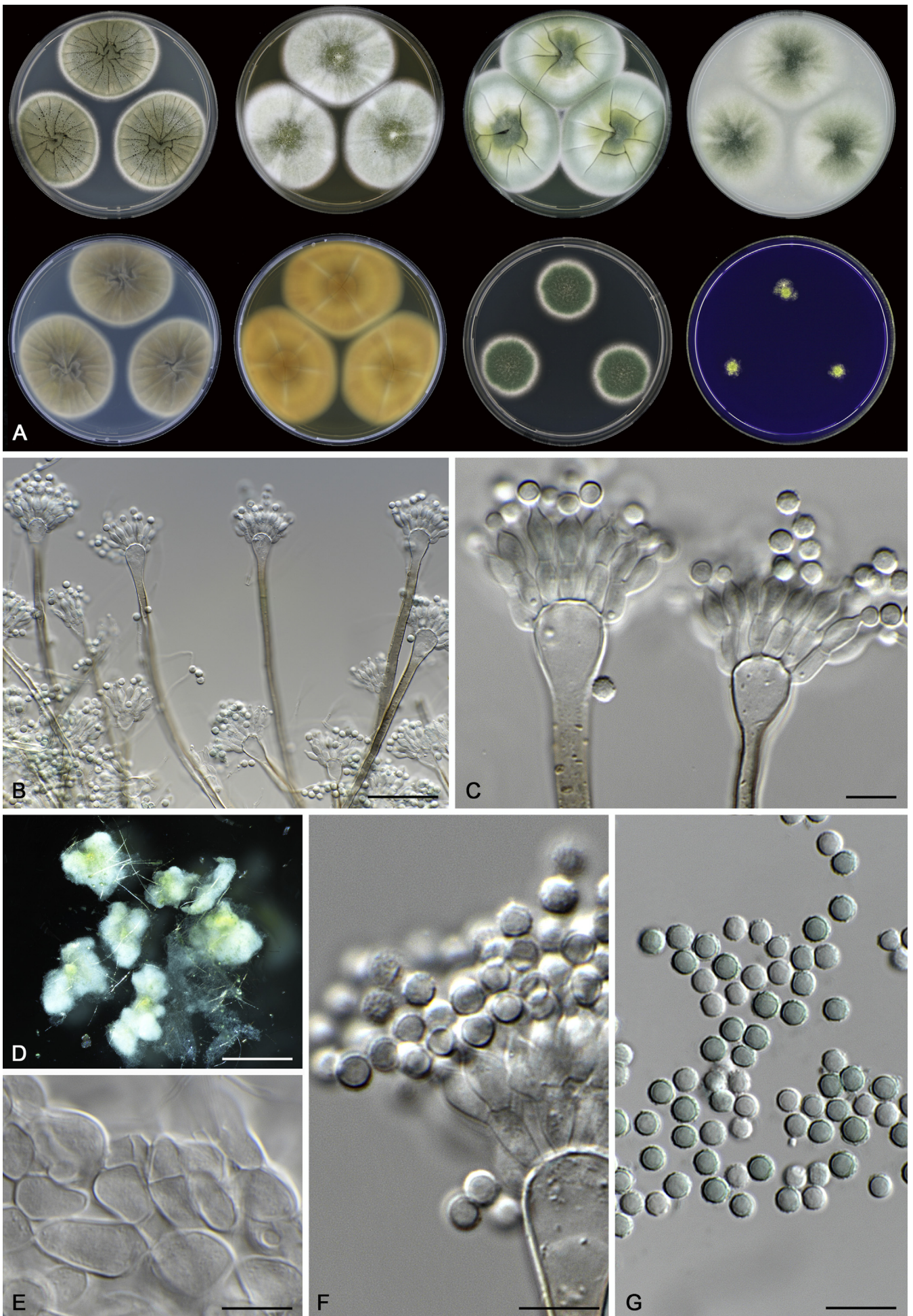
≡ *Emericella corrugata* Udagawa & Y. Horie, *Mycotaxon* 4: 535. 1976.

*Typus:* NHL 2763. Culture ex-type: CBS 191.77 = NHL 2763 = IMI 212201 = IBT 22829 = DTO 047-I9.

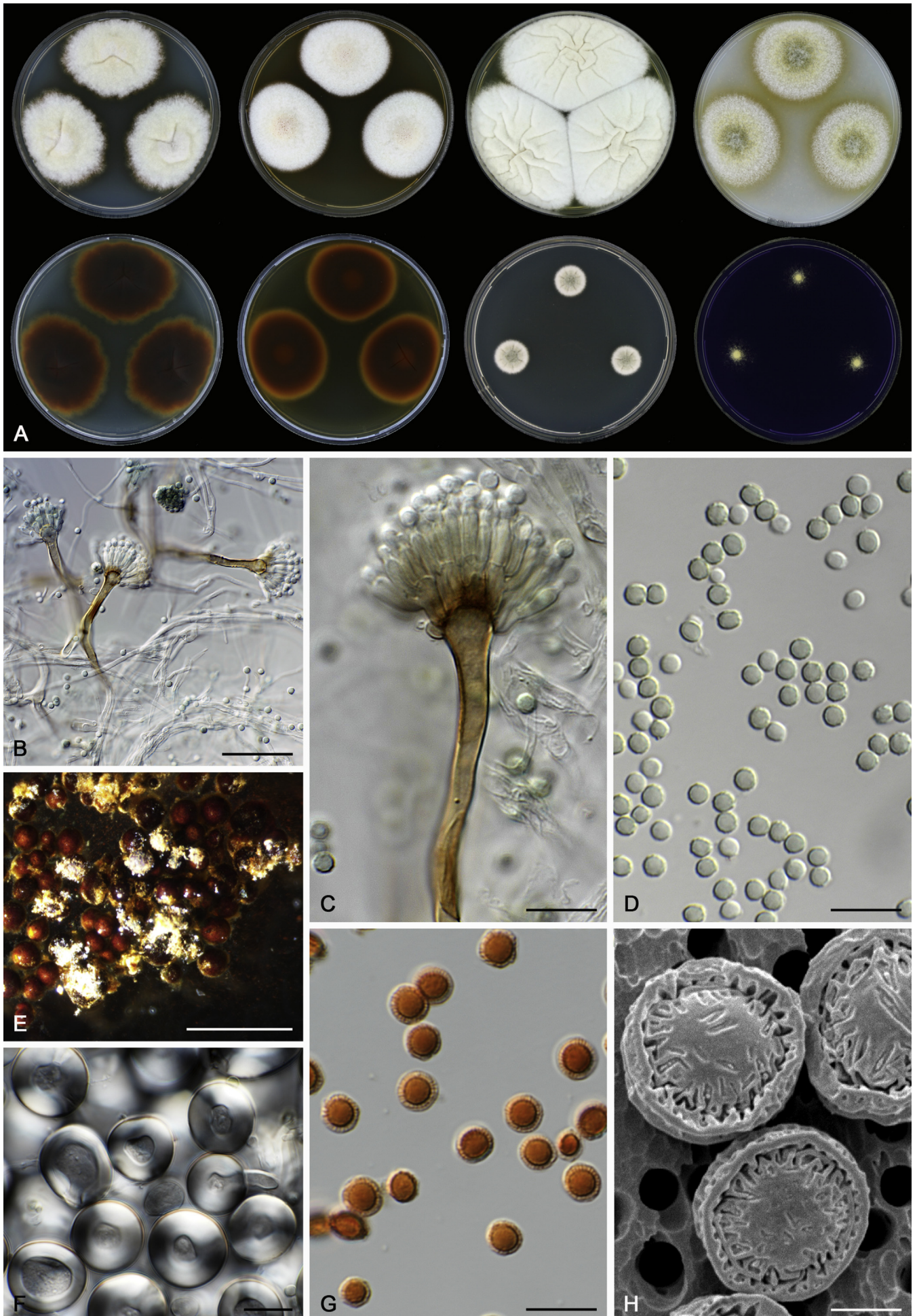
*ITS barcode:* KU866574. (Alternative markers: *BenA* = KU866814; *CaM* = KU866696; *RPB2* = KU866951).

*Colony diam, 7 d (mm):* CYA 48–49; CYA 37 °C 53–54; CYA 40 °C 48–49; MEA 43–44; MEA 37 °C >60; OA 40–42; YES >60; CREA 10–13; CYAS 23–27; DG18 14–15.

*Colony characters:* CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white to light yellow; texture floccose; sporulation absent; soluble pigments light brown; exudates absent; reverse reddish brown to brown. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium salmon at centre, white at edge; texture floccose; sporulation sparse; soluble pigments absent; exudates clear droplets; reverse reddish brown to brown. YES 25 °C, 7 d:



**Fig. 20.** *Aspergillus caespitosus* CBS 103.45<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C,F. Conidophores. D,E. Terminal or intercalary cells resembling Hülle cells. G. Conidia. Scale bars: B–C,E,G = 10  $\mu$ m; F = 8  $\mu$ m; D = 1000  $\mu$ m.



**Fig. 21.** *Aspergillus corrugatus* CBS 191.77<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.

Colonies moderately deep, sulcate; margins entire; mycelium white to light yellow; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse brown. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white to buff; texture floccose; sporulation moderately dense, conidia *en masse* greyish green; soluble pigments absent; exudates absent; reverse cream white. OA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white and light yellow; texture floccose; sporulation sparse; soluble pigments light brown; exudates absent; reverse yellowish brown. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, superficial, reddish brown to brown, globose to subglobose, 200–360 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 16–23 µm. Asci 8 spored, globose to ovate. Ascospores orange to reddish brown, in surface view globose to subglobose, spore bodies with irregularly wrinkled ornamentation, globose to subglobose, 3.5–4.5 × 3.5–4 µm; in side view lenticular, with two pleated equatorial crests measuring 0.5–1 µm. Conidiophores with smooth stipes, yellowish brown, 40–120 × 3.5–5.5 µm; vesicles pale brown, subclavate, 8–10 µm wide, fertile over the upper half to two thirds; metulae hyaline, pale green to brown, 5–8 × 2.5–4 µm; phialides hyaline to pale green, flask-shaped, 6–8 × 2.5–3.5 µm. Conidia echinulate, globose to subglobose, 2.5–3.5 µm.

**Extrolites:** asperthecin, asperugins, an austalide (tentatively identified), emecorrugatin, gregatins, shamixanthone, sterigmatocystin, versicolorins, violaceols.

**Distinguishing characters:** *Aspergillus corrugatus* is close to *A. foveolatus*, *A. rugulosus* and *A. spinulosporus*, but differs in its ascospore ornamentation. The convex walls are irregularly wrinkled in *A. corrugatus*, in contrast to the finely pitted convex walls in *A. foveolatus*, rugulose walls in *A. rugulosus* and echinulate walls in *A. spinulosporus*.

***Aspergillus croceus*** Hubka, A. Nováková, Frisvad, S.W. Peterson & M. Kolařík, *Plant Syst. Evol.* 302: 1291. 2016. MycoBank MB816281.

**Typus:** Holotype PRM 924053; isotype 924054. Culture ex-type: CBS 134396 = CCF 4405 = NRRL 62495 = IBT 33602.

**ITS barcode:** LN873931. (Alternative markers: *BenA* = LN873944; *CaM* = LN873957; *RPB2* = LN873976).

**Colony characters:** Fide Hubka *et al.* (2016) colonies on CYA at 25 °C attain 20–37 mm diam in 14 days (11–16 mm in 7 days), velutinous, plane, delicately furrowed to wrinkled with floccose vivid orange (No. 48) colony centre, colony margin plane, 2–3 mm wide, strong brown (No. 55), sporulation color greyish olive (110), greyish olive green (No. 127) to dark olive (No. 108), Hülle cells visible in some strains after 14 days, no exudate, no soluble pigment, reverse dark reddish brown (No. 44) with paler 1-mm-wide colony margin. No growth on CYA at 37 °C. Colonies on MEA at 25 °C attain 17–32 mm diam in 14 days (9–13 mm in 7 days), velutinous, plane to delicately furrowed with paler floccose central part, 3–5 mm in diam, deep orange (No. 69) with paler colony margin, brilliant yellow (83)-colored margins in some

strains, sporadic sporulation in greyish olive (No. 110) to greyish olive green (No. 127), but in some strains more intense sporulation in greyish green (No. 150), no exudate, no soluble pigment, reverse brownish orange (No. 54) to strong brown (No. 55) with strong orange (No. 50) 1–2 mm margin. Colonies on CZA at 25 °C attain 19–28 mm diam in 14 days (7–12 mm in 7 days), velutinous to floccose, plane, mycelium light brownish gray (No. 63), brownish gray (No. 64) to strong reddish brown (No. 40) with medium brown (No. 58) to strong brown (No. 55) higher colony centre (12 mm) with sporulation (zone up to 12 mm in diam) in greyish olive green (No. 127), in some strains whitish mycelial overgrowth in the colony centre, no exudate or small droplets of dark brown (No. 59) exudate, soluble pigment medium pink (No. 5) to medium red (No. 15), reverse vivid deep red (No. 13) to dark reddish brown (No. 44) with deep red (No. 13) margin. Colonies on CREA at 25 °C attain 9–20 mm diam in 14 days (8–12 mm in 7 days), plane, submerged orange-colored mycelium, sparse sporulation, no acid production.

**Micromorphology:** Fide Hubka *et al.* (2016) stipes on MEA light brown to brown, rough-walled, warty to crustose, non-septate or occasionally with septum (sometimes separating vesicle and stipe), most commonly 90–200 × 3.5–5 µm diam, occasionally longer; vesicles pyriform, spathulate or clavate, 7–15 µm diam; metulae cylindrical, 7.5–10.5 µm long, covering 1/3–1/2 of vesicle; phialides ampulliform (6.5–) 7–9 (–9.5) µm long; conidia globose or subglobose, green in mass, 2–3 (–3.5) µm diam, smooth to finely roughened. Hülle cells arranged in clusters, globose, subglobose or pyriform, 8–18.5 × 8–11 (–17) µm, produced after 14 or more days cultivation at 25 °C. Sexual state not observed.

**Extrolites:** Fide Hubka *et al.* (2016) kotanins, norsolorinic acid, orlandin, siderin, sterigmatocystin, versicolorins.

**Distinguishing characters:** This species is closely related to *A. unguis* and *A. israelensis*, but the latter two produce narrower vesicles, (8–10 µm) in *A. unguis* and (7–10 µm) in *A. israelensis*.

**Notes:** For an illustration of the species, readers are referred to Hubka *et al.* (2016).

***Aspergillus desertorum*** (Samson & Mouch) Samson, Visagie & Houbraken, *Stud. Mycol.* 78: 155. 2014. MycoBank MB809587. Fig. 22.

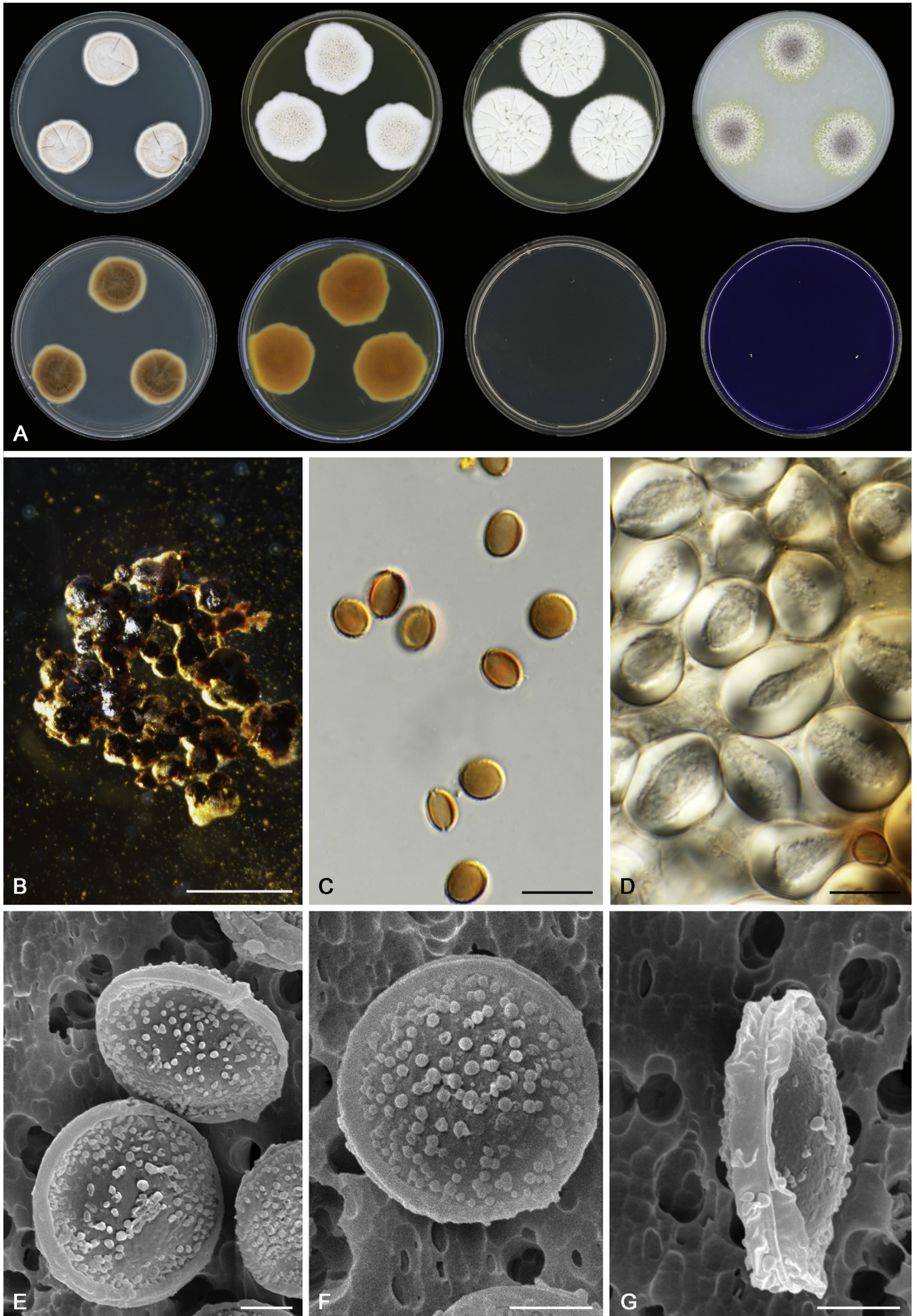
= *Emericella desertorum* Samson & Mouch., *Antonie van Leeuwenhoek* 40: 121. 1974.

**Typus:** CBS H-7045. Culture ex-type: CBS 653.73 = NRRL 5921 = IMI 343076 = IBT 21899 = DTO 048-A1.

**ITS barcode:** EF652505. (Alternative markers: *BenA* = EF652329; *CaM* = EF652417; *RPB2* = EF652241).

**Colony diam, 7 d (mm):** CYA 20–35; CYA 37 °C 29–53; CYA 40 °C 29–47; MEA 32–40; MEA 37 °C 43–60; OA 30–36; YES 41–50; CREA 0–2; CYAS 0–23; DG18 0–17.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium saffron and white; texture floccose; sporulation absent; soluble pigments absent; exudates light brown droplets; reverse yellowish brown. MEA



**Fig. 22.** *Aspergillus desertorum* CBS 653.73<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B. Ascumata. C, E–G. Ascospores. D. Hülle cells. Scale bars: B = 30  $\mu\text{m}$ ; C–D = 10  $\mu\text{m}$ ; E–G = 2  $\mu\text{m}$ .



25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates clear droplets; reverse orange to reddish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture velvety; sporulation absent; soluble pigments absent; exudates absent; reverse light brown. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white and light yellow; texture floccose; sporulation absent; soluble pigments light yellow; exudates light brown droplets; reverse greyish yellow. Violet ascomata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata cleistothecial, superficial, violet to brown reddish, globose to subglobose, 100–300 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale brown, globose, ovoid or pyriform, 10–25 µm. Asci 8 spored, globose to subglobose. Ascospores reddish brown, in surface view globose to subglobose, spore bodies tuberculate, 6.5–7.5 × 6–7.5 µm; in side view broadly lenticular, with two low equatorial crests measuring 0.5 µm wide; Anamorph absent.

*Extrolites*: asperthecin, calbistrins, desertorin A, B & C, emindols, nidulol, paxillin, silvaticol, terrequinone A.

*Distinguishing characters*: *Aspergillus desertorum* is characterized by large ascospores, which are ornamented with two low crests. Its ascospores resemble those of *A. purpureus* and *A. stercorarius*, but *A. purpureus* produces smooth ascospores and grows slower on all tested media, *A. stercorarius* produces smooth and smaller ascospores (4.5–6 × 3.5–4.5 µm).

***Aspergillus dromiae*** A.J. Chen, Frisvad & Samson, **sp. nov.** MycoBank MB816089. Fig. 23.

*Etymology*: Name refers to its origin, isolated from *Dromia erythropus* (crab, Crustacea).

*Diagnosis*: Stellate ascospores, echinulate conidia measuring 3.5–4.5 µm, vesicles measuring 12–17 µm.

*Typus*: **Venezuela**, Mochima Bay, Morro of Garapáta, *Dromia erythropus* (crab, Crustacea), isolated by J.C. Frisvad (holotype CBS H-22489, culture ex-type CBS 140633 = IBT 25166 = DTO 059-H5).

*ITS barcode*: KU866580. (Alternative markers: *BenA* = KU866885; *CaM* = KU866703; *RPB2* = KU866958).

*Colony diam*, 7 d (mm): CYA 39–40; CYA 37 °C 10–11; CYA 40 °C No growth; MEA 45–47; MEA 37 °C 1–2; OA 40–45; YES 45–50; CREA 10–11; CYAS 33–34; DG18 18–27.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium greyish olive; texture floccose; sporulation absent; soluble pigments absent; exudates clear to light brown droplets; reverse dark olive; ascomata present after 1 wk. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium light yellow and white; texture granular at centre due to ascomata production; sporulation absent; soluble pigments absent; exudates clear droplets; reverse dark brown at centre, yellowish brown at edge; ascomata present after 1 wk. YES 25 °C, 7 d: Colonies moderately deep, sulcate;

margins entire; mycelium white and light yellow; texture floccose to granular due to ascomata production; sporulation absent; soluble pigments absent; exudates absent; reverse yellowish brown; ascomata present after 1 wk. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose; sporulation dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse greenish yellow. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture granular due to ascomata production; sporulation absent; soluble pigments absent; exudates clear droplets; reverse pale yellow green; ascomata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata cleistothecial, superficial, reddish brown to dark brown, globose to subglobose, 450–800 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale yellowish brown, globose to ovoid, 16–31 µm. Asci 8 spored, stellate. Ascospores orange to reddish brown, in surface view stellate, 11–15 µm; spore bodies smooth, globose to subglobose, 3–4.5 × 3.5–4.5 µm; in side view broadly lenticular, with two stellate equatorial crests; undissected part of crests 1–1.5 µm broad, with 2–3 µm long extensions; crests ornamented with longitudinal, 0.3–0.4 µm wide pleats. Conidiophores with smooth stipes, pale brown, 300–410 × 4.5–6.5 µm; vesicles hyaline to pale brown, subclavate to subglobose, 12–17 µm wide, fertile over the upper half; metulae hyaline, 6–8 × 3–4.5 µm; phialides hyaline, flask-shaped, 6.5–10 × 3.5–4.5 µm. Conidia echinulate, globose to subglobose, 3.5–4.5 µm. (Anamorphic structures were observed from DG18).

*Extrolites*: a desertorin, emericellin, 2-ω-hydroxyemodin, shamixanthones.

*Distinguishing characters*: *Aspergillus dromiae* resembles *A. stella-maris* and *A. miraensis*, however *A. stella-maris* produces wider (3.5–7 µm), septate conidiophores, while *A. miraensis* produces smaller conidia (2–3.5 µm).

***Aspergillus falconensis*** Y. Horie *et al.*, Trans. Mycol. Soc. Japan 30: 257. 1989. MycoBank MB127891. Fig. 24.

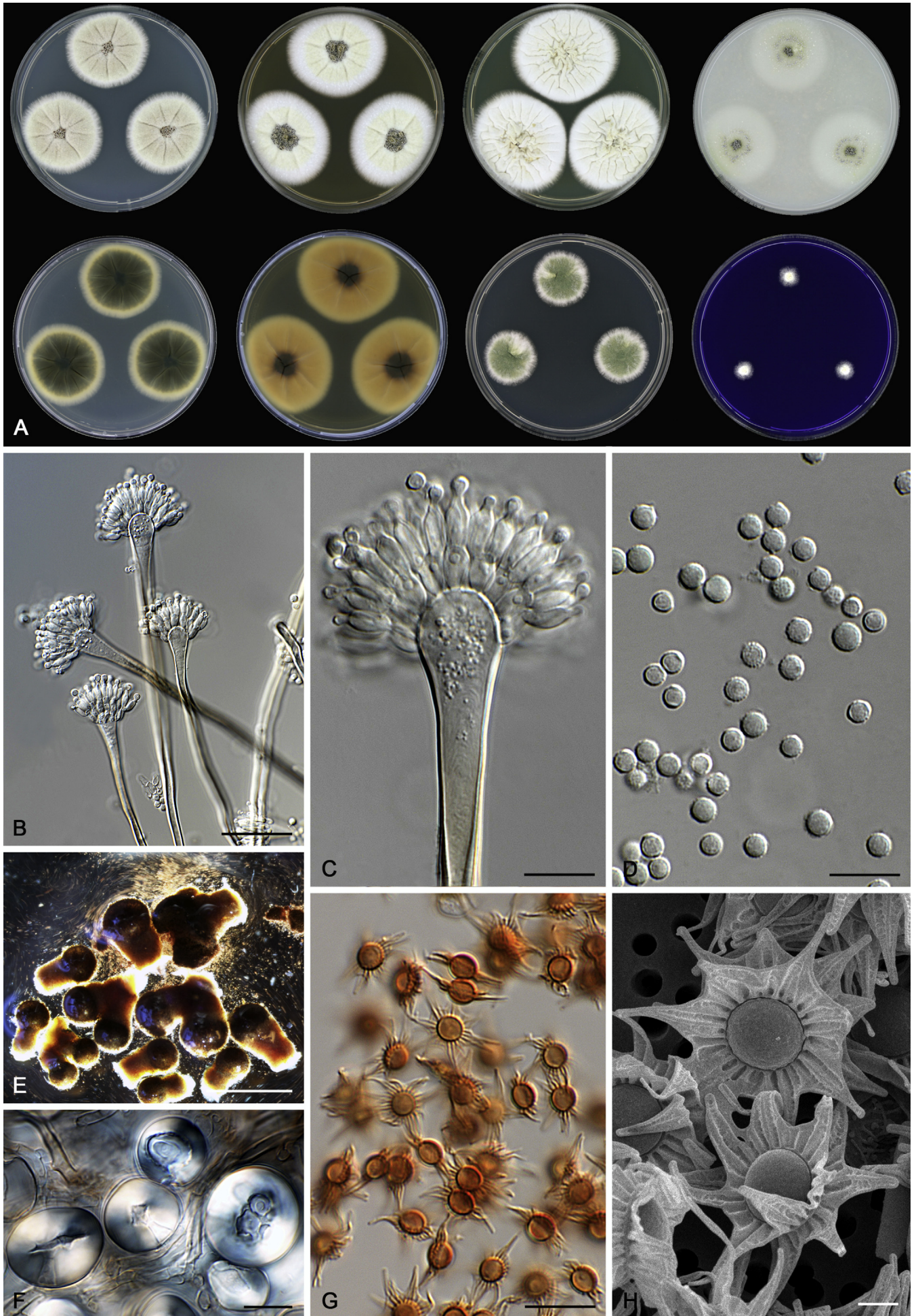
= *Emericella falconensis* Y. Horie *et al.*, Trans. Mycol. Soc. Japan 30: 257. 1989.

*Typus*: CBM 10001. Culture ex-type: CBS 271.91 = IFM 4997 = NHL 2999 = ATCC 76117 = IBT 14808 = DTO 048-A2.

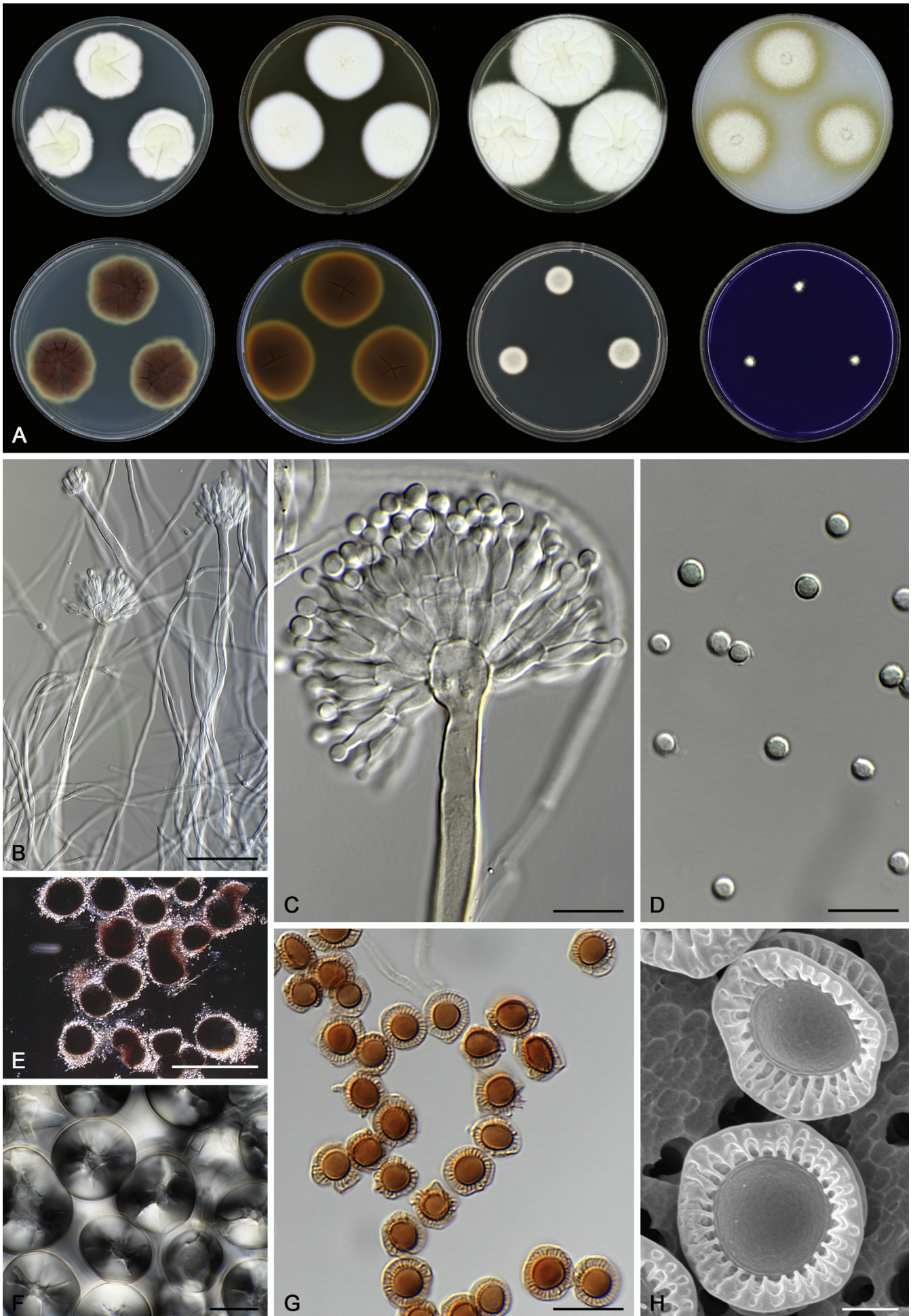
*ITS barcode*: KU866575. (Alternative markers: *BenA* = KU866815; *CaM* = KU866697; *RPB2* = KU866952).

*Colony diam*, 7 d (mm): CYA 30–40; CYA 37 °C 34–52; CYA 40 °C 30–45; MEA 34–45; MEA 37 °C 43–60; OA 33–48; YES 47–>60; CREA 2–18; CYAS 2–20; DG18 2–24.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium light yellow and white; texture floccose; sporulation absent; soluble pigments absent; exudates light brown droplets; reverse reddish brown to brown. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium light yellow and white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse reddish brown to brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium light yellow and white; texture velvety;



**Fig. 23.** *Aspergillus dromiae* CBS 140633<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



**Fig. 24.** *Aspergillus falconensis* CBS 271.91<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30 µm; C,D,F,G = 10 µm; E = 1000 µm; H = 2 µm.

sporulation sparse; soluble pigments absent; exudates absent; reverse yellowish brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation moderately dense; conidia *en masse* greyish green; soluble pigments absent; exudates absent; reverse light yellow. OA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium light yellow and white; texture floccose; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments yellowish brown; exudates clear droplets; reverse yellowish brown. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, superficial, reddish brown to dark brown, globose to subglobose, 300–700 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 14–25 µm. Asci 8 spored, globose to subglobose. Ascospores orange to reddish brown, in surface view globose to subglobose, spore bodies smooth, 4–6 × 3–3.5 µm; in side view lenticular, with two equatorial crests measuring 1–2 µm wide; crests ornamented with longitudinal, 0.3–0.4 µm wide pleats. Conidiophores with smooth stipes, light brown, 75–240 × 4–6.5 µm; vesicles hyaline to pale brown, globose to subclavate, 8–10 µm wide, fertile over the upper half; metulae hyaline, 6–10 × 2–3.5 µm; phialides hyaline, flask-shaped, 6–9 × 2–4 µm. Conidia echinulate, globose to subglobose, 2.5–4 µm, green in mass. (Anamorphic structures were observed from YES).

**Extrolites:** asperthecin, an austrialide (tentatively identified), austinol, desertorins, falconensins, falconensons, shamixanthonones, sterigmatocystin, versicolorins, violaceols, viridicatumtoxin.

**Distinguishing characters:** *Aspergillus falconensis* is characterized by ascospores with two conspicuously pleated crests up to 2 µm wide, which distinguish it from closely related *A. fruticosus* and *A. navahoensis*.

***Aspergillus filifer*** Zalar, Frisvad & Samson, *Mycologia* 100: 787. 2008. MycoBank MB507357. Fig. 25.

≡ *Emericella filifera* Zalar, Frisvad & Samson, *Mycologia* 100: 787. 2008.

= *Emericella appendiculata* Y. Horie & D.M. Li, *Mycoscience* 39: 161. 1998. = *Aspergillus appendiculatus* Y. Horie & D.M. Li, *Mycoscience* 39: 161. 1998. nom. illeg. [Art. 52.1; McNeill *et al.* (2012)] = *Aspergillus chinensis* Samson, Visagie & Houbraken, *Stud. Mycol.* 78: 155. 2014.

**Typus:** CBS H-19886. Culture ex-type: CBS 113636 = IBT 23443 = DTO 011-A5.

**ITS barcode:** EU448277. (Alternative markers: *BenA* = EF428372; *CaM* = EU443973; *RPB2* = KU866932).

**Colony diam, 7 d (mm):** CYA 32–40; CYA 37 °C 24–30; CYA 40 °C No growth; MEA 35–42; MEA 37 °C 23–30; OA 28–34; YES 40–48; CREA 6–13; CYAS 15–24; DG18 20–27.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white and pale olive; texture floccose; sporulation absent; soluble pigments absent; exudates clear to light brown droplets; reverse greyish brown at centre, buff at edge; Ascomata present after 1 wk. MEA 25 °C, 7 d: Colonies moderately deep, plane to slightly sulcate; margins entire; mycelium white and light yellow; texture floccose; sporulation absent; soluble pigments absent; exudates clear to light brown

droplets; reverse dark brown at centre, yellowish brown at edge. Ascomata present after 1 wk. YES 25 °C, 7 d: Colonies moderately deep to deep, sulcate; margins entire; mycelium white and light yellow; texture velvety; sporulation sparse to moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates clear droplets; reverse light brown to cream yellow. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse pale yellow green. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture granular due to ascomata production; sporulation absent; soluble pigments absent; exudates clear droplets; reverse pale brownish green. Ascomata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, superficial, greyish green to brown, globose to subglobose 220–660 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale yellowish brown, globose to ovoid, 13–24 µm. Asci 8 spored, stellate, globose to subglobose. Ascospores brown, in surface view globose to subglobose, spore bodies 3.5–4.5 × 3–4 µm; in side view broadly lenticular, with two equatorial crests measuring 0.5–1.2 µm wide; Crest bearing hyaline, filiform appendages, measuring 3–6 µm long with swollen tips. Convex surface tuberculate. Conidiophores with smooth stipes, yellowish brown, 120–250 × 3–5 µm; vesicles hyaline to pale yellowish brown, subclavate to subglobose, 7–13 µm wide, fertile over the upper half to two thirds; metulae hyaline to pale yellowish brown, 7–10 × 3–5 µm; phialides hyaline to pale yellowish brown, flask-shaped, 7–11 × 2–4 µm. Conidia echinulate, globose to subglobose, 3–4 µm.

**Extrolites:** asperthecin, asperugins, asteltoxin, dihydroterrein, 2-ω-hydroemodin, emericellin, shamixanthonones, terrein, a varitriol.

**Distinguishing characters:** Appendaged ascospores ornamented with capitate swellings. Morphologically this species is close to *A. undulatus* and *A. qinqixianii*, but can be easily distinguished from *A. undulatus* by filiform appendages and from *A. qinqixianii* by capitate swellings on convex surface of ascospores.

**Notes:** Phylogenetically and morphologically *Aspergillus appendiculatus* (= *Aspergillus chinensis*) (Samson *et al.* 2014) is identical with *A. filifer*, and is considered a synonym of *A. filifer* as did Matsuzawa *et al.* 2012 and Hubka *et al.* 2016.

***Aspergillus foveolatus*** Y. Horie, *Trans. Mycol. Soc. Japan* 19: 313. 1978. MycoBank MB309221. Fig. 26.

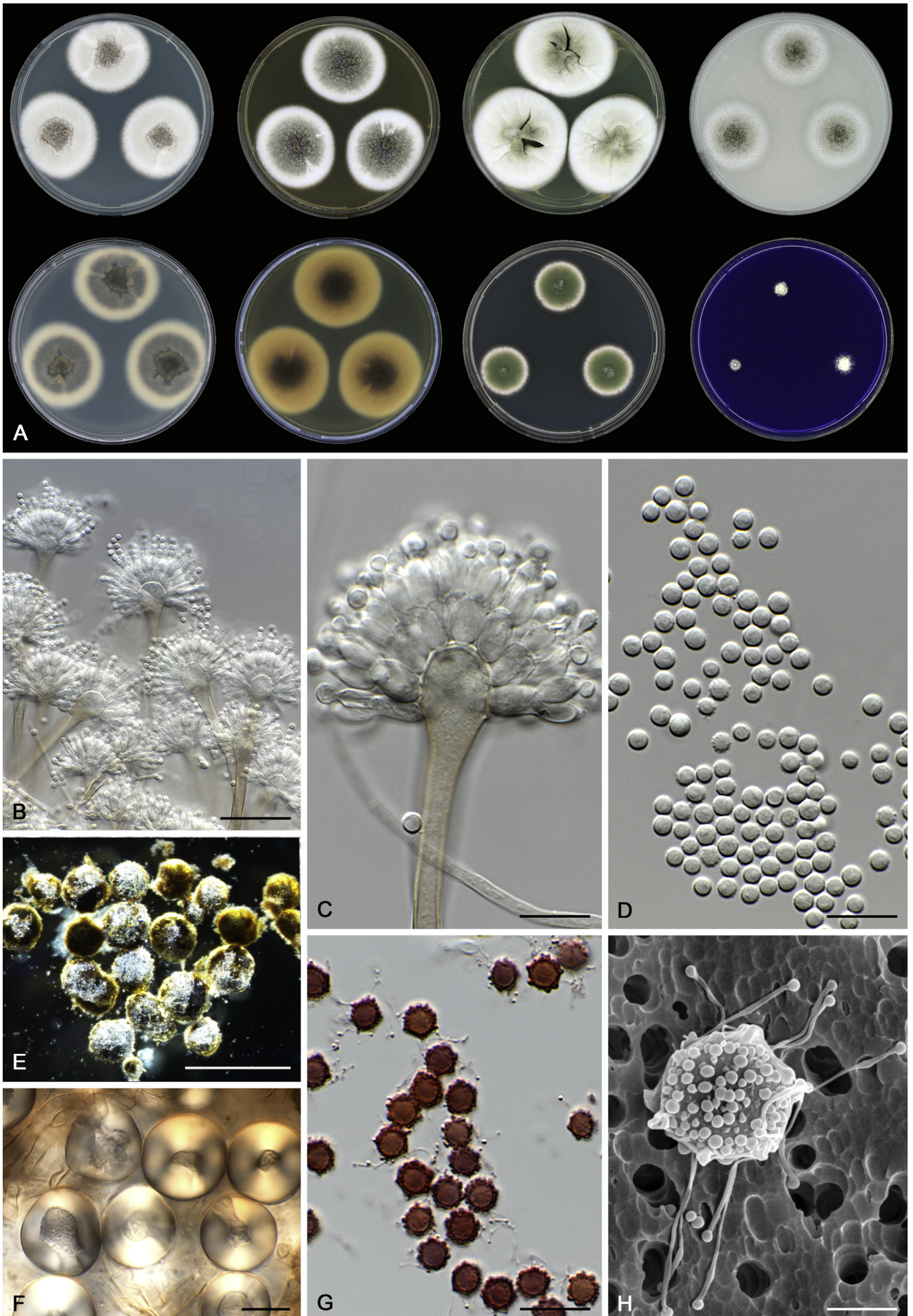
≡ *Emericella foveolata* Y. Horie, *Trans. Mycol. Soc. Japan* 19: 313. 1978.

**Typus:** IFM 4547. Culture ex-type: CBS 279.81 = IFM 4547 = NHL 2839 = NBRC 30559 = IFO 30559 = IBT 22847 = DTO 320-D2.

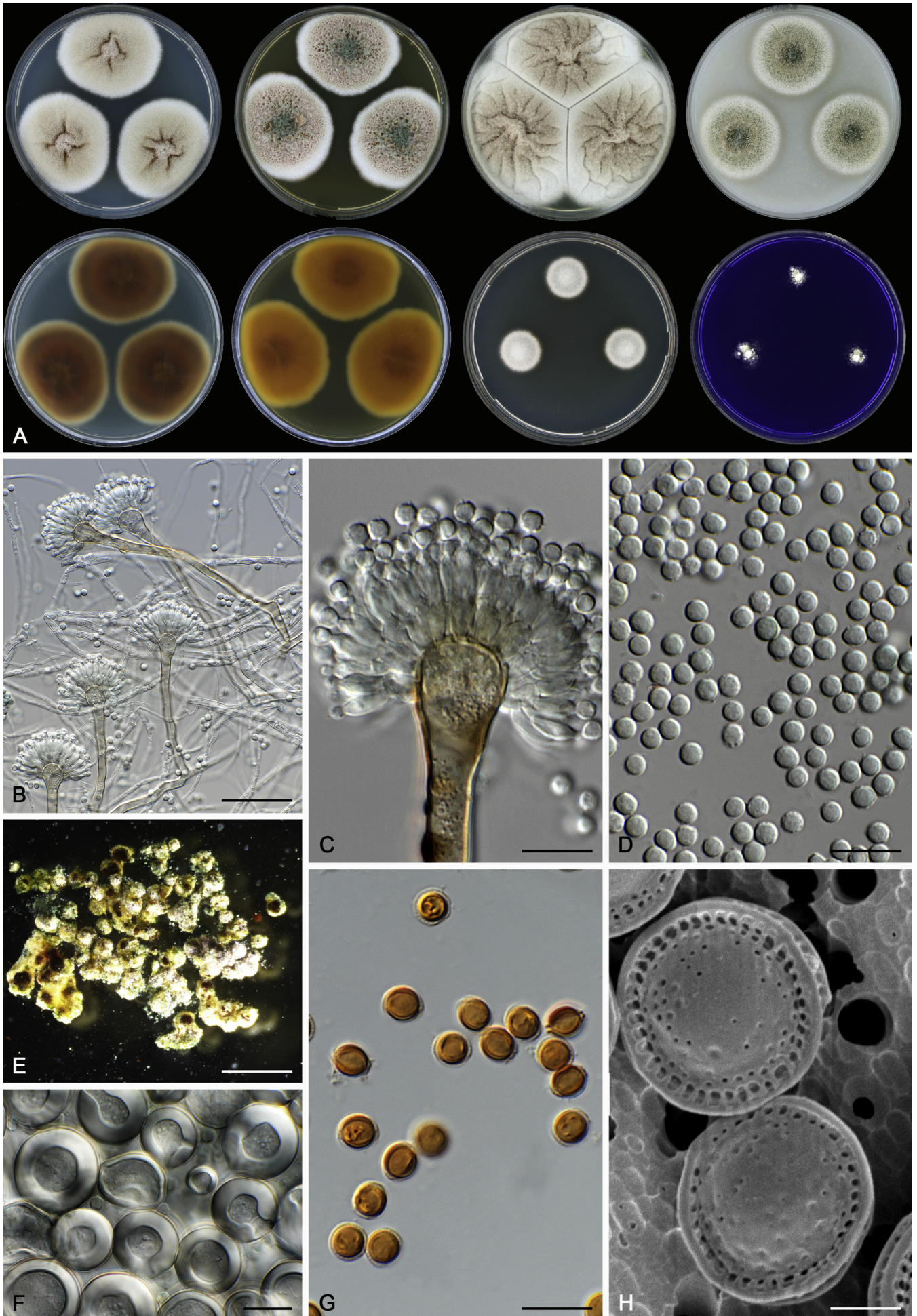
**ITS barcode:** KX423658. (Alternative markers: *BenA* = KX423622; *CaM* = KX423635; *RPB2* = KU867034).

**Colony diam, 7 d (mm):** CYA 50–51; CYA 37 °C >60; CYA 40 °C >60; MEA 50–52; MEA 37 °C >60; OA 35–40; YES >60; CREA 19–20; CYAS 39–40; DG18 21–24.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose;



**Fig. 25.** *Aspergillus filifer* CBS 113636<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascospores. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30 µm; C,D,F,G = 10 µm; E = 1000 µm; H = 2 µm.



**Fig. 26.** *Aspergillus foveolatus* CBS 279.81<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascogonia. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.

sporulation moderately dense, conidia *en masse* pale green; soluble pigments absent; exudates light brown droplets; reverse brown. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* greyish green to dark green; soluble pigments absent; exudates clear droplets; reverse yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* pale green; soluble pigments absent; exudates clear droplets; reverse brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* greyish green to dark green; soluble pigments light brown; exudates absent; reverse cream white. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, superficial, dark brown, globose to subglobose, 100–280 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 7–21.5 µm. Asci 8 spored, globose to subglobose. Ascospores orange to reddish brown, in surface view globose to subglobose, spore bodies finely pitted, 4–5 × 3.5–4.5 µm; in side view lenticular, with two equatorial crests measuring 0.5–1 µm wide. Conidiophores with smooth stipes, light brown to brown, 40–200 × 4.5–6.5 µm; vesicles light brown, subglobose to subclavate, 12–15 µm wide, fertile over the upper half to two thirds; metulae hyaline, 5–7 × 2–4 µm; phialides hyaline, flask-shaped, 6–8 × 2–3 µm. Conidia echinulate, globose to subglobose, 3–4.5 µm.

**Extrolites:** asperthecin, asperugins, 2-ω-hydroxyemodin, emericellin, emestrin, paxillin, shamixanthes, sterigmatocystin, versicolorins, violaceols.

**Distinguishing characters:** *Aspergillus foveolatus* can be easily recognized by pitted ascospores.

***Aspergillus fruticosus*** Raper & Fennell, Gen. *Aspergillus*: 506. 1965. MycoBank MB326630. Fig. 27.

≡ *Emericella fruticulosa* (Raper & Fennell) Malloch & Cain, Can. J. Bot. 50: 61. 1972. ≡ *Aspergillus fruticans* Samson & W. Gams, Adv. Pen. Asp. Syst.: 40. 1985.

**Typus:** IMI 139279. Culture ex-type: CBS 486.65 = NRRL 4903 = ATCC 16823 = IMI 139279 = O-1077 = QM 8033 = WB 4903 = IBT 33973 = DTO 047-H8.

**ITS barcode:** EF652483. (Alternative markers: *BenA* = EF652307; *CaM* = EF652395; *RPB2* = EF652219).

**Colony diam, 7 d (mm):** CYA 24–25; CYA 37 °C 35–36; CYA 40 °C 30–31; MEA 35–36; MEA 37 °C 50–51; OA 30–31; YES 46–47; CREA 3–5; CYAS 13–14; DG18 25–26.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium white and light yellow; texture floccose; sporulation moderately dense, conidia *en masse* pale green; soluble pigments absent; exudates light brown droplets; reverse dark brown. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white and light yellow;

texture floccose; sporulation moderately dense; conidia *en masse* blue green; soluble pigments absent; exudates clear droplets; reverse reddish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white and light yellow; texture velvety; sporulation moderately dense, conidia *en masse* blue green; soluble pigments absent; exudates absent; reverse brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation moderately dense; conidia *en masse* pale green; soluble pigments absent; exudates absent; reverse light yellow at centre, olive green at edge. OA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium light yellow; texture floccose; sporulation moderately dense, conidia *en masse* blue green; soluble pigments yellowish brown; exudates clear droplets; reverse yellowish brown. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, superficial, blackish to dark brown, globose to subglobose, 230–500 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 10–20 µm. Asci 8 spored, globose to subglobose. Ascospores orange to reddish brown, in surface view globose to subglobose, spore bodies smooth, 4.5–5.5 × 3–5 µm; in side view lenticular, with two equatorial crests measuring 0.8–1 µm wide; crests ornamented with longitudinal, 0.3–0.4 µm wide pleats. Conidiophores with smooth stipes, light brown, 40–200 × 4–6 µm; vesicles hyaline to pale brown, subglobose to subclavate, 8–12 µm wide, fertile over the upper half to two thirds; metulae hyaline, 5–6 × 3–4.5 µm; phialides hyaline, flask-shaped, 6–9 × 2–3.5 µm. Conidia echinulate, globose to subglobose, 3.5–4 µm, green in mass.

**Extrolites:** asperthecin, 2-ω-hydroxyemodin, falconensins, falconensons, sterigmatocystin, versicolorins, violaceols.

**Distinguishing characters:** *Aspergillus fruticosus* is close to *A. falconensis* morphologically and phylogenetically, but the ascospore crests of *A. falconensis* (1–2 µm) are wider than in *A. fruticosus* (0.8–1 µm).

***Aspergillus israelensis*** A.J. Chen, Frisvad & Samson, sp. nov. MycoBank MB816091. Fig. 28.

**Etymology:** Name refers to its origin, isolated from evaporation pond, Ein Bokek, Dead Sea, Israel.

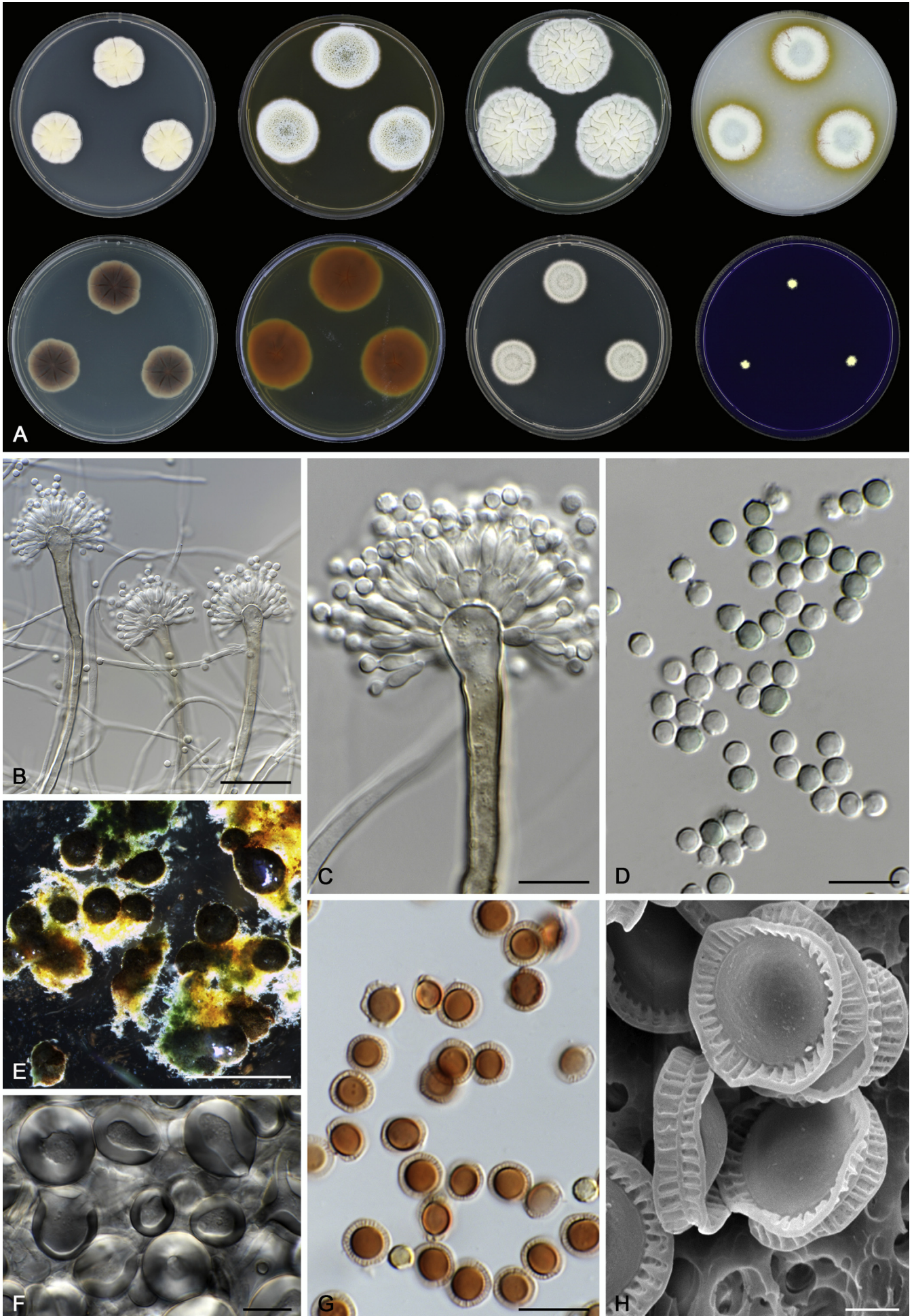
**Diagnosis:** Slow growth on CYA, MEA, OA and YES, narrow conidiophore stipes (3.5–4.5 µm), vesicles (7–10 µm) and globose, tuberculate conidia measuring 2.5–3.5 µm.

**Typus:** **Israel**, Dead Sea, Ein Bokek, evaporation pond, 2002, isolated by L. Butinar (holotype CBS H-22491, culture ex-type: CBS 140627 = IBT 24293 = DTO 325-E2).

**ITS barcode:** KU866677. (Alternative markers: *BenA* = KU866915; *CaM* = KU866797; *RPB2* = KU867062).

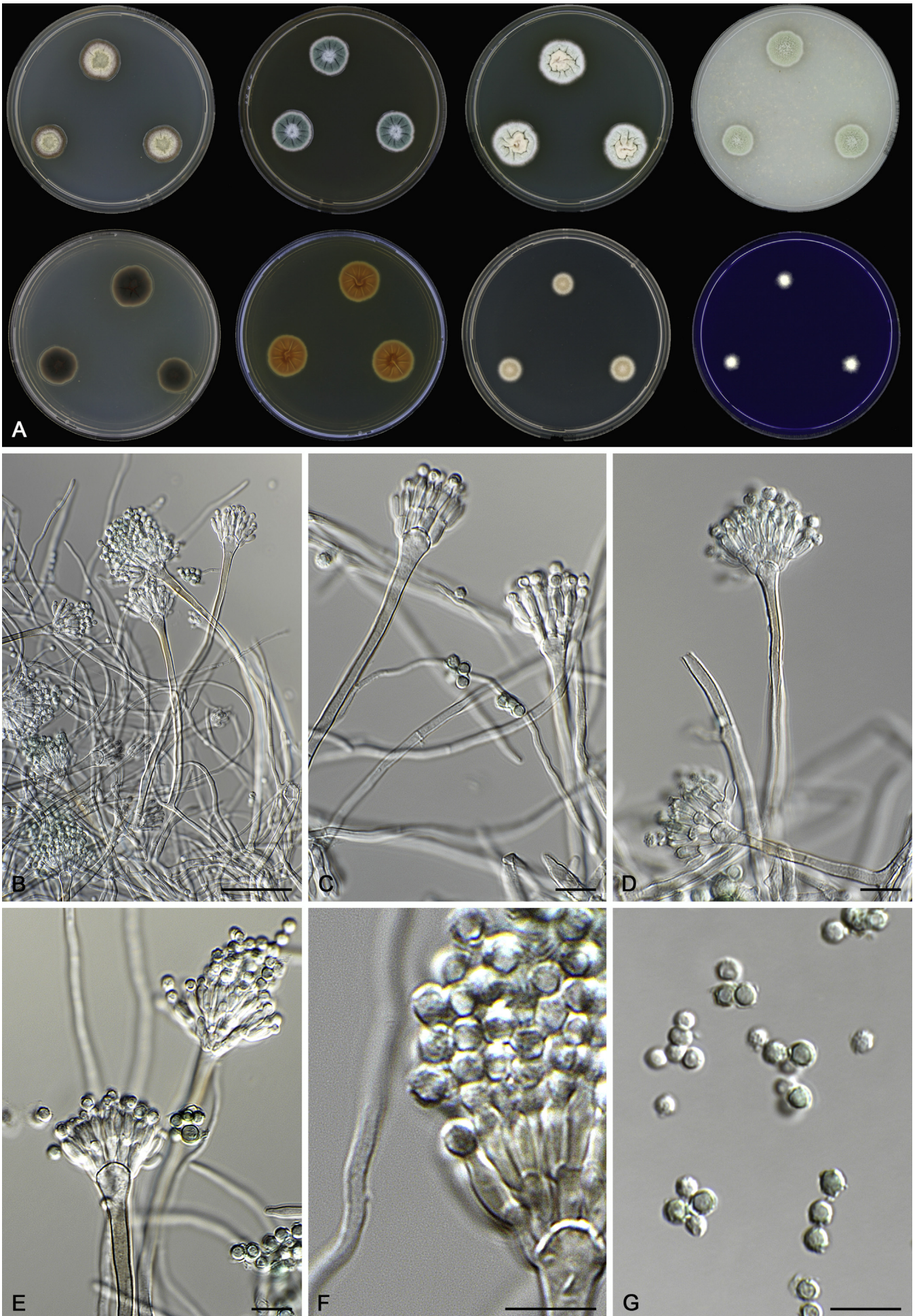
**Colony diam, 7 d (mm):** CYA 10–19; CYA 37 °C No growth; CYA 40 °C No growth; MEA 15–20; MEA 37 °C No growth; OA 14–15; YES 14–22; CREA 8–9; CYAS 12–16; DG18 10–13.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white, wood brown at edge;



**Fig. 27.** *Aspergillus fruticosus* CBS 486.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.





**Fig. 28.** *Aspergillus israelensis* CBS 140627<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–F. Conidiophores. G. Conidia. Scale bars: B = 30  $\mu$ m; C–E, G = 10  $\mu$ m; F = 8  $\mu$ m.

texture velvety; sporulation moderately dense, conidia *en masse* greyish green; soluble pigments absent; exudates absent; reverse dark brown. MEA 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture floccose at centre, velvety at edge; sporulation dense, conidia *en masse* dark green; soluble pigments absent; exudates absent; reverse yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium pale buff; texture velvety; sporulation moderately dense, conidia *en masse* pale green; soluble pigments absent; exudates absent; reverse light brown to yellowish brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white and light buff; texture floccose; sporulation moderately dense, conidia *en masse* pale green; soluble pigments absent; exudates absent; reverse deep olive buff. OA 25 °C, 7 d: Colonies low, plane; margins entire; texture velvety to floccose; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent to light brown; exudates absent; reverse light greyish olive. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata not observed. Conidiophores with smooth stipes, pale brown, 90–160 × 3.5–4.5 µm; vesicles hyaline to pale brown, hemisphere to subclavate, 7–10 µm wide, fertile over the upper half; metulae hyaline to pale brown, 5–8 × 2.5–3.5 µm; phialides hyaline, flask-shaped, 6–8 × 2–2.5 µm. Conidia globose, tuberculate, 2.5–3.5 µm, green in mass.

**Extrolites:** an emindol (and many extrolites, of unknown chemical constitution, only found in this species).

**Distinguishing characters:** Compared to other non-ascospore species, *A. israelensis* grows slower on most of the media (CYA, MEA, OA and YES), it resembles *A. unguis* and *A. asperescens*, but *A. unguis* produces echinulate conidia; *A. asperescens* produces subglobose to ellipsoidal conidia.

***Aspergillus jaipurensis*** Samson, Visagie & Houbraken, Stud. Mycol. 78: 155. 2014. MycoBank MB809592. Fig. 29.  
 ≡ *Emericella indica* Stchigel & Guarro, Mycol. Res. 103: 1059. 1999.  
 (non *Aspergillus indicus* B.S. Mehrotra & Agnihotri, Mycologia 54: 403. 1963)

**Typus:** IMI 378525. Culture ex-type: CBS 952.97 = IMT 378525 = FMR 6232 = IBT 23715 = DTO 320-A9.

**ITS barcode:** KU866623. (Alternative markers: *BenA* = AY339988; *CaM* = KU866761; *RPB2* = KU867024).

**Colony diam, 7 d (mm):** CYA 25–33; CYA 37 °C 38–43; CYA 40 °C 34–36; MEA 32–36; MEA 37 °C 55–>60; OA 31–34; YES 48–51; CREA 5–6; CYAS 14–15; DG18 14–20.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium light brown at centre, white at edge; texture velvety; sporulation sparse; soluble pigments absent; exudates light brown droplets; reverse wood brown. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates light brown droplets; reverse wood brown to yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture

floccose; sporulation absent; soluble pigments absent; exudates absent; reverse light brown. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse cream white. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* pale green to yellow green; soluble pigments absent; exudates absent; reverse light brown. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, superficial, violet to dark brown, globose to subglobose, 150–500 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale yellowish, globose to ovoid, 14–25 µm. Asci 8 spored, globose to subglobose. Ascospores purplish red, in surface view globose to subglobose, spore bodies smooth, 6–7.5 × 5.5–6 µm; in side view lenticular, with two pleated equatorial crests measuring 0.8–1 µm; crests ornamented with longitudinal, 0.2 µm wide pleats. Conidiophores with smooth stipes, pale yellowish brown, 30–100 × 4–6 µm; vesicles hyaline to pale brown, subclavate to subglobose, 7–9 µm wide, fertile over the upper half; metulae hyaline to pale brown, 5–6.5 × 2.5–3.5 µm; phialides hyaline to pale brown, flask-shaped, 5–7 × 2–3.5 µm. Conidia verrucose to tuberculate, globose to subglobose, 4–6.5 × 3–4.5 µm. (Anamorphic structures were observed from OA).

**Extrolites:** asperugins, an austalide (tentatively identified), emestrin, emindols, shamixanones, violaceols.

**Distinguishing characters:** *Aspergillus jaipurensis* is characterized by large, purplish red ascospores, which can easily distinguish it from other species in section *Nidulantes*.

**Notes:** In combination with the recent adoption of the one fungus one name concept, *Emericella indica* was transferred to *Aspergillus*. Since the name *A. indicus* is already occupied, the new name *A. jaipurensis* was proposed (Samson et al. 2014), which was named after the city Jaipur in India, the origin of the type strain.

***Aspergillus latilabiatu***s A.J. Chen, Frisvad & Samson, sp. nov. MycoBank MB816093. Fig. 30.

**Etymology:** The name refers to the lip shaped crests of ascospores.

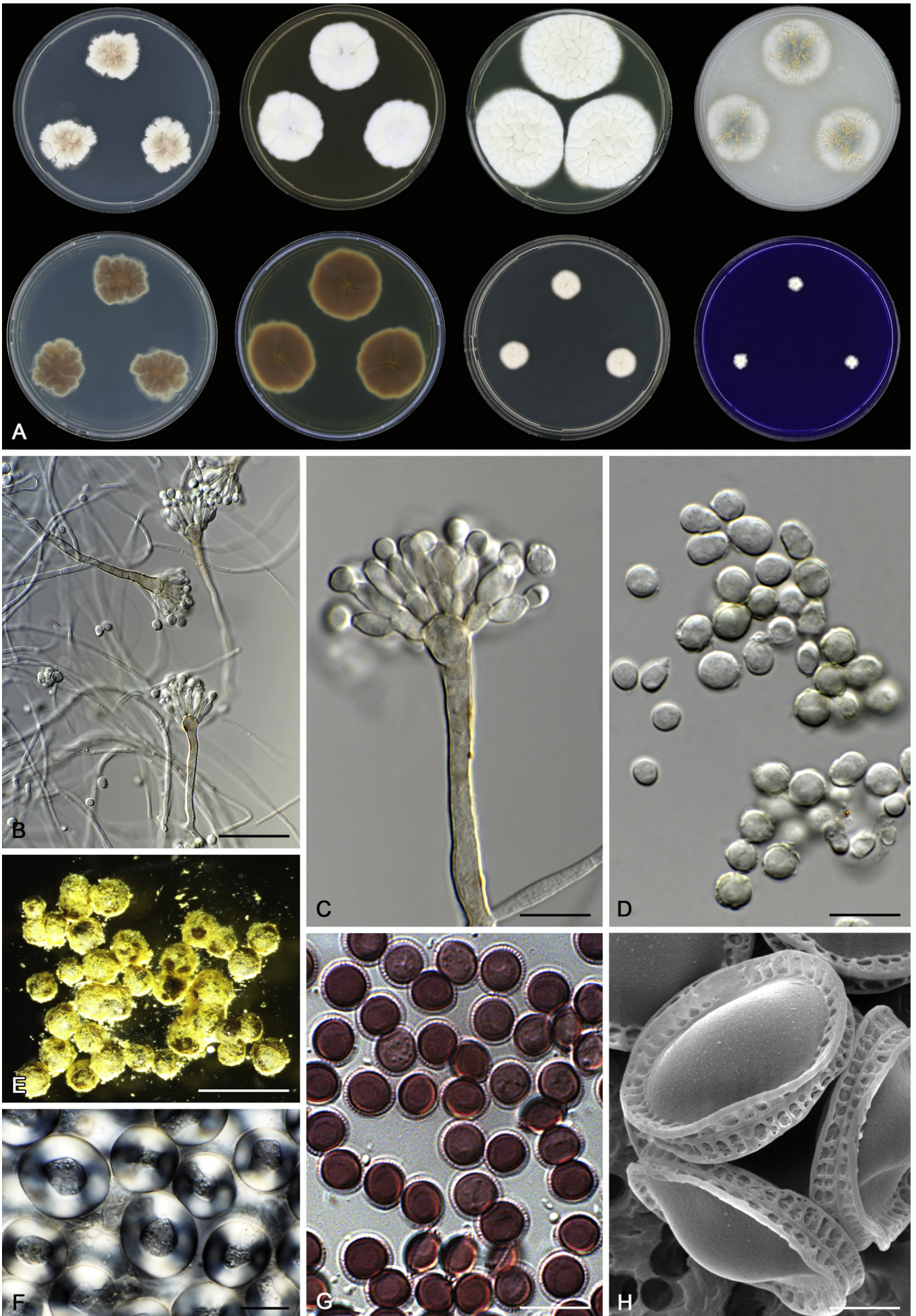
**Diagnosis:** Brown, smooth ascospores with two thick equatorial crests.

**Typus:** Algeria, Kerzaz, sheep dung, 1993, isolated by M. Locquin-Linard (holotype CBS H-22514, culture ex-type: CBS 426.93 = IBT 33959 = DTO 320-B2).

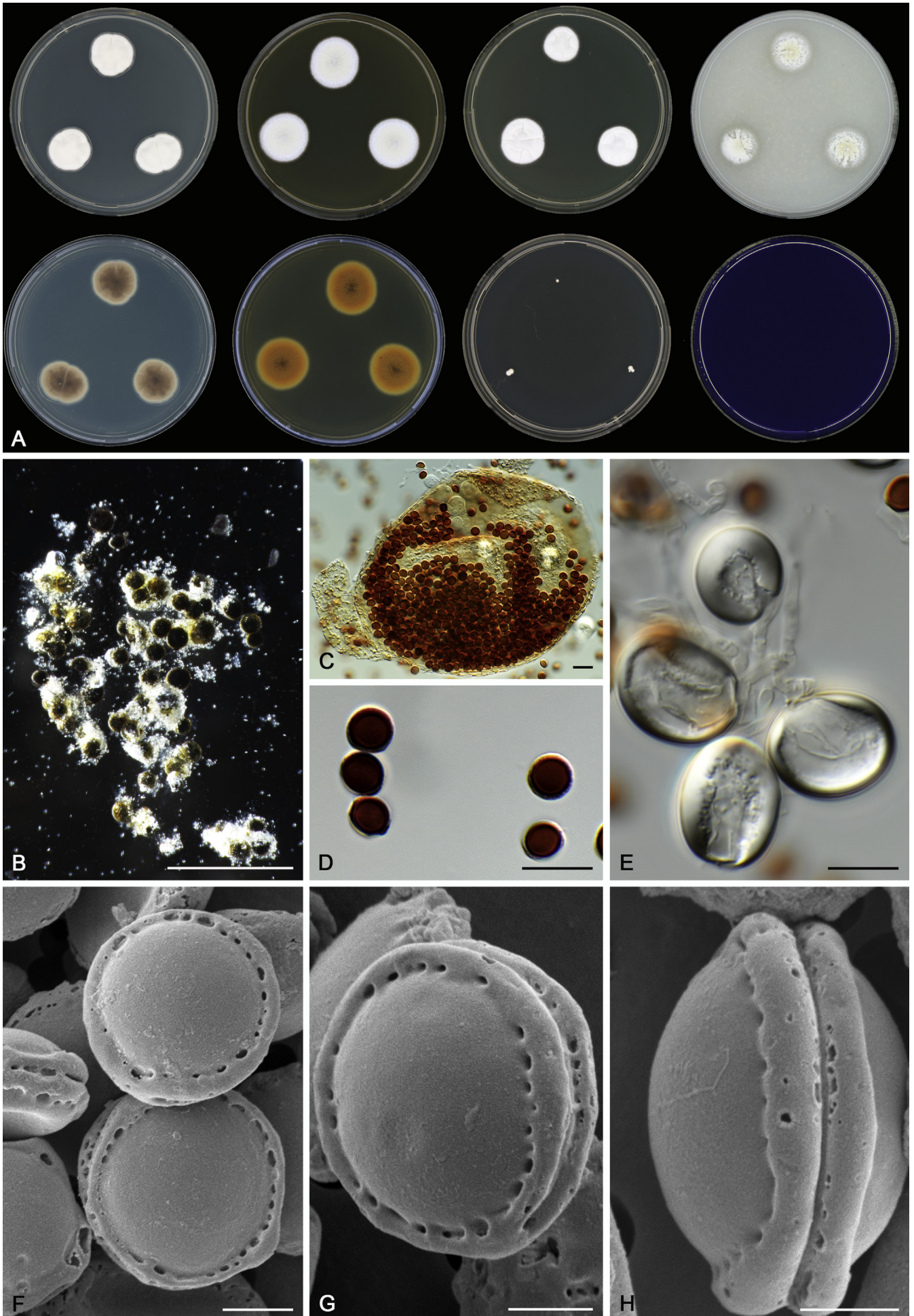
**ITS barcode:** KU866624. (Alternative markers: *BenA* = KU866864; *CaM* = KU866762; *RPB2* = KU867025).

**Colony diam, 7 d (mm):** CYA 22–23; CYA 37 °C 33–37; CYA 40 °C 25–28; MEA 27–28; MEA 37 °C 41–42; OA 22–23; YES 27–28; CREA No growth; CYAS 16–17; DG18 1–4.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins slightly irregular; mycelium white;



**Fig. 29.** *Aspergillus jaipurensis* CBS 952.97<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



**Fig. 30.** *Aspergillus latilabiatu* CBS 426.93<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Ascomata. D,F–H. Ascospores. E. Hülle cells. Scale bars: B = 30  $\mu$ m; C–E = 10  $\mu$ m; F–H = 2  $\mu$ m.

texture floccose to velvety; sporulation absent; soluble pigments absent; exudates absent; reverse brown. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse yellowish brown to reddish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse light brown. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse cream white. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture velvety; sporulation absent; soluble pigments absent; exudates absent; reverse yellowish brown to brown. CREA 25 °C, 7 d: No growth.

**Micromorphology:** Ascomata cleistothecial, superficial, blackish to dark brown, globose, 100–160 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 13–24 µm. Asci 8 spored, globose to subglobose. Ascospores brown, in surface view globose to subglobose, spore bodies smooth, 5.5–7 × 4.5–6 µm; in side view lenticular, with two equatorial crests measuring 0.5–1 µm wide; crests smooth. Anamorph absent.

**Extrolites:** asperthecin, emericellin, emerins, a versicolorin.

**Distinguishing characters:** *Aspergillus latilabiatatus* is close to *A. navahoensis* and *A. purpureus*, but *A. navahoensis* produces reddish brown, smaller ascospores (3.5–4.5 × 3–3.5 µm); *A. purpureus* grows slower on CYA, MEA, YES and OA.

***Aspergillus latus*** (Thom & Raper) A.J. Chen, Frisvad & Samson, **comb. nov.** MycoBank MB816100. Fig. 31.

**Basionym:** *Aspergillus nidulans* var. *latus* Thom & Raper, *Mycologia* 31: 660. 1939.

≡ *Emericella nidulans* var. *lata* (Thom & Raper) Subram., *Curr. Sci.* 41: 758 1972.

= *Aspergillus sublatus* Y. Horie, *Trans. Mycol. Soc. Japan* 20: 481. 1979. = *Emericella sublata* Y. Horie, *Trans. Mycol. Soc. Japan* 20: 481. 1979.

= *Aspergillus montenegroi* Y. Horie, Miyaji & Nishim., *Mycoscience* 37: 137. 1996 = *Emericella montenegroi* Y. Horie, Miyaji & Nishim., *Mycoscience* 37: 137. 1996.

**Typus:** CBS H-7051. Culture ex-type: CBS 492.65 = ATCC 16848 = IMI 074181 = NRRL 200 = QM 7425 = WB 200 = IBT 22844 = DTO 047-H2.

**ITS barcode:** KF465768. (Alternative markers: *BenA* = AB248334; *CaM* = KU866693; *RPB2* = KU866946).

**Colony diam, 7 d (mm):** CYA 43–52; CYA 37 °C >60; CYA 40 °C 54– >60; MEA 38–51; MEA 37 °C >60; OA 33–46; YES 58– >60; CREA 12–46; CYAS 25–46; DG18 13–31.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire or slightly irregular; mycelium white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse dark brown to yellowish brown. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse*

yellow green to olive green; soluble pigments absent; exudates light brown droplets; reverse yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white and light yellow; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse light yellowish brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white and pale yellow; texture floccose; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse cream white. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture velvety; sporulation sparse to moderately dense, conidia *en masse* yellow green; soluble pigments light brown; exudates clear droplets; reverse light yellowish brown. Ascomata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, superficial, dark violet to reddish brown, globose to subglobose, 150–400 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 14–30 µm. Asci 8 spored, globose to subglobose. Ascospores light orange, orange or reddish brown, in surface view globose to subglobose, spore bodies smooth, incompletely reticulate or ribbed, globose to subglobose, 3.5–5 × 3–5 µm; in side view lenticular, with two pleated equatorial crests measuring 1–1.5 µm. Conidiophores with smooth stipes, pale brown, 150–300 × 4.5–5.6 µm; vesicles pale brown, subglobose to subclavate, 10–12.5 µm wide, fertile over the upper half; metulae hyaline to pale green, 3.5–8 × 3–4 µm; phialides hyaline to pale green, flask-shaped, 6.5–11 × 2–3.5 µm. Conidia echinulate, globose to subglobose, 2.5–5 µm, green in mass.

**Extrolites:** asperthecin, asperugins, an austalide (tentatively identified), emericellin, an emindol, shamixanthones, sterigmatocystin, versicolorins, a violaceol.

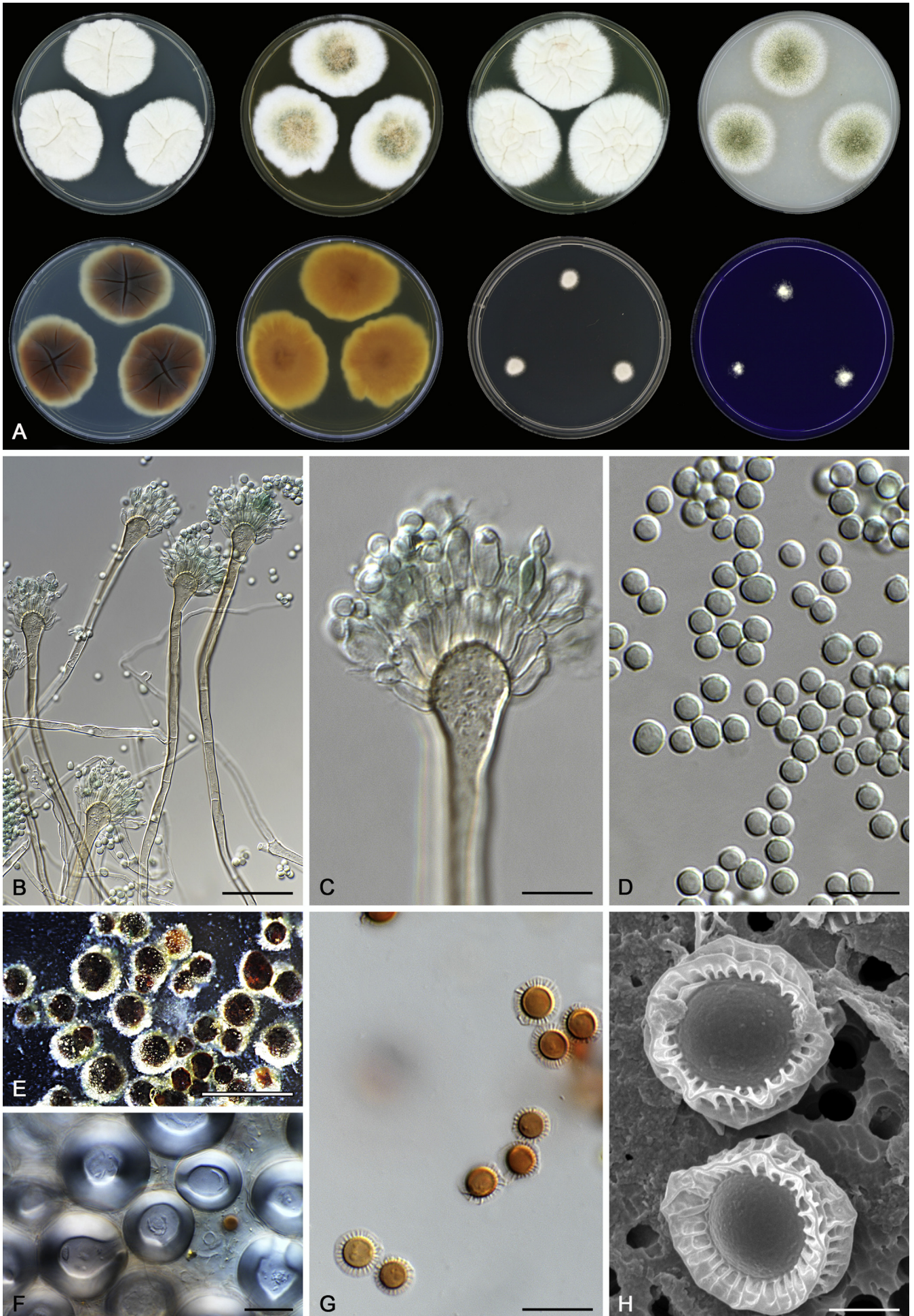
**Distinguishing characters:** *Aspergillus latus* resembles *A. nidulans*, *A. quadrilineatus* and *A. spinulosporus*, but can be distinguished by two wider crests and smooth convex.

**Notes:** Horie (1979) described *Aspergillus sublatus* based on its relatively smaller ascospores compared with *A. latus*, but we observed similar ascospores in the type culture: 4–4.5 × 3–5 µm in CBS 140630 (ex-type of *A. sublatus* Fig. 4I,J); 3.5–5 × 3–5 µm in CBS 492.65 (ex-type of *A. latus* Fig. 4G,H). *Aspergillus montenegroi* produces similar ascospores measuring 3.6–4.8 × 3.2–3.6 µm, some of the ascospores have smooth convex, while some have incompletely reticulate or ribbed ornamentation on convex walls (Horie *et al.* 1996b). *Aspergillus sublatus* and *A. montenegroi* are phylogenetically identical to *A. latus*, and are considered synonyms.

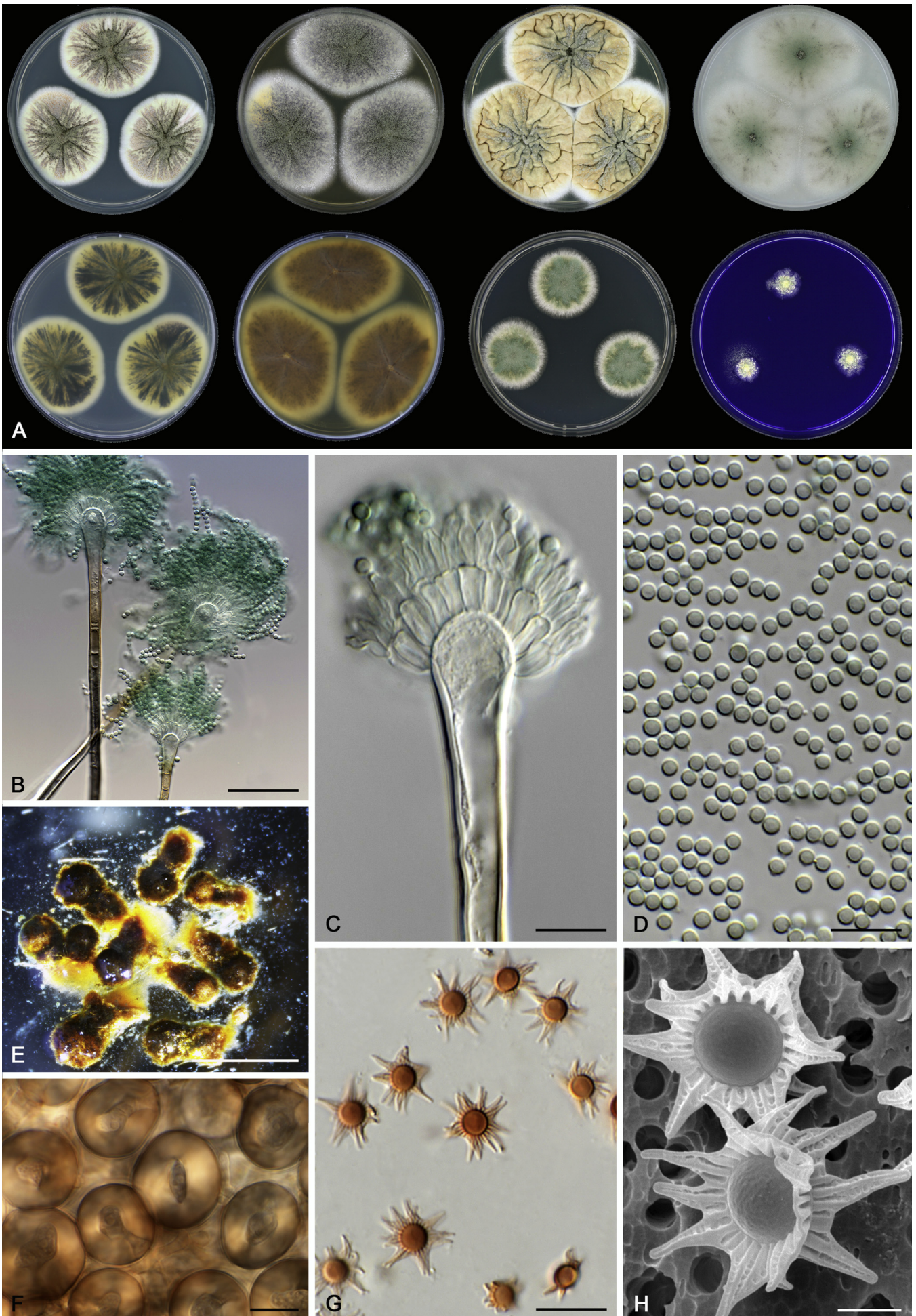
In Matsuzawa *et al.* (2012), the ex-type of *A. latus* clustered with *A. quadrilineatus* based on *BenA*, but clustered with *A. nidulans* based on *CaM* and *actin*, we re-sequenced this strain, and it shows consistent position with *A. quadrilineatus* based on *BenA*, *CaM* and *RPB2*.

***Aspergillus miraensis*** (Zhang, Chen & Guo) Hubka, S.W. Peterson & M. Kolařík, *Plant Syst. Evol.* 302: 1288. 2016. Mycobank MB816283. Fig. 32.

≡ *Emericella miraensis* Zhang, Chen & Guo, *Mycotaxon* 125: 132. 2013.



**Fig. 31.** *Aspergillus latus* CBS 492.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



**Fig. 32.** *Aspergillus miraensis* CBS 140625<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.

*Typus*: CGMCC 3.14984. Culture ex-type: CBS 140625 = CGMCC 3.14984 = IBT 33946 = IBT 36278 = DTO 323-B2.

*ITS barcode*: KU866642 (Alternative markers: *BenA* = KC342577; *CaM* = KU866780; *RPB2* = KU867045).

*Colony diam*, 7 d (mm): CYA 47–48; CYA 37 °C No growth; CYA 40 °C No growth; MEA >60; MEA 37 °C No growth; OA >60; YES >60; CREA 13–20; CYAS 42–45; DG18 33–34.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium light yellow and white; texture granular due to ascumata production; sporulation moderately dense, conidia *en masse* olive green; soluble pigments absent; exudates absent; reverse light yellow with radiate dark brown; large amount of ascumata present after 1 wk. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate to sulcate; margins entire; mycelium white and saffron; texture granular due to ascumata production; sporulation moderately dense, conidia *en masse* olive green; soluble pigments absent; exudates clear droplets; reverse yellowish brown. YES 25 °C, 7 d: Colonies deep, sulcate; margins entire; mycelium saffron and white; texture floccose; sporulation moderately dense, conidia *en masse* greyish green; soluble pigments absent; exudates absent; reverse cream yellow. Ascumata present after 1 wk. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse light yellow to yellowish green. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture granular due to ascumata production; sporulation sparse, conidia *en masse* yellow green; soluble pigments absent; exudates clear droplets; reverse greyish olive. Ascumata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascumata cleistothecial, superficial, reddish brown, globose to subglobose, 320–600 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale yellowish brown, globose to ovoid, 14–22 µm. Asci 8 spored, stellate to subglobose. Ascospores orange to reddish brown (violet in original description of Zhang *et al.* 2013), in surface view stellate, 8–10 µm; spore bodies smooth, (verrucose in original description of Zhang *et al.* 2013) globose to subglobose, 2–4 × 2–3 µm; in side view broadly lenticular, with two stellate equatorial crests; undissected part of crests 0.7–1 µm broad, with 1.5–2.5 µm long extensions; crests ornamented with longitudinal, 0.3–0.4 µm wide pleats. Conidiophores with smooth stipes, light brown, 300–500 × 5–6 µm; vesicles hyaline to pale green, subclavate to subglobose, 12–15 µm wide, fertile over the upper half to two thirds; metulae hyaline to pale green, 5–8 × 3–4 µm; phialides hyaline to pale green, flask-shaped, 6–8 × 2–3.5 µm. Conidia echinulate, globose to subglobose, 2–3.5 µm.

*Extrolites*: aflatoxin B1, asperthecin, 2- $\omega$ -hydroxyemodin, a desertorin, emericellin, shamixanones, sterigmatocystin.

*Distinguishing characters*: *Aspergillus miraensis* is close to *A. stellatus* and *A. stella-maris*, but can be distinguished by

smaller ascospores and conidia. In addition, *A. miraensis* grows faster on CYA, MEA, YES and OA plates.

***Aspergillus multicolor*** Sappa, *Allionia* 2: 87. 1954. MycoBank MB292849. Fig. 33.

*Typus*: IMI 69875. Culture ex-type: CBS 133.54 = NRRL 4775 = ATCC 16804 = IFO 8133 = IMI 69857 = LSHBBB .356 = QM 1952 = WB 4281 = WB 4775 = DTO 053-C9.

*ITS barcode*: EF652477. (Alternative markers: *BenA* = EF652301; *CaM* = EF652389; *RPB2* = EF652213).

*Colony diam*, 7 d (mm): CYA 39–40; CYA 37 °C 7–8; CYA 40 °C No growth; MEA 46–47; MEA 37 °C 5–6; OA 44–45; YES 55–56; CREA 8–12; CYAS 25–26; DG18 21–22.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium pink to purple drab; texture velvety; sporulation moderately dense, conidia *en masse* dull green to olive green; soluble pigments absent; exudates light brown droplets; reverse greyish olive. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium pink to purple drab; texture velvety; sporulation moderately dense, conidia *en masse* dull green to olive green; soluble pigments absent; exudates light brown droplets; reverse buffy brown. YES 25 °C, 7 d: Colonies deep, sulcate; margins entire; mycelium pink to purple drab; texture velvety; sporulation absent; soluble pigments absent; exudates light brown droplets; reverse greyish olive. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture velvety to floccose; sporulation dense, conidia *en masse* yellow green to olive green; soluble pigments absent; exudates absent; reverse light brown at centre, cream yellow at edge. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium pink to purple drab; texture velvety; sporulation limited at centre, conidia *en masse* blue green; soluble pigments light brown; exudates clear droplets; reverse deep olive buff. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascumata not observed. Conidiophores with smooth stipes, pale brown, 300–350 × 5–7 µm; vesicles hyaline, globose to subclavate, 16–20 µm wide, fertile over the two thirds; metulae hyaline, 6–10 × 3–4 µm; phialides hyaline, flask-shaped, 8–9 × 2.5–3 µm. Conidia globose to subglobose, echinulate, 3.5–5.5 µm. Hülle cells pale pink, globose to ovoid, 12–20 µm.

*Extrolites*: asticolourin A, B, C, violaceols.

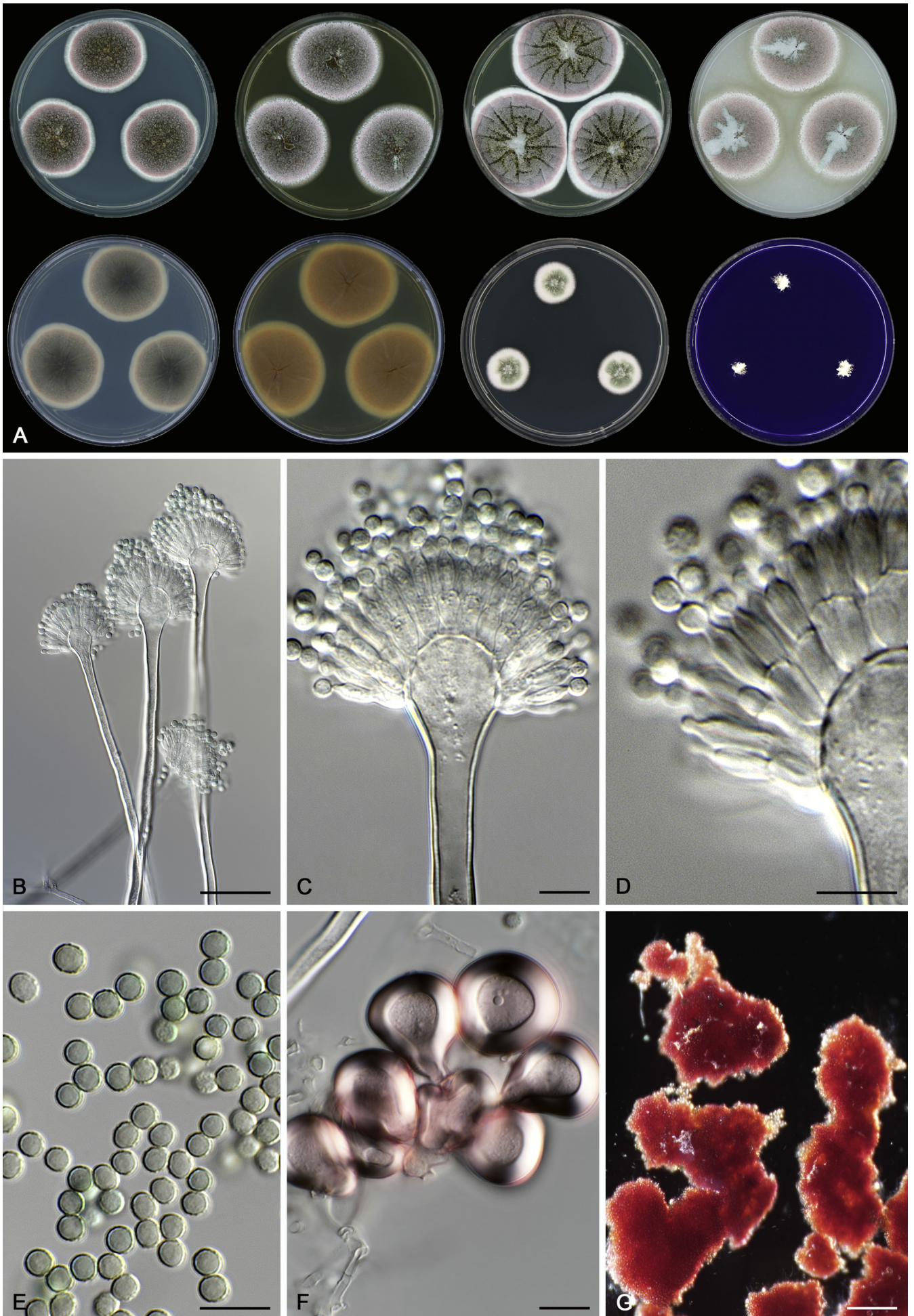
*Distinguishing characters*: The pink to purple drab mycelium and pink Hülle cells can easily distinguish *A. multicolor* from other related species. Brown Hülle cells were mentioned in Raper & Fennell (1965).

***Aspergillus mulundensis*** Bills & Frisvad, *J Antibiot.* 69: 143. 2016. MycoBank MB813062. Fig. 34.

= *Aspergillus sydowii* var. *mulundensis* Roy *J Antibiot.* 40:275. 1987. *nomen nudum*

*Typus*: DSMZ 5745. Culture ex-type: CBS 140610 = DSMZ 5745 = IBT 33104 = DTO 316-C9.





**Fig. 33.** *Aspergillus multicolor* CBS 133.54<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–E. Conidiophores and Conidia. F,G. Hülle cells. Scale bars: B = 30  $\mu$ m; C–F = 10  $\mu$ m; G = 1000  $\mu$ m.

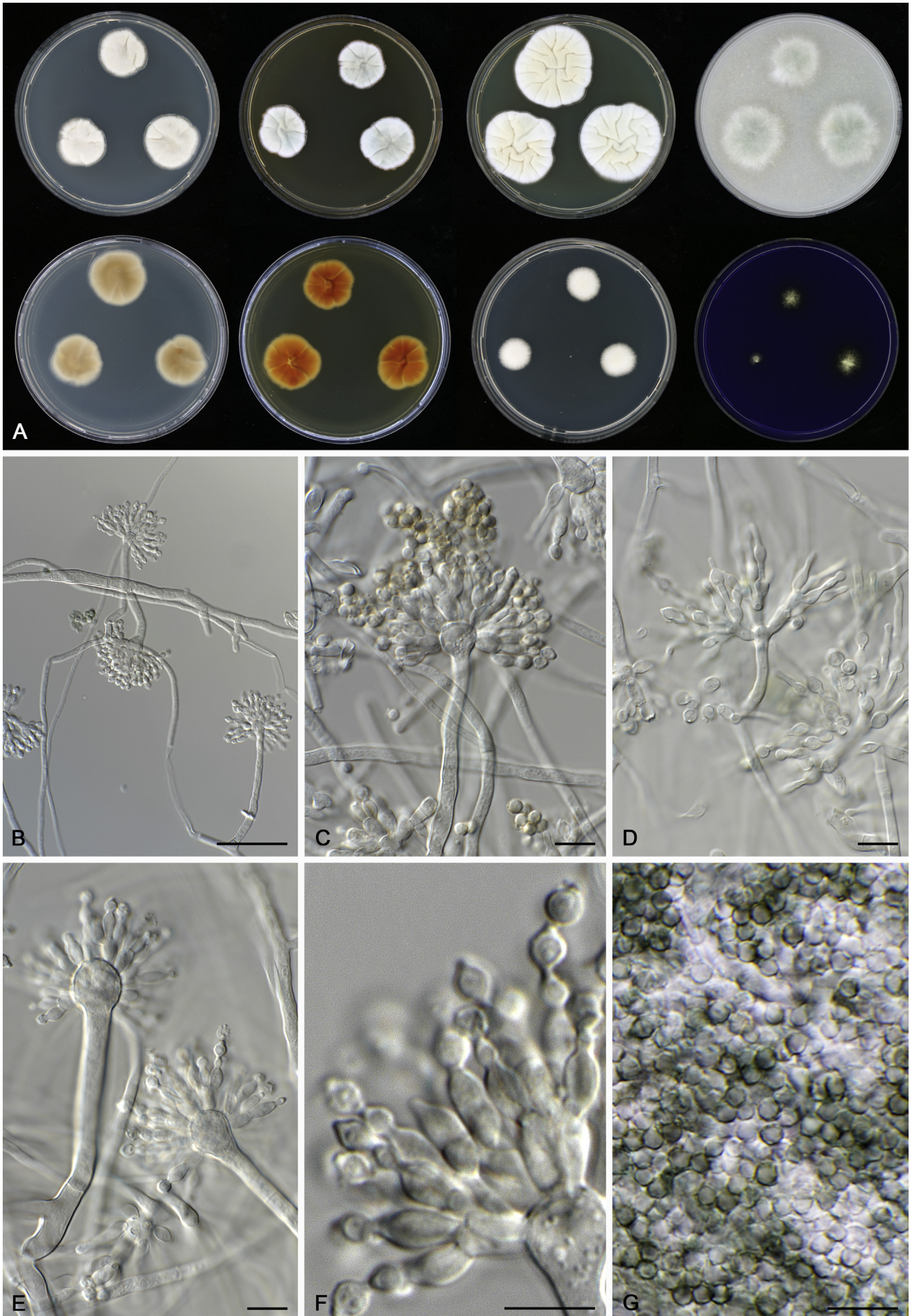


Fig. 34. *Aspergillus mulundensis* CBS 140610<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–F. Conidiophores. G. Conidia. Scale bars: B = 30  $\mu$ m; C–E, G = 10  $\mu$ m; F = 8  $\mu$ m.

ITS barcode: KU866604. (Alternative markers: *BenA* = KU866833; *CaM* = KU866729; *RPB2* = KU866989).

*Colony diam*, 7 d (mm): CYA 22–23; CYA 37 °C 4–8; CYA 40 °C No growth; MEA 24–25; MEA 37 °C 5–6; OA 30–31; YES 36–37; CREA 6–11; CYAS 13–15; DG18 15–17.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white and buff; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse yellowish brown. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins slightly irregular; mycelium white and light yellow; texture velvety; sporulation moderately dense, conidia *en masse* blue green; soluble pigments absent; exudates light brown droplets; reverse reddish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white and light yellow; texture velvety; sporulation absent; soluble pigments absent; exudates absent; reverse saffron. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse cream white. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* pale green to blue green; soluble pigments light brown; exudates clear droplets; reverse light brown. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata not observed. Conidiophores with smooth stipes, hyaline, 33–70 × 2.5–4.5 µm; vesicles hyaline, globose to subclavate, 5.5–15 µm wide, fertile over the two thirds; metulae hyaline, 5–7 × 2.5–4.5 µm; phialides hyaline, flask-shaped, 6–7.5 × 2.5–4 µm. Conidia globose to subglobose, echinulate, 2.5–3.5 µm. Hülle cells (18.7–31.2 × 25–37.5 µm) were reported in the first publication of the nomen nudum *Aspergillus sydowii* var. *mulundensis* (Roy et al. 1987).

*Extrolites*: deoxymulundocandin, dibenzofurans (asticolourins?), mulundocandin, emericellamides, sclerotiorins or similar azaphilones with the same UV spectra as sclerotiorins (sclerotiorins tentatively identified).

*Distinguishing characters*: Phylogenetically *Aspergillus mulundensis* is close to *A. multicolor*, but *A. multicolor* produces longer conidiophores (300–350 µm), larger vesicles (16–20 µm) and conidia (3.5–5.5 µm). Morphologically *A. mulundensis* resembles *A. aurantiobrunneus*, but *A. mulundensis* grows faster on all tested media.

***Aspergillus navahoensis*** M. Chr. & States, Mycologia 74: 226. 1982. MycoBank MB110496. Fig. 35.

≡ *Emericella navahoensis* M. Chr. & States, Mycologia 74: 226. 1982.

*Typus*: NY SD-5. Culture ex-type: CBS 351.81 = NRRL 13002 = ATCC 44663 = IMI 259971 = IMI 304939 = IBT 10950 = LCP 84.2561 = DTO 047-H7.

ITS barcode: EF652424. (Alternative markers: *BenA* = EF652248; *CaM* = EF652336; *RPB2* = EF652160).

*Colony diam*, 7 d (mm): CYA 34–35; CYA 37 °C 30–33; CYA 40 °C 26–27; MEA 24–25; MEA 37 °C 35–38; OA 40–42; YES 34–35; CREA 2–8; CYAS 18–19; DG18 15–16.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium luteous; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse brown. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins slightly irregular; mycelium light yellow and white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse dark brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium light yellow; texture velvety; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments light brown; exudates absent; reverse dark brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium luteous; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse yellowish brown to brown. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium light yellow and white; texture floccose; sporulation moderately dense, conidia *en masse* pale green; soluble pigments light brown; exudates light brown droplets; reverse yellowish brown. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata cleistothecial, superficial, blackish to dark brown, globose, 140–400 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 13–23 µm. Asci 8 spored, globose to subglobose. Ascospores orange to reddish brown, in surface view globose to subglobose, spore bodies smooth, 3.5–4.5 × 3–3.5 µm; in side view lenticular, with two equatorial crests measuring 0.7–1 µm wide, 0.4 µm thick; crests smooth. Conidiophores with smooth stipes, light brown, 35–150 × 2.5–3 µm; vesicles hyaline to pale brown, subclavate to globose, 6–8 µm wide, fertile over the upper half to two thirds; metulae hyaline, 6–9.5 × 3–4.5 µm; phialides hyaline, flask-shaped, 6–8 × 2.5–3 µm. Conidia echinulate, globose to subglobose, 3.5–4.5 µm, green in mass. (Anamorphic structures were observed from OA).

*Extrolites*: asperthecin, falconensins, cf. falconensons, gregatins, sterigmatocystin, 6,7,8-hydroxy-3-methylisocoumarin, versicolourins, violaceols.

*Distinguishing characters*: *Aspergillus navahoensis* is close to *A. fruticulosus*, *A. nidulans* and *A. pachycristatus*, but can be easily distinguished by smooth, thick crests of ascospores, longer metulae and narrower vesicles.

***Aspergillus nidulans*** (Eidam) G. Winter, Rabenh. Krypt.-Fl., ed. 2, 1: 62. 1884. MycoBank MB182069. Figs 36, 37.

≡ *Sterigmatocystis nidulans* Eidam, Beitr. Biol. Pflanzen 3: 393.1883.

≡ *Emericella nidulans* (Eidam) Vuill., C. R. hebdom. Seanc. Acad. Sci. Paris 184: 137. 1927. ≡ *Aspergillus nidulellus* Samson & W. Gams, Adv. Pen. Asp. Syst.: 44. 1985.

= *Aspergillus nidulans* (Eidam) Wint. var. *dentatus* D.K. Sandhu & R.S. Sandhu, Mycologia 55: 297. 1963. = *Emericella dentata* var. *dentata* (D.K. Sandhu & R.S. Sandhu) Subram., Curr. Sci. 41: 758. 1972. = *Emericella dentata* (D.K. Sandhu & R.S. Sandhu) Y. Horie, Trans. Mycol. Soc. Japan 21: 491.1980. = *Aspergillus dentatulus* Ismail, Abdel-Sater & Zohri, Mycotaxon 53: 397. 1995.

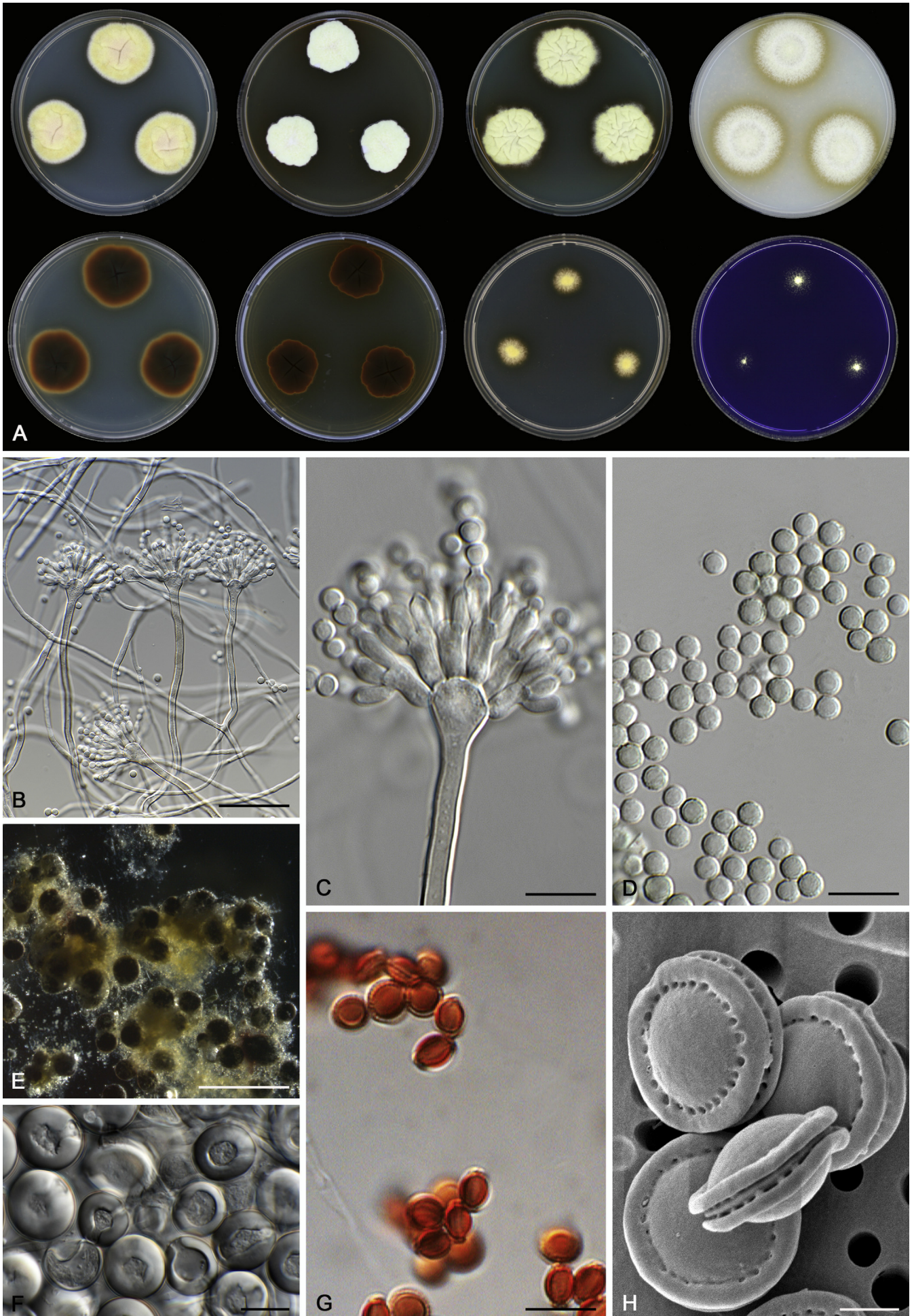
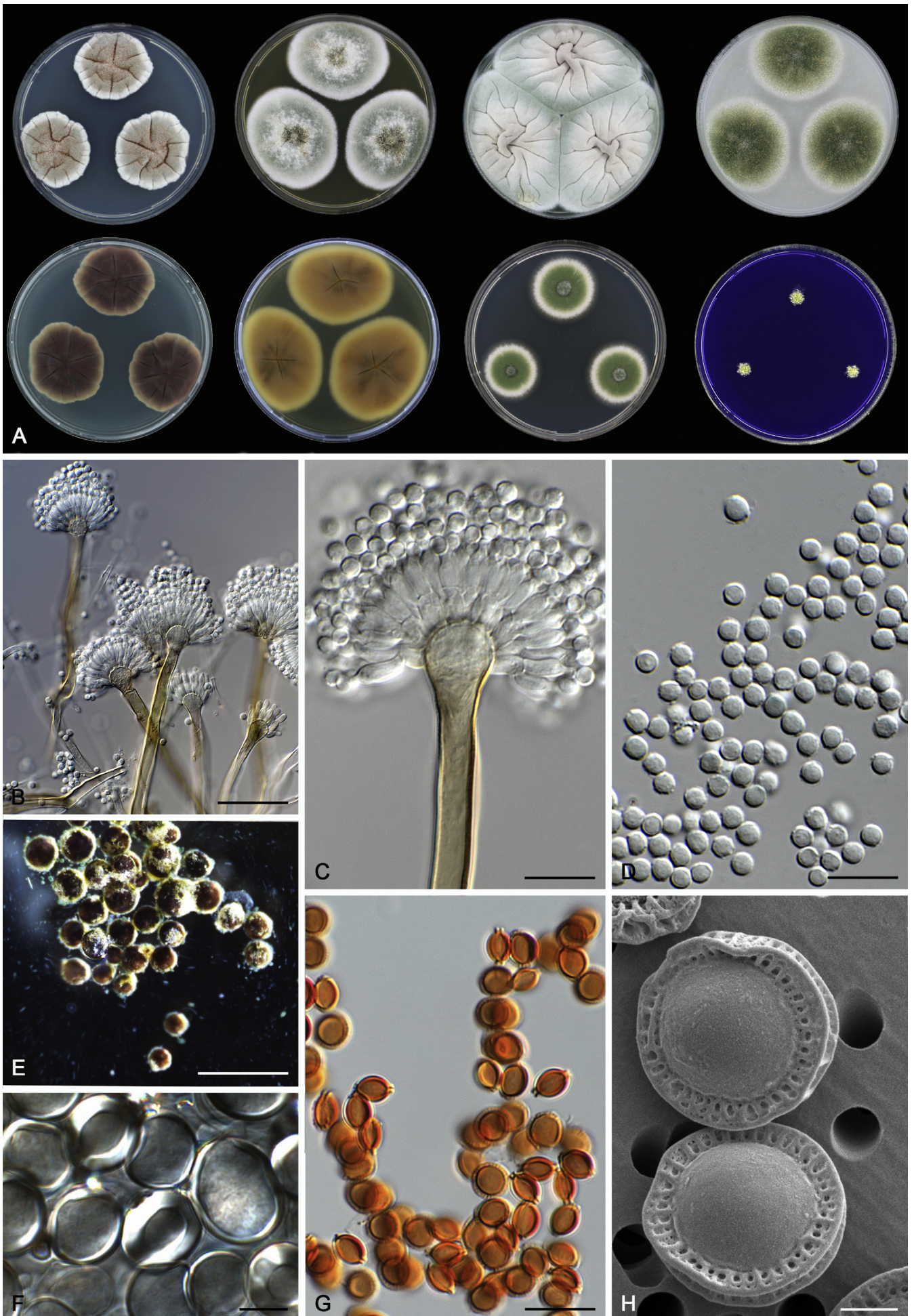
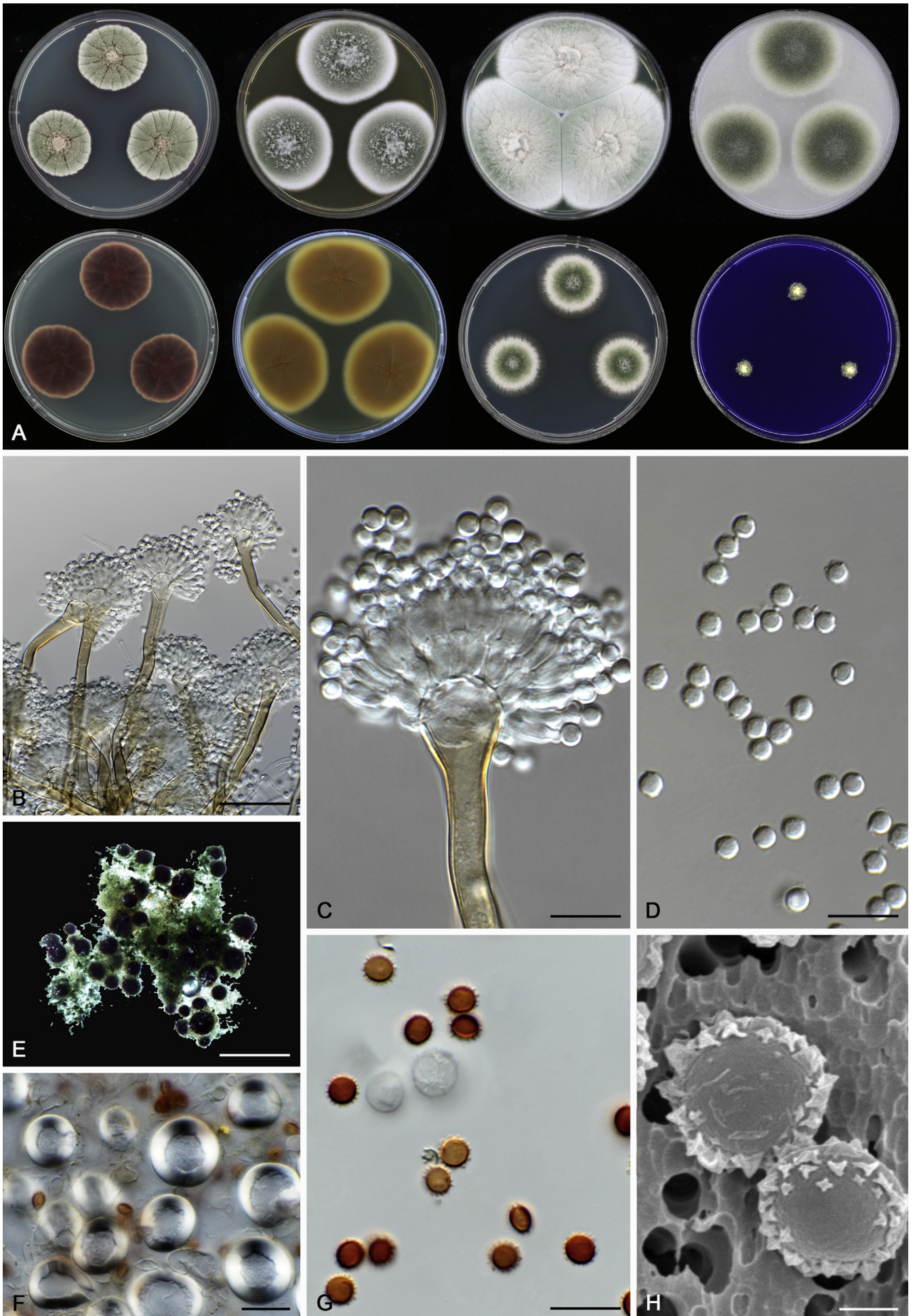


Fig. 35. *Aspergillus navahoensis* CBS 351.81<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



**Fig. 36.** *Aspergillus nidulans* CBS 589.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



**Fig. 37.** *Aspergillus nidulans* CBS 114.63 (ex-type of *A. dentatus*). A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu\text{m}$ ; C,D,F,G = 10  $\mu\text{m}$ ; E = 1000  $\mu\text{m}$ ; H = 2  $\mu\text{m}$ .

*Typus*: IMI 86806. Culture ex-type: CBS 589.65 = NRRL 187 = ATCC 10074 = IHEM 3563 = IMI 126691 = IMI 86806 = QM 1985 = Thom 4640.5 = WB 187 = DTO 047-H9.

*ITS barcode*: EF652427. (Alternative markers: *BenA* = EF652251; *CaM* = EF652339; *RPB2* = EF652163).

*Colony diam*, 7 d (mm): CYA 30–39; CYA 37 °C 47–58; CYA 40 °C 49–55; MEA 41–52; MEA 37 °C >60; OA 36–52; YES >60; CREA 5–10; CYAS 14–40; DG18 22–38.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* olive green; purple red soluble pigment produced after 2 wks; exudates clear droplets; reverse dark reddish brown. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose; sporulation dense, conidia *en masse* greyish green; soluble pigments absent; exudates clear droplets; reverse yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* pale green to yellow green; soluble pigments absent; exudates absent; reverse brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse greyish green. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* yellow green; soluble pigments absent; exudates clear droplets; reverse buffy brown, ascomata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata cleistothecial, superficial, violet to dark brown, globose to subglobose, 150–420 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 12–20 µm. Asci 8 spored, globose to subglobose. Ascospores orange to reddish brown, in surface view globose to subglobose, spore bodies smooth, globose to subglobose, 3.5–5 × 3–4.5 µm; in side view lenticular, with two pleated equatorial crests measuring 0.5–1 µm, crests entire or dentate. Conidiophores with smooth stipes, yellowish brown, 70–220 × 5–8 µm; vesicles pale brown, globose to subclavate, 8–14.5 µm wide, fertile over the upper half to two thirds; metulae hyaline, pale green to pale brown, 5–8 × 2.5–4.5 µm; phialides hyaline to pale green, flask-shaped, 6–8 × 2.5–3.5 µm. Conidia echinulate, globose to subglobose, 3–4 µm.

*Extrolites*: asperthecin, asperugins, austinol, cordycepin, dehydroaustinol, 2-ω-hydroxyemodin, diorcinol, emericellin, shamixanones, sterigmatocystin, versicolorins, violaceols. Asperugins were only detected on CYA with 5 % NaCl. Many further extrolites have been found in this species (Nielsen *et al.* 2011) using different combinations of media, after biological interaction etc (Table 6).

*Distinguishing characters*: *Aspergillus nidulans* resembles *A. quadrilineatus*, but differs in two crests in contrast to four crests on the ascospores of *A. quadrilineatus*.

*Notes*: *Aspergillus nidulans* var. *dentatus* (CBS 114.63), isolated from diseased human fingernails, showed almost full phenotypic

agreement with *A. nidulans* except for its dentate equatorial crests (Sandhu & Sandhu 1963), our observation confirms the original description (Figs 3C, D, 37). *Aspergillus dentatus* shares identical sequences (ITS, *BenA*, *CaM* and *RPB2*) and extrolites with *A. nidulans*, therefore is considered a synonym here.

***Aspergillus olivicola*** Frisvad, Zalar & Samson, *Mycologia* 100: 781. 2008. MycoBank MB507362. Fig. 38.

≡ *Emericella olivicola* Frisvad, Zalar & Samson, *Mycologia* 100: 788. 2008.

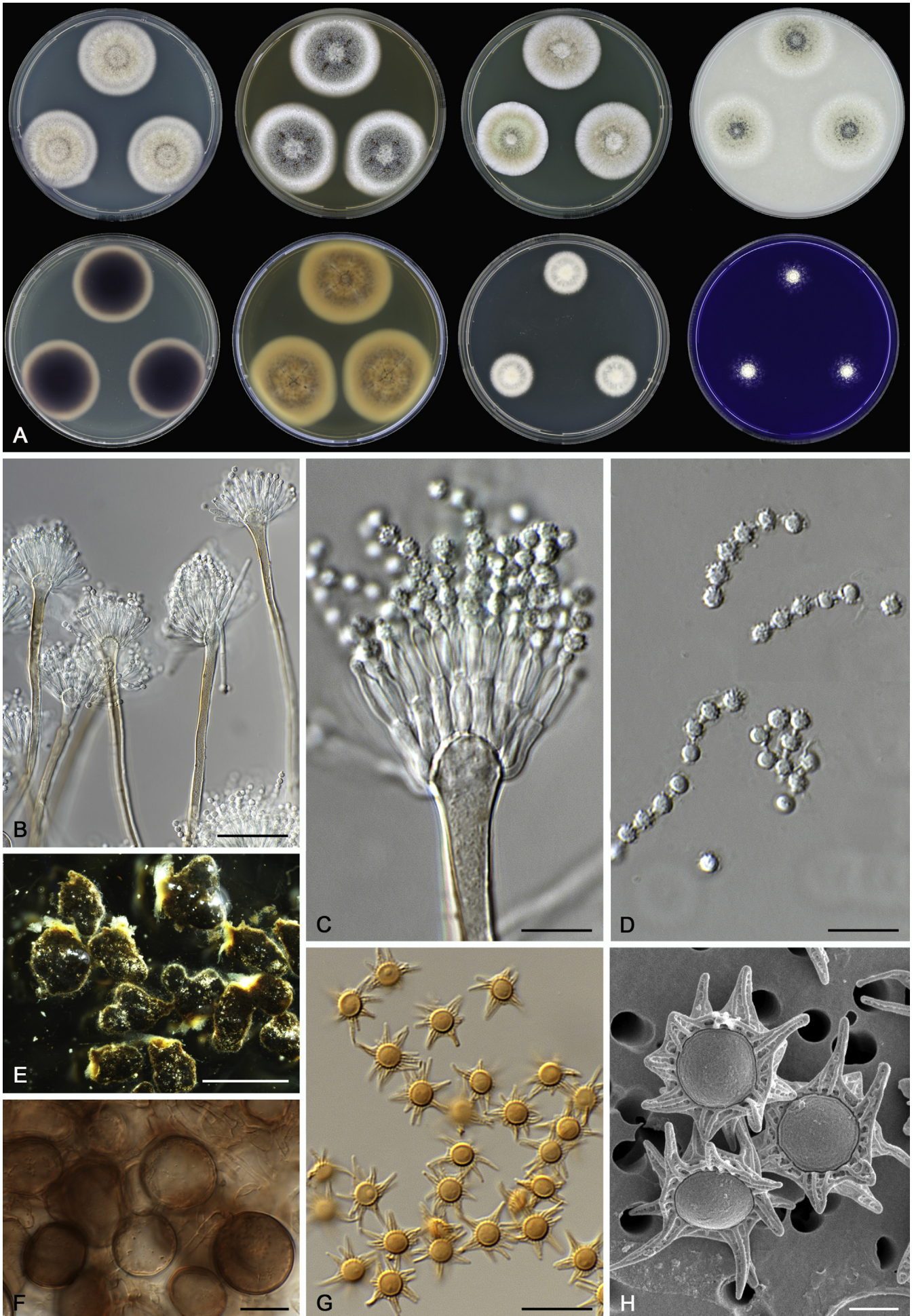
*Typus*: CBS H-19888. Culture ex-type: CBS 119.37 = IBT 21903 = IBT 26499 = DTO 011-A8 = DTO 002-I2.

*ITS barcode*: EU448268. (Alternative markers: *BenA* = AY339996; *CaM* = EU443986; *RPB2* = KU866923).

*Colony diam*, 7 d (mm): CYA 30–36; CYA 37 °C 0–14; CYA 40 °C No growth; MEA 33–42; MEA 37 °C 5–10; OA 30–35; YES 24–39; CREA 12–18; CYAS 27–30; DG18 20–25.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, plane to slightly sulcate; margins entire; mycelium gray to greyish violet; texture floccose; sporulation absent to moderately dense, conidia *en masse* olive green; soluble pigments absent; exudates absent; reverse dark violet to dark brown. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate to sulcate; margins entire; mycelium white; texture granular due to ascomata production; sporulation moderately dense, conidia *en masse* pale green; soluble pigments absent; exudates clear droplets; reverse yellowish brown to cream brown with brown dots, large amount of ascomata present after 1 wk. YES 25 °C, 7 d: Colonies moderately deep, plane to slightly sulcate; margins entire; mycelium smoke gray; texture floccose; sporulation sparse to moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse dark brown at centre, cream white at edge. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse cream white. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture granular due to ascomata production; sporulation sparse; soluble pigments absent; exudates clear droplets; reverse white. Ascomata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata cleistothecial, superficial, greenish brown, globose to subglobose, 400–770 µm, surrounded by numerous Hülle cells; Hülle cells brown, globose to ovoid, 15–28 µm. Asci 8 spored, stellate to subglobose. Ascospores orange to reddish brown, in surface view stellate, 7.5–11 µm; spore bodies smooth, globose to subglobose, 3–4.5 × 3–4 µm; in side view broadly lenticular, with two stellate equatorial crests; undissected part of crests 0.4–0.7 µm broad, with 1–3 µm long extensions; crests ornamented with longitudinal, 0.3–0.5 µm wide pleats. Conidiophores with smooth stipes, yellowish brown, 150–340 × 4–5.5 µm; vesicles hyaline to pale brown, subglobose to subclavate, 8–15 µm wide, fertile over the upper half to two thirds; metulae hyaline, 7.5–10.5 × 2–3.5 µm; phialides hyaline to pale brown, flask-shaped, 7.5–12.5 × 1.5–3 µm. Conidia coarsely echinulate to tuberculate, globose to subglobose, 2–3.5 µm.



**Fig. 38.** *Aspergillus olivicola* CBS 119.37<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



*Extrolites*: aflatoxin B1 and B2, asperugins, asteltoxin, desertorins, emericellin, shamixanthones, sterigmatocystin, terrein, varitriols.

*Distinguishing characters*: Thin-walled Hülle cells, relatively long metulae (7.5–10.5 × 2–3.5 µm) and phialides (7.5–12.5 × 1.5–3 µm), coarsely echinulate conidia, these characters distinguish *A. olivicola* from other stellate ascospored species.

***Aspergillus omanensis*** Y. Horie & Udagawa, Mycoscience 36: 391. 1995. MycoBank MB414655.

≡ *Emericella omanensis* Y. Horie & Udagawa, Mycoscience 36: 391. 1995.

*Typus*: CBM FA-700. Culture ex-type: CBM FA-700 = IFM 54275.

*ITS barcode*: n.a. (Alternative markers: *BenA* = AB248347; *CaM* = AB524047; *RPB2* = n.a.).

*Colony characters*: Fide Horie & Udagawa (1995) colonies on Czapek's solution agar growing restrictedly, attaining a diameter of 25–26 mm in 14 days at 25 °C, more or less floccose, plane, consisting of a thin mycelial felt, producing scattered cleistothecia, Yellowish White (3A2 after Korner & Wanschler 1978) to pale Orange (6A3); conidial heads limited in number, not affecting the colony colour; reverse Brownish Orange (7C4) to Brown (7E6). Colonies on MEA spreading broadly, attaining a diameter of 56–57 mm in 14 days at 25 °C, more or less floccose, plane, consisting of a thin mycelial felt, granular in appearance due to the production of abundant cleistothecia with Hülle cells, overgrown by loose network of aerial hyphae and numerous conidial heads, Greenish Gray (1C2) to Greyish Green (1D3); reverse Greyish Orange (5B3) to Brownish Orange (5C4).

*Micromorphology*: Fide Horie & Udagawa (1995), cleistothecia superficial, scattered or aggregated in a thin layer, globose to subglobose, 180–370 µm in diam, surrounded by a hyaline to pale yellowish brown layer of scattered hyphae bearing numerous globose to subglobose thick-walled Hülle cells measuring 10–35 µm in diam; peridium brown to dark brown, thin, of texture intricate, 2–3-layered; outermost layer consisting of hyphal cells measuring 3–17 µm wide. Asci irregularly disposed, 8-spored, globose to subglobose or ovoid, 11–13.5 × 10–11 µm, evanescent. Ascospores at first hyaline to pale reddish brown, becoming brownish red, broadly lenticular, 4.5–5.5 × 4–4.5 µm including crests, with two conspicuously pleated equatorial crests measuring about 1 µm wide, with a tuberculate or verruculose convex wall. Conidial heads greyish green, short columnar to columnar, 70–190 µm long and 40–70 µm wide. Conidiophores arising mostly from aerial hyphae; stipes short, more or less sinuous, 50–120 × 4–7 µm, orange gray to brownish orange, smooth-walled; vesicles subglobose to subclavate, orange gray, 10–14 µm in diam, fertile over the upper half. Aspergilla biseriata; metulae greyish white to pale greyish green, 4–7 × 2–3 µm; phialides greyish white to pale greyish green, 5–8 × 2–4 µm. Conidia globose to subglobose, 4–5.5 µm in diam, verruculose.

*Extrolites*: Strain not available.

*Distinguishing characters*: Molecular analysis shows *A. omanensis* as a unique species. Fide Horie & Udagawa (1995) its morphology resembles that of *A. spinulosporus* and

*A. desertorum*, but can be distinguished from *A. spinulosporus* by tuberculate or verruculose ornamentation on ascospore convex walls; and from *A. desertorum* by much smaller ascospores. Unfortunately, the type strain is unavailable and cannot be investigated during our study.

***Aspergillus pachycristatus*** Matsuzawa, Y. Horie & Yaguchi, Mycoscience 53: 439. 2012. MycoBank MB580944. Fig. 39.

≡ *Emericella pachycristata* Matsuzawa, Y. Horie & Yaguchi, Mycoscience 53: 439. 2012.

*Typus*: IFM 55265. Culture ex-type: IFM 55265 = NBRC 104790.

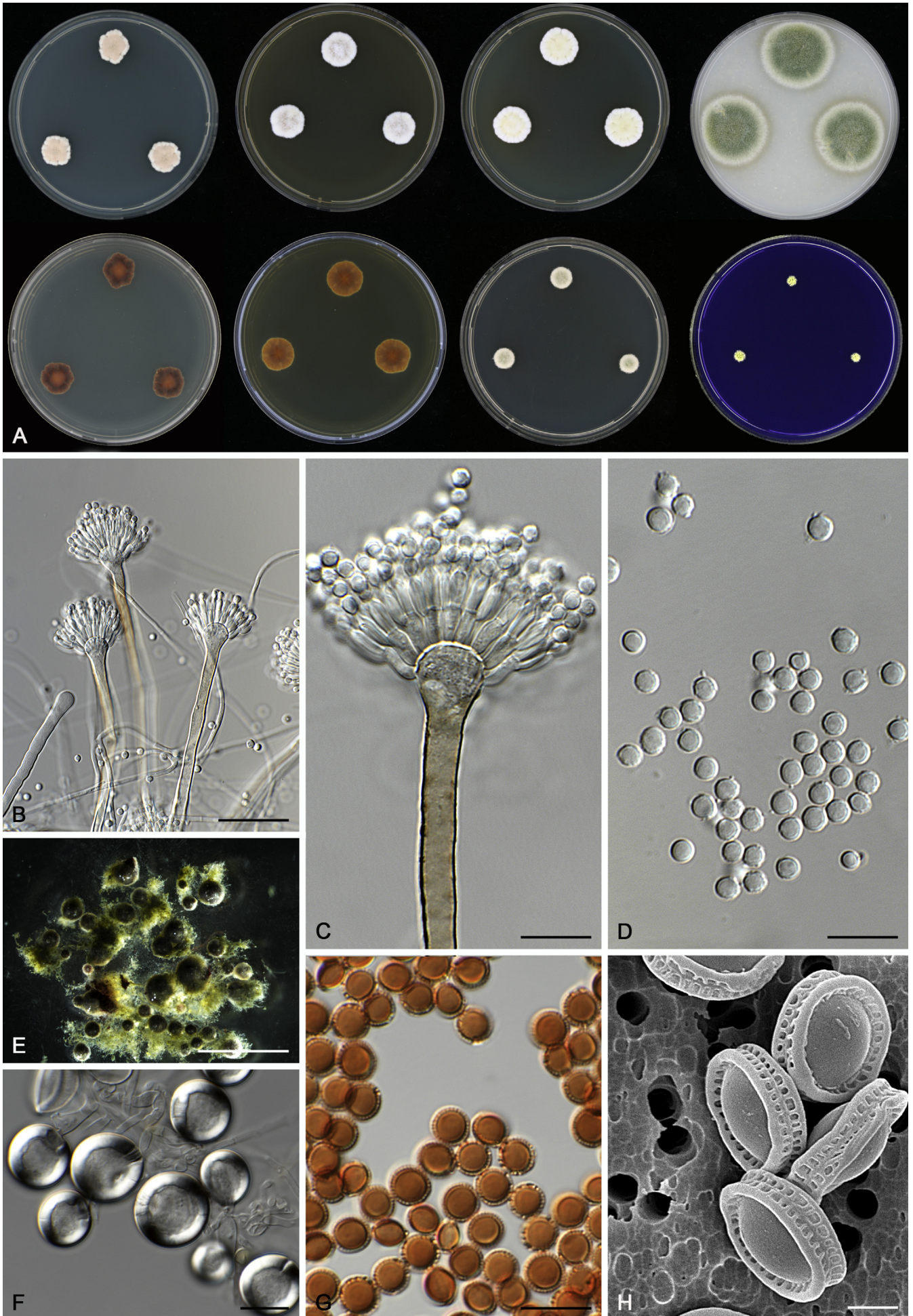
*ITS barcode*: n.a. (Alternative markers: *BenA* = AB375875; *CaM* = AB524062; *RPB2* = n.a.).

*Colony diam*, 7 d (mm): CYA 13–14; CYA 37 °C 45–56; CYA 40 °C 42–54; MEA 15–16; MEA 37 °C >60; OA 25–32; YES 17–19; CREA 3–4; CYAS 10–12; DG18 7–10.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins slightly irregular; mycelium white and rosy buff; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse dark reddish brown. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates light brown to purple droplets, large amount of purple droplets present on MEA at 37 °C after 1 wk; reverse dark reddish brown. Ascomata present after 2 wks. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium white and light yellow; texture floccose; sporulation moderately dense, conidia *en masse* greyish green; soluble pigments absent; exudates absent; reverse reddish brown. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins slightly irregular; mycelium buff; texture floccose; sporulation moderately dense, conidia *en masse* greyish green; soluble pigments absent; exudates absent; reverse ochraceous buff. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white and light yellow; texture floccose to velvety; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments light brown; exudates absent; reverse cream white to light brown. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata cleistothecial, superficial, blackish to dark brown, globose to subglobose, 200–500 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 11–21 µm. Asci 8 spored, globose to subglobose. Ascospores orange to reddish brown, in surface view globose to subglobose, spore bodies smooth, 4–5 × 3.5–4 µm; in side view lenticular, with two equatorial crests measuring 0.7–1 µm wide, 0.4 µm thick; crests ornamented with longitudinal, 0.3–0.4 µm wide pleats. Conidiophores with smooth stipes, light brown, 150–260 × 5–6 µm; vesicles hyaline to pale brown, subclavate, 8–12 µm wide, fertile over the upper half to two thirds; metulae hyaline, 5.5–7.5 × 2.5–4 µm; phialides hyaline, flask-shaped, 6–9 × 2.5–3.5 µm. Conidia echinulate, globose to subglobose, 3–4 µm. (Anamorphic structures were observed from OA).

*Extrolites*: asperugins, echinocandins, emecorrugatin, sterigmatocystin, versicolorins, violaceols.



**Fig. 39.** *Aspergillus pachycristatus* NRRL 11440. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.

*Distinguishing characters:* Morphologically, *Aspergillus pachycristatus* resembles *A. nidulans*, but the ascospore crests are thicker in *A. pachycristatus*. The smooth ascospore convex can distinguish it from phylogenetically related *A. rugulosus*.

***Aspergillus pluriseminatus*** (Stchigel & Guarro) Samson, Visagie & Houbraken, *Stud. Mycol.* 78: 155. 2014. MycoBank MB809595.

≡ *Emericella pluriseminata* Stchigel & Guarro, *Mycologia* 89: 937. 1997.

*Typus:* FMR 5588; isotype IMI 370867. Culture ex-type: CBS 100523 = FMR 5588 = IMI 370867 = DTO 011-H1.

*ITS barcode:* KU866566. (Alternative markers: *BenA* = AY339989; *CaM* = EU443988; *RPB2* = KU866937).

*Colony diam, 7 d (mm):* CYA 20–25; CYA 37 °C No growth; CYA 40 °C No growth; MEA 31–32; MEA 37 °C No growth; OA 12–22; YES 28–30; CREA No growth; CYAS 1–2; DG18 1–2.

*Colony characters:* CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium pale pink to pale yellow at centre, white at edge; texture velvety; sporulation absent; soluble pigments absent; exudates clear droplets; reverse reddish brown. MEA 25 °C, 7 d: Colonies sulcate, plane; margins entire; mycelium white; texture velvety; sporulation absent; soluble pigments absent; exudates light brown droplets; reverse yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium pale pink to pale yellow at centre, white at edge; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse yellowish brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse cream white to yellow. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse reddish brown to yellowish brown. CREA 25 °C, 7 d: No growth.

*Micromorphology:* *Fide* Stchigel & Guarro (1997) ascomata superficial, globose, nonostiolate, blackish, with green iridescence, 80–250 µm diam, produced very late, appearing after 2–3 months, surrounded by a felt of hyphae and Hülle cells and supported by masses of scattered hyphae and Hülle cells; Hülle cells pale yellowish to orange-brown, globose to irregularly shaped, thick-walled, 10–22 µm diam. Peridium 4–12 µm thick, pale to yellowish-brown, semi-translucent to translucent, *textura intricate* to *epidermoidea*, 3–7 layered, cells of the outer layer measuring 3–14 µm diam. Asci 16 spored (8 spored according to Zalar *et al.* 2008), globose to broadly ellipsoidal, with several broad wall protrusions, 22–35 µm diam, evanescent. Ascospores one-celled, at first hyaline, becoming violet-brown, lenticular, 7–9 × 6–7 µm (crest not included), with two conspicuously pleated, stellate and striate equatorial crests, 4–8 µm wide; convex surface tuberculate under SEM. Anamorph absent.

*Extrolites:* Dibenzofurans (asticolourins?), sclerotiorins (tentatively identified), violaceols.

*Distinguishing characters:* The large, violet stellate ascospores with tuberculate convex surface can distinguish *Aspergillus pluriseminatus* from other related species.

*Notes:* According to Stchigel & Guarro (1997), ascomata of *A. pluriseminatus* are produced very late, and only produced on PCA. Unfortunately, we could not find ascomata on several kinds of media including PCA after 3 months. Zalar *et al.* (2008) observed 8 spored instead of 16 spored asci in *A. pluriseminatus*.

***Aspergillus purpureus*** Samson & Mouch., Antonie van Leeuwenhoek 41: 350. 1975. MycoBank MB309237.

Fig. 40.

≡ *Emericella purpurea* Samson & Mouch., Antonie van Leeuwenhoek 41: 350. 1975.

*Typus:* CBS 754.74. Culture ex-type: CBS 754.74 = NRRL 6133 = IMI 334937 = LCP 82.3323 = DTO 047-H5.

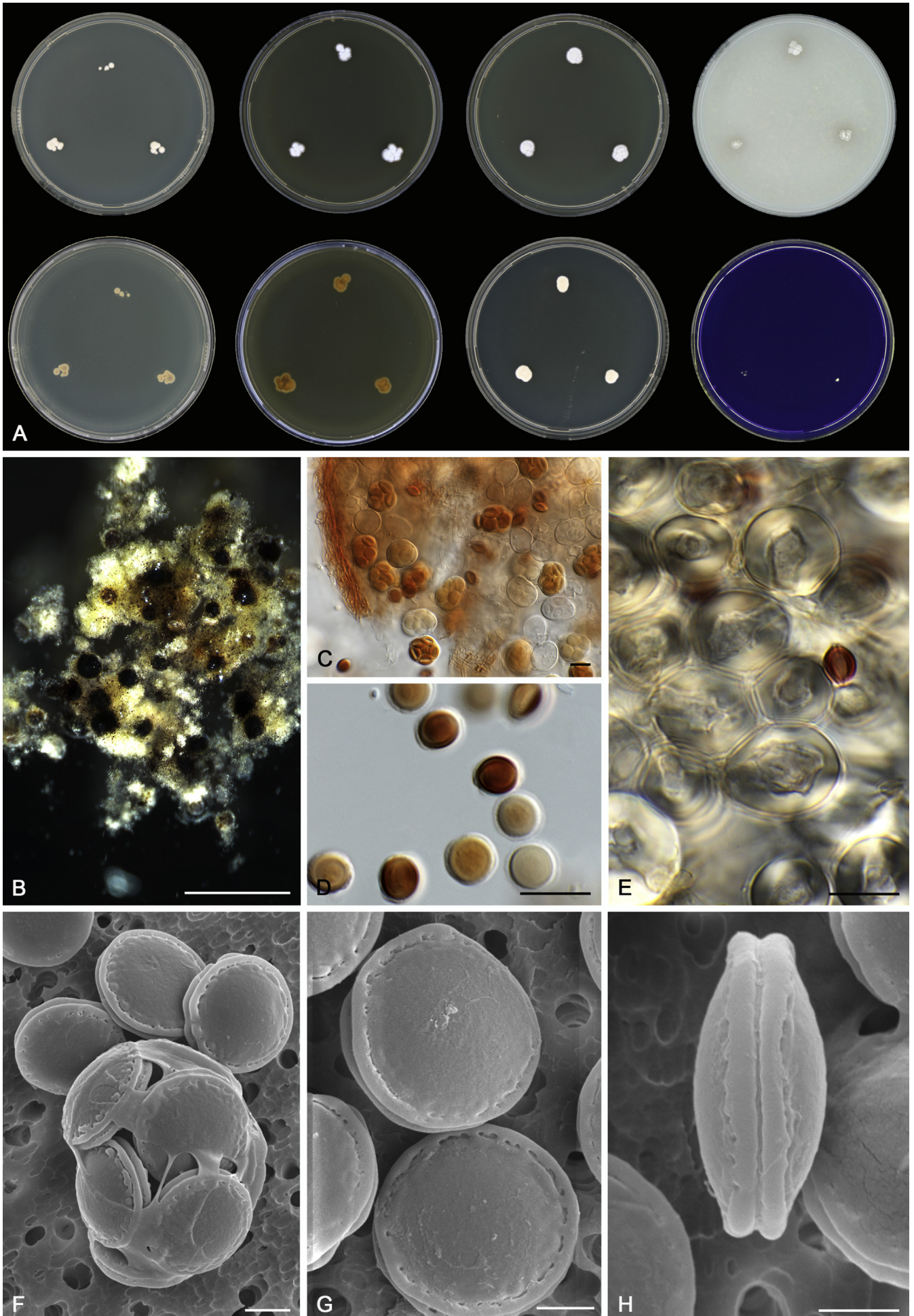
*ITS barcode:* EF652506. (Alternative markers: *BenA* = EF652330; *CaM* = EF652418; *RPB2* = EF652242).

*Colony diam, 7 d (mm):* CYA 5–7; CYA 37 °C No growth; CYA 40 °C No growth; MEA 7–10; MEA 37 °C No growth; OA 5–7; YES 7–9; CREA 1–2; CYAS No growth; DG18 7–8.

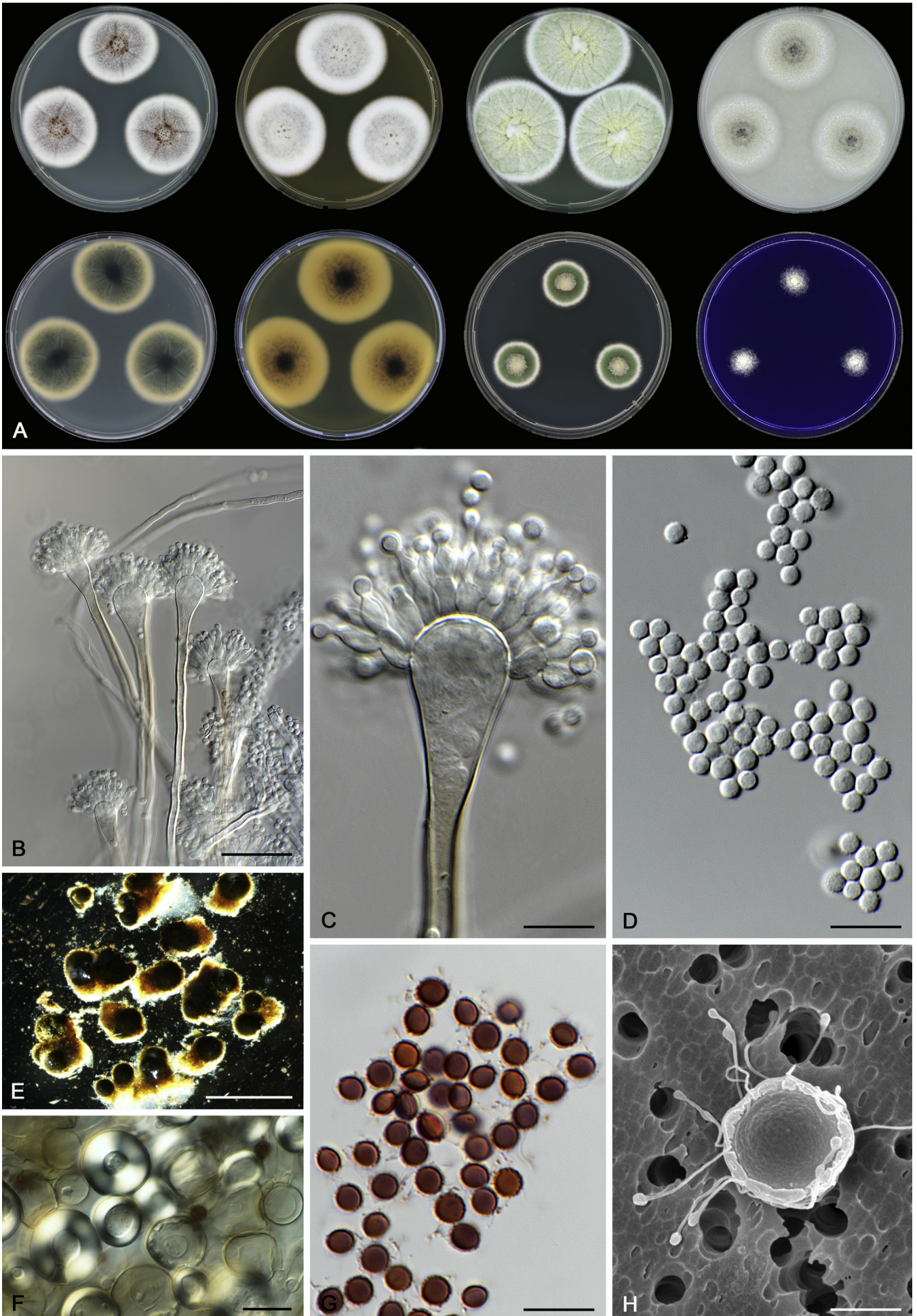
*Colony characters:* CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse rosy buff; MEA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse reddish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse dark brown at centre, cream yellow at edge. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse cream white. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse white. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology:* Ascomata cleistothecial, superficial, blackish to dark brown, globose to subglobose, 90–200 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale yellowish brown, globose to ovoid, 8–20 µm. Asci 8 spored, globose to subglobose. Ascospores brown, in surface view globose to subglobose, spore bodies smooth, 6–7 × 4.5–5 µm; in side view lenticular, with two low crests measuring 0.3–0.6 µm wide. *Fide* Samson & Mouchacca (1975) conidial structures mostly absent on Czapek or MEA, but sometimes produced in old slant cultures on the glass surface; on Czapek agar with 20 % or more sucrose conidiophores are produced after one month. Conidial heads white, radiate, biserial. Conidiophores hyaline, 40–50 × 2.5–5 µm. Vesicles ellipsoidal to clavate, 6–8 µm in diam. Metulae cylindrical, 3.5–6 × 2.5–3.5 µm bearing 2 to 3 phialides each. Phialides flask-shaped with short but distinct neck, 6–8 × 2.5–3 µm. Conidia ellipsoidal to cylindrical, hyaline, smooth, 3.5–5.5 × 1.5–2 µm.

*Extrolites:* calbistrins, emerins, emindol PA, epurpurin A–C, norsolorinic acid, shamixanthones, variecolins, versicolorins.



**Fig. 40.** *Aspergillus purpureus* CBS 754.74<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B. Ascomata. C. Asci. D,F–H. Ascospores. E. Hülle cells. Scale bars: B = 1000  $\mu$ m; C–E = 10  $\mu$ m; F–H = 2  $\mu$ m.



**Fig. 41.** *Aspergillus qingxianii* CBS 128788<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascospores. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.

**Distinguishing characters:** *Aspergillus purpureus* can be distinguished from other related species by large brown ascospores and the restricted growth on tested media.

**Notes:** Hyaline conidiophores, smooth-walled cylindrical conidia (3.5–5.5 × 1.5–2 µm) were recorded in the original description (Samson & Mouchacca 1975), but are not confirmed in this study.

***Aspergillus qinqixianii*** Y. Horie, Abliz & R.Y. Li, Mycoscience 41: 183. 2000. MycoBank MB464660. Fig. 41.

≡ *Emericella qinqixianii* Y. Horie, Abliz & R.Y. Li, Mycoscience 41: 183. 2000.

**Typus:** CBM FA-866. Culture ex-type: CBS 128788 = IFM 55020 = CMB-FA-866 = DTO 098-H6.

**ITS barcode:** KU866600. (Alternative markers: *BenA* = AB524360; *CaM* = AB524051; *RPB2* = KU866980).

**Colony diam, 7 d (mm):** CYA 40–42; CYA 37 °C 23–30; CYA 40 °C No growth; MEA 45–46; MEA 37 °C 26–28; OA 35–38; YES 54–55; CREA 16–17; CYAS 25–34; DG18 21–25.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white and gray; texture floccose; sporulation sparse; soluble pigments absent; exudates clear to light brown droplets; reverse dark olive green; Ascomata present after 1 wk. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white and light yellow; texture floccose; sporulation sparse; soluble pigments absent; exudates clear to light brown droplets; reverse dark brown at centre, yellowish brown at edge. Ascomata present after 1 wk. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse cream yellow to dark brown. Ascomata present after 1 wk. DG18 25 °C, 7 d: Colonies moderately deep; plane; margins entire; mycelium buff at centre, white at edge; texture floccose; sporulation dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse pale yellow green. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture granular due to ascomata production; sporulation moderately dense; conidia *en masse* yellow green; soluble pigments absent; exudates clear to light brown droplets; reverse pale olive. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, superficial, greyish green to brown, globose to subglobose, 200–510 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale yellowish brown, globose to ovoid, 16–24 µm. Asci 8 spored, stellate. Ascospores brown, in surface view globose to subglobose, spore bodies smooth, 3.5–4.5 × 3–4 µm; in side view broadly lenticular, with two equatorial crests measuring 0.5 µm wide; Crest bearing hyaline, filiform appendages, measuring 3–7 µm long with swollen tips. Conidiophores with smooth stipes, yellowish brown, 120–280 × 3–5 µm; vesicles hyaline to pale yellowish brown, subglobose to subclavate, 7–12 µm wide, fertile over the upper half; metulae hyaline to pale yellowish brown, 4–8 × 3–5 µm; phialides hyaline to pale yellowish brown, flask-shaped, 7–8 × 2–4 µm. Conidia echinulate, globose to subglobose, 3–4 µm.

**Extrolites:** Asteltoxin, asperthecin, emericellin, 2-ω-hydroxy-yemodin, shamixanthones, terrein (CBS 128789 in addition produced curvularin and dehydrocurvularin).

**Distinguishing characters:** *Aspergillus qinqixianii* is close to *A. filifer*, they share identical *CaM*, but can be distinguished by small differences in *BenA* and *RPB2*. Morphologically these two species can be easily differentiated by the ornamentation on convex surface, the ascospores of *A. qinqixianii* have smooth ascospore convex in contrast with tuberculate convex in *A. filifer*.

***Aspergillus quadrilineatus*** Thom & Raper, Mycologia 31: 660. 1939. MycoBank MB275888. Fig. 42.

≡ *Emericella quadrilineata* (Thom & Raper) C.R. Benj., Mycologia 47: 680. 1955. ≡ *Aspergillus tetrazonus* Samson & W. Gams, Adv. Pen. Asp. Syst., 48. 1985.

= *Aspergillus nidulans* var. *acristatus* Fennell & Raper, Mycologia 47: 79. 1955. = *Emericella nidulans* (Eidam) Vuill. var. *acristata* (Fennell & Raper) Subram. Curr. Sci. 41: 758. 1972. (later homonym). = *Emericella acristata* (Fennell & Raper) Y. Horie, Trans. Mycol. Soc. Japan 21: 491. 1980 = *Aspergillus acristatulus* Ismail, Abdel-Sater & Zohri, Mycotaxon 53: 396. 1995.

= *Aspergillus parvathecicus* Raper & Fennell, Gen. *Aspergillus*: 509. 1965. = *Emericella parvathecica* (Raper & Fennell) Malloch & Cain, Can. J. Bot. 50: 62. 1972. = *Aspergillus microthecicus* Samson & W. Gams, Adv. Pen. Asp. Syst.: 43. 1985.

= *Aspergillus floriformis* Samson and Mouch., Antonie van Leeuwenhoek 40: 343, 1975.

= *Aspergillus miyajii* Y. Horie, Mycoscience 37: 323. 1996. ≡ *Emericella miyajii* Y. Horie, Mycoscience 37: 323. 1996.

**Typus:** IMI 089351. Culture ex-type: CBS 591.65 = NRRL 201 = ATCC 16816 = IMI 089351ii = IMI 89351 = LSHBA 546 = QM 7465 = Thom 4138.N8 = WB 201 = DTO 048-A9.

**ITS barcode:** EF652433. (Alternative markers: *BenA* = EF652257; *CaM* = EF652345; *RPB2* = EF652169).

**Colony diam, 7 d (mm):** CYA 26–46; CYA 37 °C >60; CYA 40 °C >60; MEA 31–47; MEA 37 °C >60; OA 41–48; YES >60; CREA 8–11; CYAS 18–33; DG18 22–28.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium buff and white; texture floccose; sporulation sparse; light brown soluble pigments produced after 2 wks; exudates clear droplets; reverse dark brown. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium buff and white; texture floccose; sporulation sparse; soluble pigments absent; exudates clear droplets; reverse yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium buffy brown fading into white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse dark brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium buff; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse light brown. OA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium buff and white; texture floccose; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments light brown; exudates clear droplets; reverse yellowish brown, ascomata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, developing throughout the colony, reddish brown, globose to subglobose,

100–700 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 10–24 µm. Asci 8 spored, globose to subglobose. Ascospores orange to reddish brown, in surface view globose to subglobose, spore bodies smooth, globose to subglobose, 4–4.5 × 3–4.5 µm; in side view lenticular, with two plaited equatorial crests about 0.5–1 µm in width paralleled by a secondary narrower pair which are sometimes indistinct, crests are entire, defective or with irregular protuberance. Conidiophores with smooth stipes, pale brownish, 50–150 × 4–5.5 µm; vesicles pale brown, globose, 10–13 µm wide, fertile over the upper half to two thirds; metulae hyaline, 5–7 × 2–4.5 µm; phialides hyaline, flask-shaped, 5–7 × 2–4 µm. Conidia echinulate, globose to subglobose, 3–4 µm.

*Extrrolites*: asperthecin, asperugins, echinocandins, emestrin, emericellin, emindols, quadrilineatin, shamixanthone, sterigmatocystin, violaceols.

*Distinguishing characters*: *Aspergillus quadrilineatus* is close to *A. nidulans* and *A. latus*, but can be distinguished by four crests.

*Notes*: Phylogenetically *Aspergillus acristatus*, *A. floriformis*, *A. parvathecicus* and *A. miyajii* are identical with *A. quadrilineatus* and are considered as synonyms as did Hubka et al. (2016). Morphologically these species have minor differences in ascospore crests. *Aspergillus acristatus* was introduced as a crest-free variety of *A. nidulans* (Fig. 42I), Fennell and Raper (1955) suggested a close relationship between *A. acristatus* and *A. quadrilineatus*, because a number of *A. quadrilineatus* strains also show reduced four crests. *Aspergillus floriformis* was described as an anamorphic species, only Hülle cells were mentioned in the original description (Samson & Mouchacca 1975), but the ex-type (CBS 937.73) of *A. floriformis* is now degenerated and does not produce any anamorphic or teleomorphic structures. Also the ex-type (CBS 493.65) of *A. parvathecicus* which was described with ascospores does not produce the teleomorph. Hubka et al. (2016) speculated that both *A. parvathecicus* and *A. miyajii* represent atypical *A. quadrilineatus* strains characterized by smaller ascomata with delayed maturation in the first and ascospores with aberrant development and shape in the latter. We agree with their opinion, one strain (CBS 853.96) collected from Spain further confirms the diversity of ascospore phenotype in *A. quadrilineatus*, the ascospore crests in this isolate are irregularly protuberant (Fig. 3G, H), phylogenetically it is identical in ITS, *CaM* and *BenA* with other *A. quadrilineatus* strains, but shows seven bp differences in *RPB2* (99.2 % similarity, 907/914 bp).

***Aspergillus recurvatus*** Raper & Fennell, Gen. *Aspergillus*: 529. 1965. MycoBank MB326653. Fig. 43.

*Typus*: IMI 36528. Culture ex-type: CBS 496.65 = NRRL 4902 = ATCC 16809 = IMI 136528 = O-566 = QM 7972 = WB 4902 = IBT 23271 = DTO 053-C8.

*ITS barcode*: EF652482. (Alternative markers: *BenA* = EF652306; *CaM* = EF652394; *RPB2* = EF652218).

*Colony diam*, 7 d (mm): CYA 12–34; CYA 37 °C 21–45; CYA 40 °C 25–29; MEA 19–21; MEA 37 °C 27–52; OA 34–36; YES 22–50; CREA 2–12; CYAS 8–14; DG18 9–15.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium lemon yellow; texture velvety; sporulation absent; soluble pigments absent; exudates light brown droplets; reverse dark brown. MEA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium light yellow and white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse reddish brown. YES 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium light yellow and white; texture floccose to velvety; sporulation absent; soluble pigments absent; exudates absent; reverse ochraceous buff. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium lemon yellow; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse yellow. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium light yellow and white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse light yellow. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata not observed. Conidiophores with smooth stipes, light brown, 40–150 × 3.5–4.5 µm; vesicles hyaline to pale brown, subclavate, 8–10 µm wide, fertile over the upper half to two thirds; metulae hyaline, 5–6 × 2.5–3.5 µm; phialides hyaline to yellowish green, flask-shaped, 4.5–5.5 × 2–3 µm. Conidia olive green, echinulate, globose to subglobose, 3–4.5 µm. Hülle cells hyaline, globose to ovoid, 18–30 µm.

*Extrrolites*: an austrialide (tentatively identified), falconensins, falconensons, violaceols.

*Distinguishing characters*: This species is characterized by yellow mycelium, which resembles *A. aurantiopurpureus*, but *A. aurantiopurpureus* produces longer conidiophores (130–260 × 3.5–5 µm), smaller conidia (3–3.5 µm) and is able to produce ascospores.

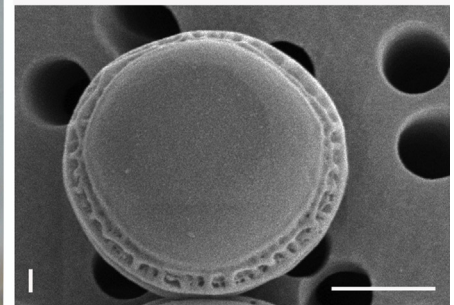
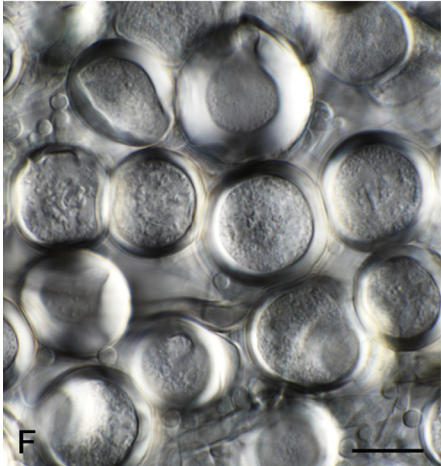
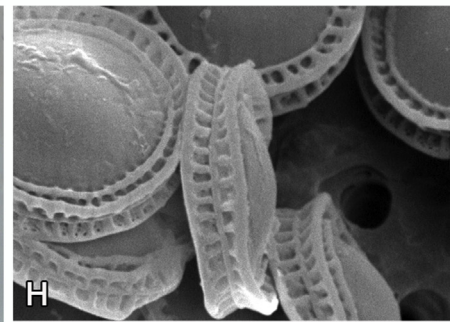
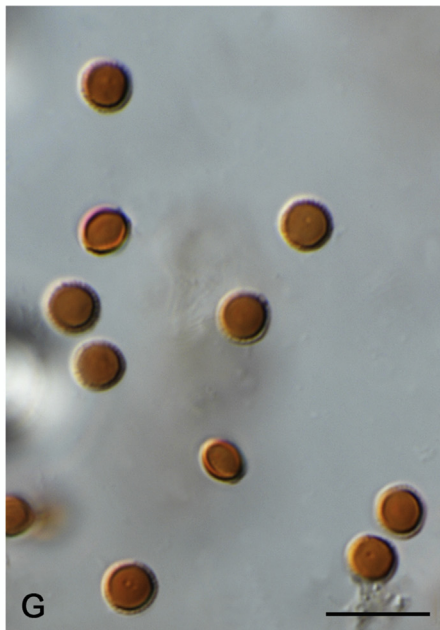
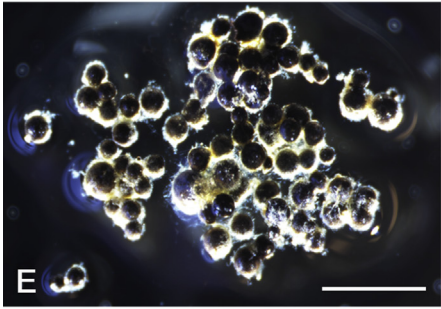
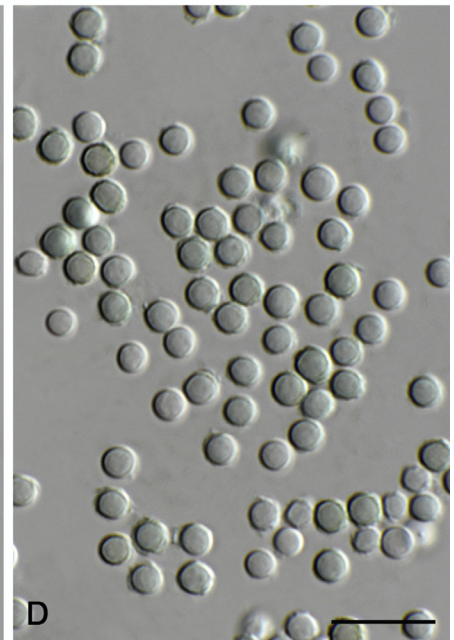
***Aspergillus rugulosus*** Thom & Raper, *Mycologia* 31: 660. 1939. MycoBank MB277104. Fig. 44.

= *Emericella rugulosa* (Thom & Raper) C.R. Benj., *Mycologia* 47: 680. 1955. = *Aspergillus rugulovalvus* Samson & W. Gams, *Adv. Penicillium Aspergillus Syst.*: 49. 1985.  
= *Emericella cleistominuta* B.S. Mehrotra & R. Prasad, *Trans. Br. Mycol. Soc.* 52: 333. 1969. = *Aspergillus cleistominutus* B.S. Mehrotra & R. Prasad, *Trans. Br. Mycol. Soc.* 52: 333. 1969.  
= *Emericella rugulosa* var. *lazulina* Horie, Miyaji & Nishimura, *Mycoscience* 37: 140. 1996.

*Typus*: IMI 136775. Culture ex-type: CBS 133.60 = NRRL 206 = ATCC 16820 = IMI 136775 = QM 1987 = Thom 4138.T11 = WB 206 = IBT 22820 = DTO 321-H1.

*ITS barcode*: EF652434. (Alternative markers: *BenA* = EF652258; *CaM* = EF652346; *RPB2* = EF652170).

*Colony diam*, 7 d (mm): CYA 14–16; CYA 37 °C 35–58; CYA 40 °C 35–55; MEA 15–22; MEA 37 °C >60; OA 35–60; YES 22–30; CREA 3–8; CYAS 10–15; DG18 4–10.





**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse reddish brown. MEA 25 °C, 7 d: Colonies deep, slightly sulcate; margins entire; mycelium white; texture floccose; sporulation absent to moderately dense, conidia *en masse* if present, olive green; soluble pigments absent; exudates absent to brown droplets; reverse reddish brown to yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse brown to light brown. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose; sporulation absent to moderately dense, conidia *en masse* if present, yellow green; soluble pigments absent; exudates absent; reverse olive brown. OA 25 °C, 7 d: Colonies low to moderately deep, plane; margins entire; mycelium olive buff and white; texture floccose; sporulation sparse to moderately dense, conidia *en masse* olive green; soluble pigments light brown; exudates absent to light brown droplets; reverse light brown. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascumata cleistothecial, superficial, reddish brown to dark brown, globose to subglobose, 220–350 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale yellowish brown, globose to ovoid, 14–24 µm. Asci 8 spored, globose to subglobose. Ascospores orange, greyish violet, reddish purple or brownish red, in surface view globose to subglobose, spore bodies conspicuously rugulose, globose to subglobose, 4–4.5 × 3.5–4 µm; in side view lenticular, with two plaited equatorial crests with sinuate and entire margins measuring 0.5–0.6 µm wide. Conidiophores with smooth stipes, pale brown, 50–200 × 5–6 µm; vesicles pale brown, hemisphere to subclavate, 8–12 µm wide, fertile over the upper half to two thirds; metulae hyaline to pale brown, 7–8 × 3–3.5 µm; phialides hyaline to pale brown, flask-shaped, 6–7 × 2.5–3 µm. Conidia echinulate, globose to subglobose, 3–4 µm, green in mass.

**Extrolites:** asperugins, echinocandins, emecorrugatin, emericellin, emestrin, sterigmatocystin, versicolorins, violaceols.

**Distinguishing characters:** *Aspergillus rugulosus* can be easily distinguished from other species by rugulose ornamentation on convex surface of ascospores.

**Notes:** The ascospore colour in *A. rugulosus* varies from greyish red to dark greyish red or reddish purple (Benjamin 1955, Raper & Fennell 1965). In this study, the type strain CBS 133.60 produces orange red ascospores, which turn to reddish purple after months. *Emericella rugulosa* var. *lazulina* was described based on its greyish magenta to greyish violet ascospores (Horie *et al.* 1996b), since it is identical in morphology (except the ascospores colour) and phylogeny with *A. rugulosus*, we treat it as a synonym as did Hubka *et al.* (2016). According to Mehrotra & Prasad (1969) *Emericella cleistominuta* differed from *A. rugulosus* in producing much smaller ascumata (15–50 µm). However, we observed ascumata measuring 200–300 µm in

*E. cleistominuta*, the ascospores of these two species are identical too (Fig. 5E–H). Based on morphological and molecular results, *E. cleistominuta* is treated as a synonym.

***Aspergillus savannensis*** A.J. Chen, Frisvad & Samson, **sp. nov.** MycoBank MB816096. Fig. 45.

**Etymology:** Name refers to its origin, isolated from A1 horizon soil, Halile Rest Camp south of Dolemile Hill, savanna.

**Diagnosis:** Moderately dense to dense sporulation on CYA, MEA, YES, OA and DG18, reddish brown, smooth ascospores, green conidia measuring 3.5–5 µm.

**Typus:** Namibia, south of Dolomite Hill (savanna), in Halili Rest Camp, A1 horizon soil, 2001, isolated by M. Christensen (holotype CBS H-22495, culture ex-type: CBS 140607 = IBT 23422 = DTO 059-H6).

**ITS barcode:** KU866581. (Alternative markers: *BenA* = KU866818; *CaM* = KU866704; *RPB2* = KU866959).

**Colony diam, 7 d (mm):** CYA 33–35; CYA 37 °C 55–56; CYA 40 °C 55–56; MEA 45–48; MEA 37 °C >60; OA 47–48; YES 64–65; CREA 6–7; CYAS 37–38; DG18 37–38.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium smoke gray; texture velvety; sporulation moderately dense, conidia *en masse* olive; soluble pigments absent; exudates light brown droplets; reverse dark reddish brown. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose at centre, velvety at edge; sporulation dense, conidia *en masse* dark green; soluble pigments absent; exudates clear droplets; reverse yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture velvety; sporulation moderately dense, conidia *en masse* pale green to yellow green; soluble pigments absent; exudates absent; reverse buff. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* yellow green to dark green; soluble pigments absent; exudates absent; reverse pale green. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* dark green; soluble pigments absent; exudates clear droplets; reverse pale yellow green. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascumata cleistothecial, superficial, dark brown, globose to subglobose, 65–120 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 11–16.5 µm. Asci 8 spored, globose to subglobose. Ascospores orange to reddish brown, in surface view globose to subglobose, spore bodies smooth, 4–5 × 3.5–4; in side view lenticular, with two equatorial crests measuring 0.5–1 µm. Conidiophores with smooth stipes, pale brown, 85–190 × 5–7 µm; vesicles pale brown, globose to subclavate, 8–15.5 µm wide, fertile over the upper half to two thirds; metulae hyaline, 4.5–8 × 3.5–4.5 µm;

**Fig. 42.** *Aspergillus quadrilineatus* CBS 591.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascumata. F. Hülle cells. G,H. Ascospores. I. Ascospores of CBS 119.55, ex-type of *A. acristatus*. Scale bars: B = 30 µm; C,D,F,G = 10 µm; E = 1000 µm; H,I = 2 µm.

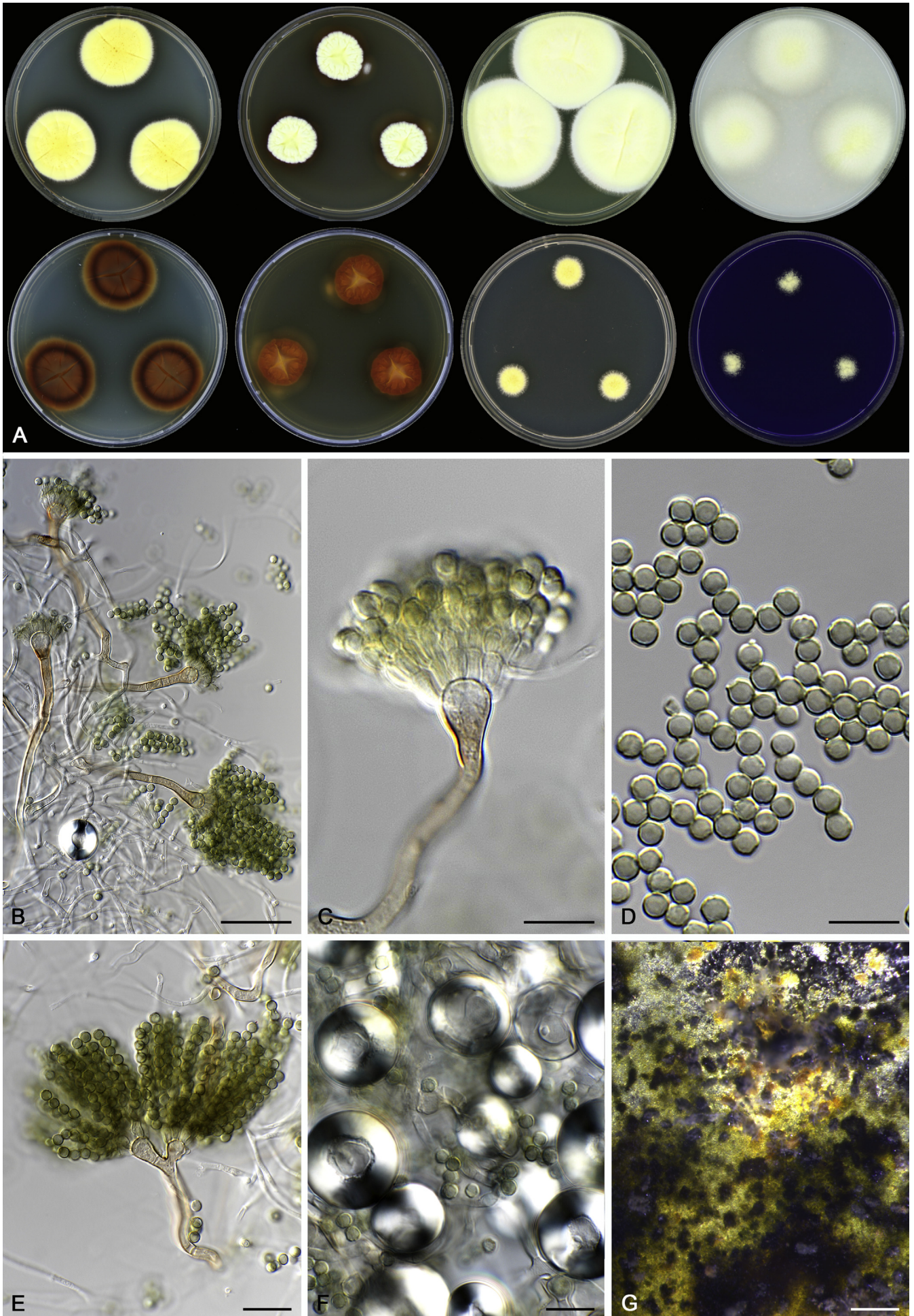
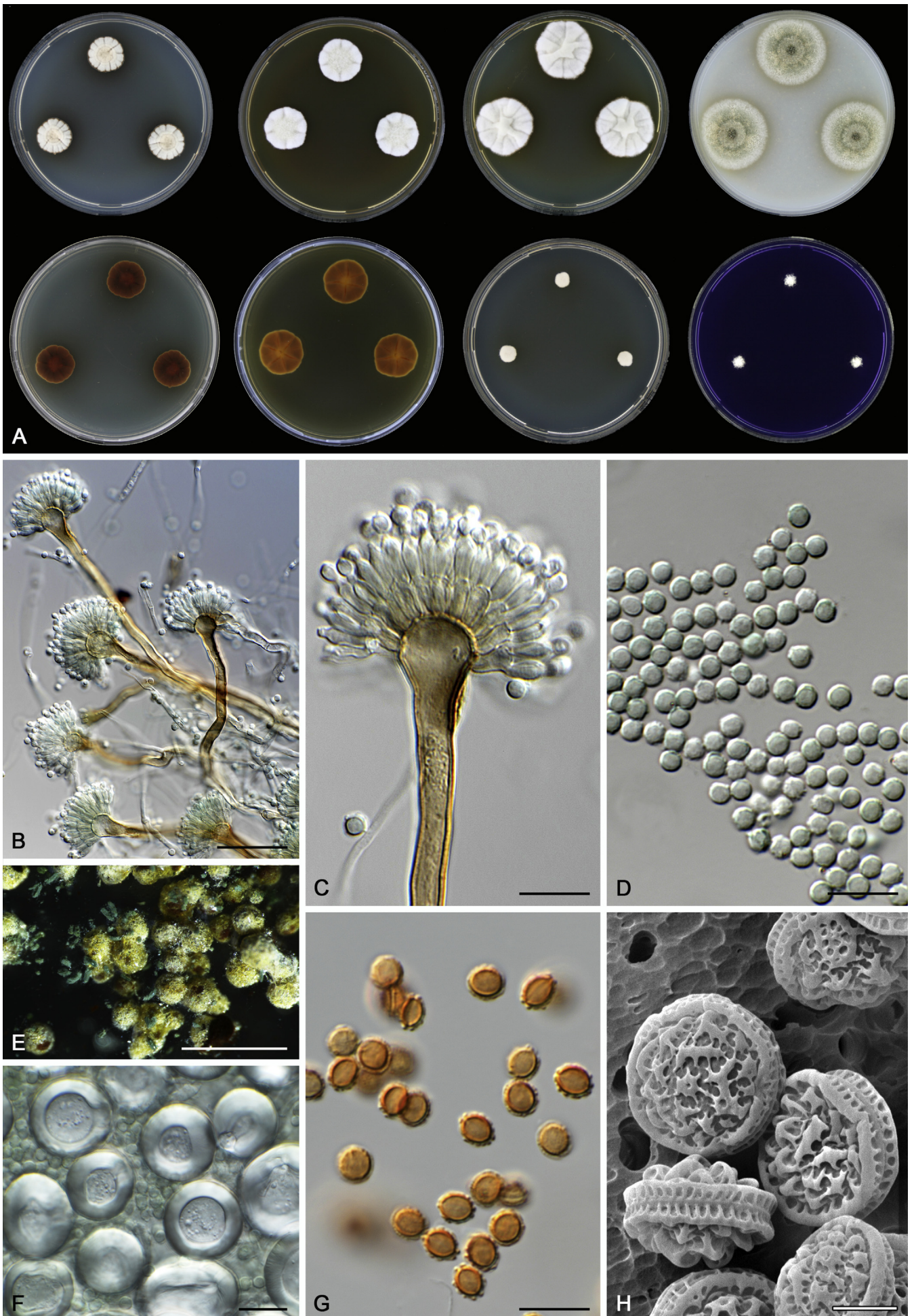
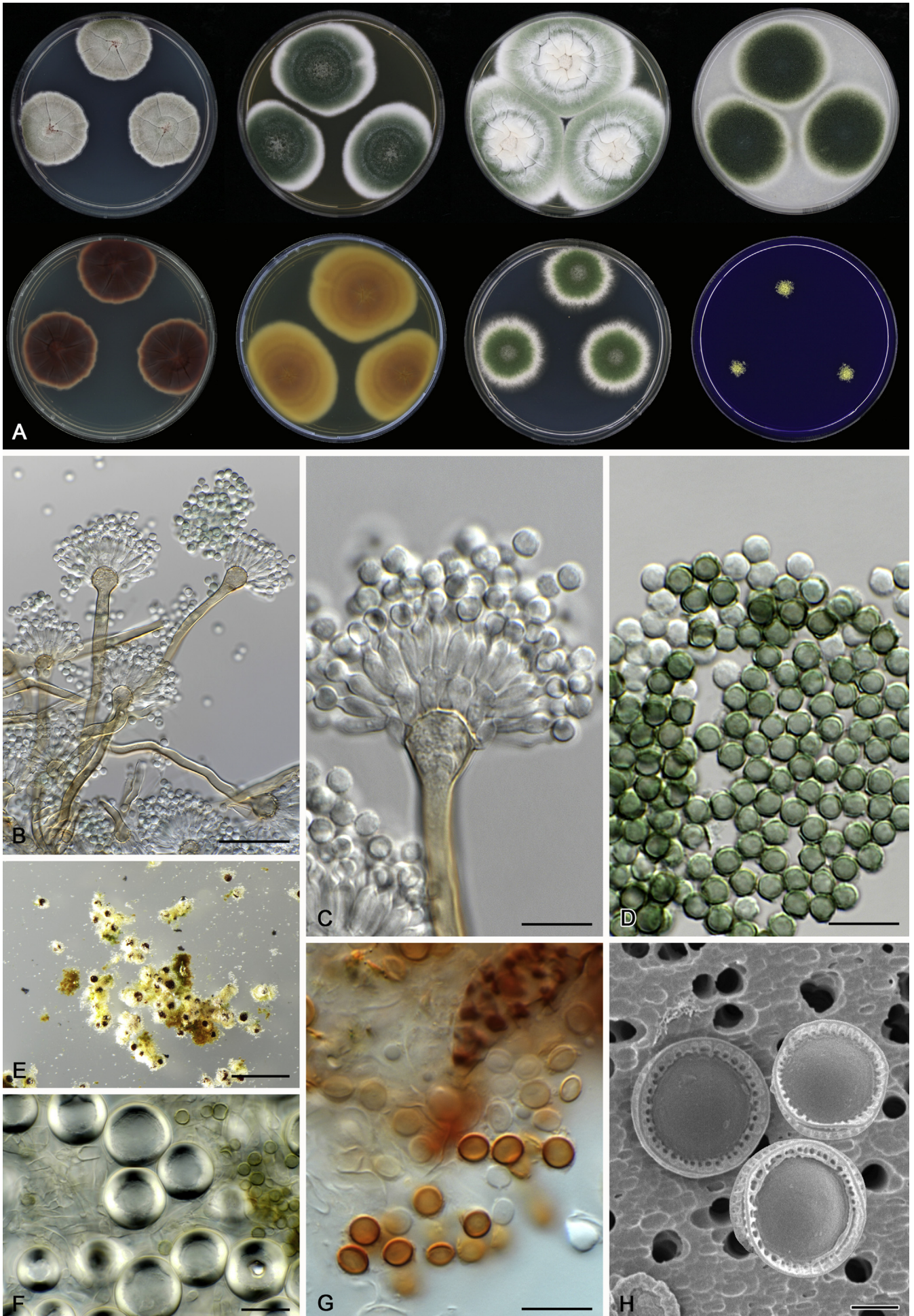


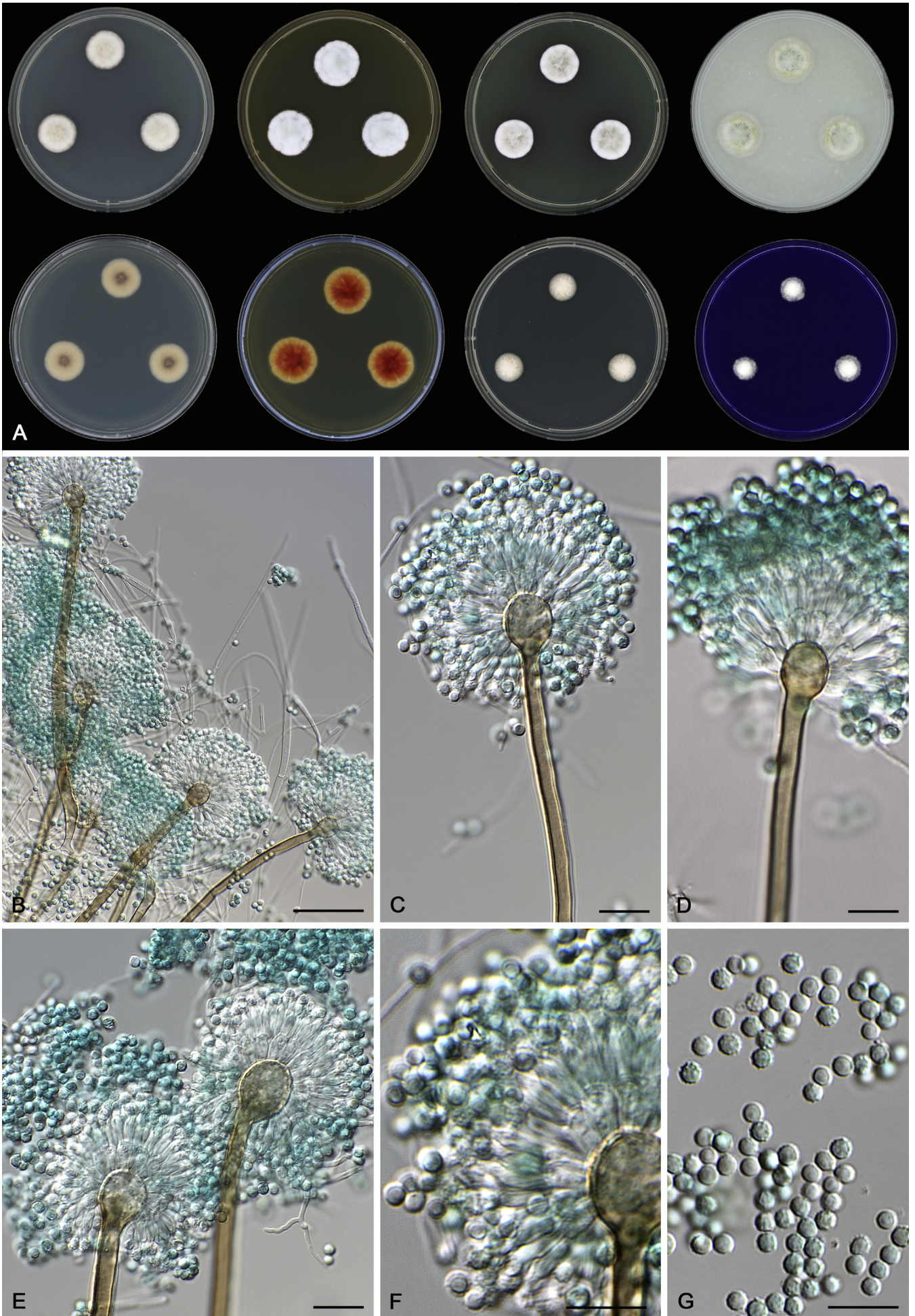
Fig. 43. *Aspergillus recurvatus* CBS 496.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–E. Conidiophores and Conidia. F,G. Hülle cells. Scale bars: B = 30  $\mu$ m; C–F = 10  $\mu$ m; G = 1000  $\mu$ m.



**Fig. 44.** *Aspergillus rugulosus* CBS 133.60<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



**Fig. 45.** *Aspergillus savannensis* CBS 140607<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



**Fig. 46.** *Aspergillus spelunceus* CBS 497.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–F. Conidiophores. G. Conidia. Scale bars: B = 30  $\mu$ m; C–G = 10  $\mu$ m.

phialides hyaline, flask-shaped, 7.5–9 × 3–4 µm. Conidia echinulate, globose to subglobose, 3.5–5 µm, green in mass.

*Extrolites*: asperthecin, desertorins, emerins, epurpurins, paspaline, paspalinine, paxillin.

*Distinguishing characters*: Phylogenetically *Aspergillus savannensis* clusters with *A. desertorum*, *A. botswanensis* and *A. stercorearius*, but the latter three species do not produce anamorph on any media, while *A. savannensis* sporulates well on CYA, MEA, YES, OA and DG18.

***Aspergillus spelunceus*** Raper & Fennell [as '*speluneus*'], Gen. *Aspergillus*: 457. 1965. MycoBank MB326656. Fig. 46.

*Typus*: IMI 211389. Culture ex-type: CBS 497.65 = NRRL 4989 = ATCC 16838 = IMI 211389 = NRRL A-3676 = QM 8898 = WB 4989 = IBT 33967 = DTO 053-C4.

*ITS barcode*: EF652490. (Alternative markers: *BenA* = EF652314; *CaM* = EF652226; *RPB2* = EF652402).

*Colony diam*, 7 d (mm): CYA 18–19; CYA 37 °C No growth; CYA 40 °C No growth; MEA 22–23; MEA 37 °C No growth; OA 20–21; YES 18–19; CREA 11–12; CYAS 13–14; DG18 13–14.

*Colony characters*: CYA 25 °C, 7 d: Colonies deep, plane; margins entire; mycelium white and buff; texture floccose; sporulation sparse to moderately dense, conidia *en masse* pale green; soluble pigments absent; exudates absent; reverse dark brown at centre, buff at edge. MEA 25 °C, 7 d: Colonies deep, sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation sparse to moderately dense, conidia *en masse* blue green; soluble pigments absent; exudates absent; reverse coral red at centre, yellowish brown at edge. YES 25 °C, 7 d: Colonies deep, slightly sulcate; margins entire; mycelium white; sporulation sparse; soluble pigments absent; exudates absent; reverse reddish brown. DG18 25 °C, 7 d: Colonies deep, plane; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse cream white. OA 25 °C, 7 d: Colonies deep, plane; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* pale green to blue green; soluble pigments absent; exudates absent; reverse cream white. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata not observed. Conidiophores with smooth stipes, yellowish brown, 130–300 × 4–6 µm; vesicles coloured as the conidiophores, globose to subglobose, 7–11 µm wide, fertile over the two thirds to whole surface; metulae hyaline, 4–6.5 × 2.5–3.5 µm; phialides hyaline, flask-shaped, 5.5–7.5 × 2–2.5 µm. Conidia globose to subglobose, tuberculate, 2.5–3.5 µm, blue green in mass.

*Extrolites*: cyclopenol, sterigmatocystin, versicolorins, viridicatin, viridicatol.

*Distinguishing characters*: *Aspergillus spelunceus* is close to *A. aureolatus* morphologically and phylogenetically, but can be distinguished by its smaller, more roughened conidia.

*Note*: According to Emmons, Hülle cells were observed in the original isolation cultures grown on an agar medium containing 1 % neopeptone and 2 % glucose as nutrient. Raper & Fennell (1965) observed limited, degenerated terminal or intercalary cells that resemble Hülle cells. During our study, Hülle cells were not observed, the capacity to produce Hülle cells seems to have disappeared with continued laboratory cultivation.

***Aspergillus spinulosporus*** Hubka, S.W. Peterson & M. Kolařík, Plant Syst. Evol. 302: 1290. MycoBank MB816282. Fig. 47.

≡ *Aspergillus nidulans* var. *echinulatus* Fennell & Raper, Mycologia 47: 79. 1955. ≡ *Emericella nidulans* var. *echinulata* (Fennell & Raper) Godeas, Mycopathol. Mycol. Appl. 46: 193. 1972. ≡ *Emericella echinulata* (Fennell & Raper) Y. Horie, Trans. Mycol. Soc. Japan 21: 492. 1980. Non *Aspergillus echinulatus* (Delacr.) Thom & Church, The Aspergilli: 107. 1926. ≡ *Aspergillus delacroixii* Samson, Visagie & Houbraken, Stud. Mycol. 78: 155. 2014.

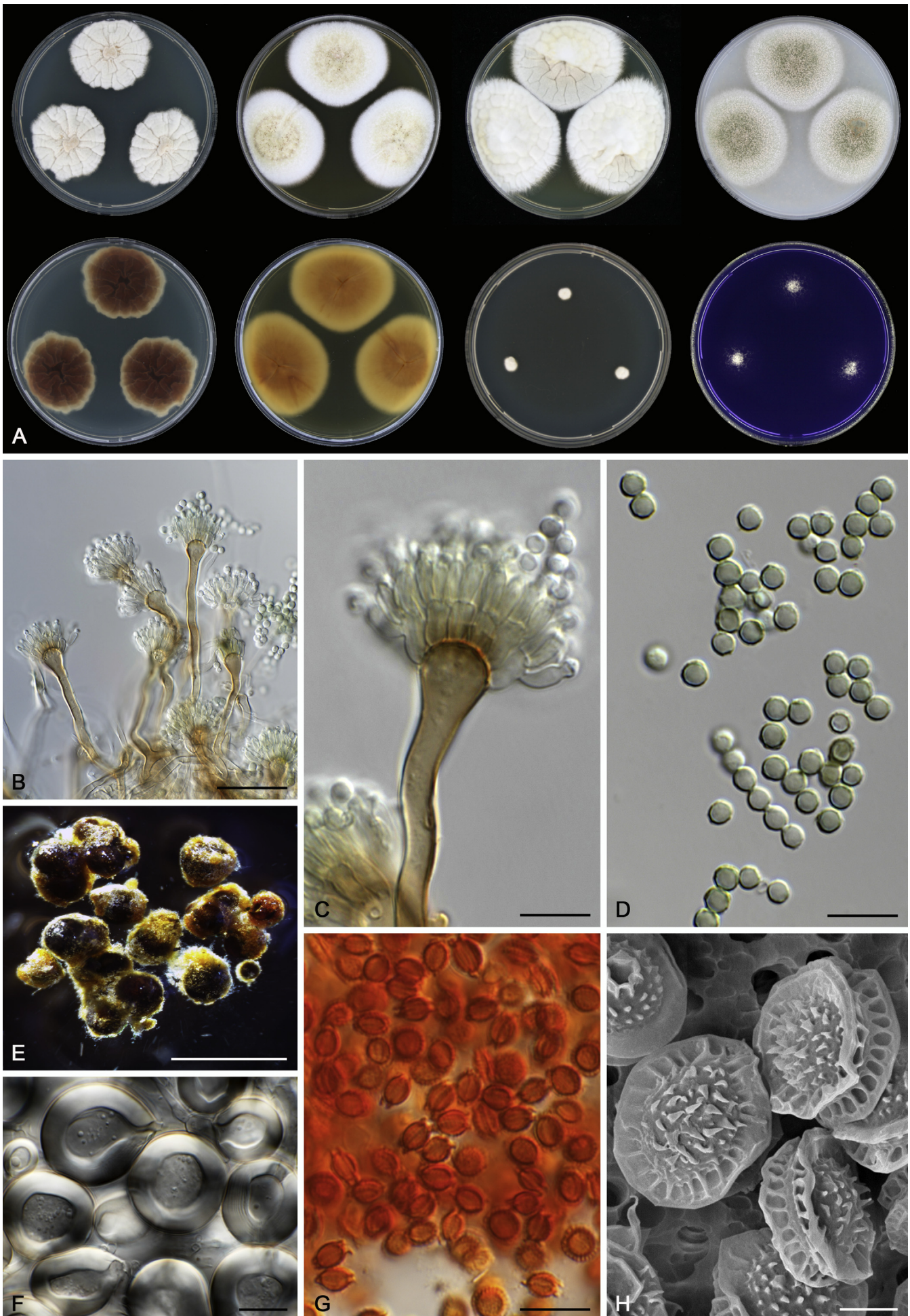
*Typus*: IMI 061454, Culture ex-type CBS 120.55 = NRRL 2395 = ATCC 16825 = IMI 061454 = LCP 84.2557 = QM 1909 = WB 2395 = IBT 22841 = DTO 047-G9.

*ITS barcode*: EF652445. (Alternative markers: *BenA* = AY573553; *CaM* = EF652357; *RPB2* = EF652181).

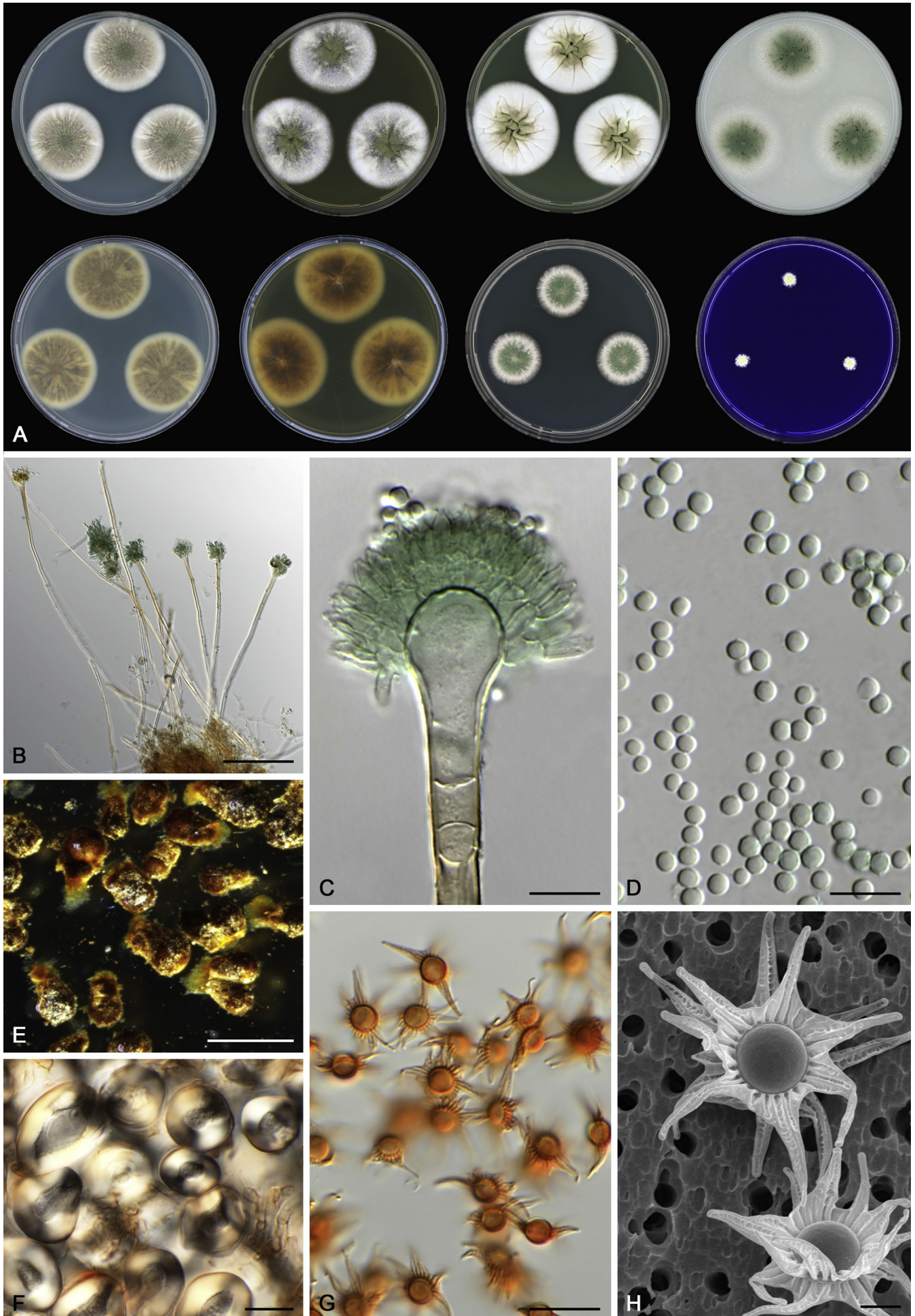
*Colony diam*, 7 d (mm): CYA 33–38; CYA 37 °C >60; CYA 40 °C >60; MEA 44–50; MEA 37 °C >60; OA 42–48; YES 55–62; CREA 15–26; CYAS 22–36; DG18 5–19.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium saffron and white; texture floccose; sporulation absent; soluble pigments absent; exudates brown droplets; reverse deep wood brown. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose; sporulation sparse; soluble pigments absent; exudates brown droplets; reverse yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium saffron and white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse yellowish brown. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse cream white. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium saffron and white; texture velvety; sporulation sparse; soluble pigments light brown; exudates absent; reverse light yellowish brown. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata cleistothecial, superficial, dark brown, globose to subglobose, 200–550 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 15–30 µm. Asci 8 spored, globose to subglobose. Ascospores orange to reddish brown, in surface view globose to subglobose, spore bodies echinulate, globose to subglobose, 3.5–4.5 × 3–4.5 µm; in side view lenticular, with two pleated equatorial crests measuring 0.8–1 µm. Conidiophores with smooth stipes, yellowish brown, 70–120 × 5–6 µm; vesicles yellowish brown, subclavate, 9–11 µm wide, fertile over the upper half; metulae pale brown to pale green, 6–8 × 3–4 µm; phialides hyaline to pale green, flask-shaped, 6–8.5 × 2–3 µm. Conidia echinulate, globose to subglobose, 3–4 µm, green in mass.



**Fig. 47.** *Aspergillus spinulosporus* CBS 120.55<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



**Fig. 48.** *Aspergillus stella-maris* CBS 113638<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 200  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



*Extrolites*: asperthecin, asperugins, shamixanthone, sterigmatocystins, versicolorins, violaceols.

*Distinguishing characters*: *Aspergillus spinulosporus* can be easily distinguished by echinulate convex surface of ascospores.

*Notes*: This species was introduced as *A. nidulans* var. *echinulatus* (Fennell & Raper 1955). Molecular data show it as a unique species, which is also proved by its special ascospore ornamentation. Since the name *A. echinulatus* is already occupied, the new name *A. delacroixii* was proposed (Samson et al. 2014). Hubka et al. (2016) treated "*A. delacroixii*" as a correctable orthographical error and proposed a new name *A. spinulosporus*. In our study we also concur with this.

***Aspergillus stella-maris*** Zalar, Frisvad & Samson, *Mycologia* 100: 789. 2008. MycoBank MB507363. Fig. 48.  
= *Emericella stella-maris* Zalar, Frisvad & Samson, *Mycologia* 100: 789. 2008.

*Typus*: CBS H-19887. Culture ex-type: CBS 113638 = IBT 23439 = DTO 011-A2.

*ITS barcode*: EU448269. (Alternative markers: *BenA* = KU866886; *CaM* = EU443978; *RPB2* = KU866929).

*Colony diam, 7 d (mm)*: CYA 35–39; CYA 37 °C No growth; CYA 40 °C No growth; MEA 38–40; MEA 37 °C No growth; OA 33–35; YES 42–49; CREA 8–11; CYAS 29–32; DG18 23–25.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white and buff; texture granular due to ascumata production; sporulation sparse to moderately dense, conidia *en masse* olive green to dark green; soluble pigments absent; exudates clear droplets; reverse buff with radiate brown. Ascumata present after 1 wk. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate to sulcate; margins entire; mycelium white and buff; texture granular due to ascumata production; sporulation moderately dense, conidia *en masse* olive green to dark green; soluble pigments absent; exudates clear droplets; reverse dark brown at centre, yellowish brown at edge. Ascumata present after 1 wk. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white and buff; texture velvety; sporulation dense, conidia *en masse* olive green; soluble pigments absent; exudates absent; reverse dark brown at centre, cream white at edge. Ascumata present after 1 wk. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse dark green at centre, olive buff at edge. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white and light yellow; texture velvety to granular; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates clear to light brown droplets; reverse pale greyish green. Ascumata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascumata cleistothecial, superficial, reddish brown, globose to subglobose, 370–770 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale yellowish brown, globose to ovoid, 16–22 µm. Asci 8 spored, stellate. Ascospores orange to reddish brown, in surface view stellate, 13–16 µm; spore

bodies smooth, globose to subglobose, 3–4.5 × 2.5–4.5 µm; in side view broadly lenticular, with two stellate equatorial; undissected part of crests 1–1.5 µm broad, with 3–4.5 µm long extensions; crests ornamented with longitudinal, 0.3–0.4 µm wide pleats. Conidiophores with smooth stipes, yellowish brown, 300–800 × 3.5–7 µm; vesicles hyaline to pale green, globose to subclavate, 9–20 µm wide, fertile over the upper two thirds; metulae hyaline to pale green, 5–9 × 3–4 µm; phialides hyaline to green, flask-shaped, 6–9 × 2–3.5 µm. Conidia smooth to finely echinulate, globose to subglobose, 3–4 µm, green in mass.

*Extrolites*: emericellin, shamixanthones, sterigmatocystin, versicolorins.

*Distinguishing characters*: Until now stellate ascospores were described for *A. pluriseminatus*, *A. venezuelensis*, *A. miraensis*, *A. stellatus*, *A. olivicola*, *A. dromiae* and *A. angustatus*. Among these species, *A. stella-maris* is close to *A. miraensis* and *A. stellatus* in vesicle shape, but can be distinguished by septate conidiophores and larger ascospores and conidia.

***Aspergillus stellatus*** Curzi, C.R. *Accad. Lincei* 19: 428. 1934. MycoBank MB254841. Fig. 49.  
= *Emericella varicolor* Berk. & Broome, *Intr. crypt. bot.* (London): 340.1857. = *Aspergillus varicolor* (Berk. & Broome) Thom & Raper, *Mycologia* 31: 663. 1939. = *Aspergillus stellifer* Samson & W. Gams, *Adv. Pen. Asp. Syst.*: 52. 1985.

*Typus*: Bowenpilly near Secundarabad, s. coll., (K). Culture ex-type: CBS 598.65 = NRRL 1858 = ATCC 16819 = IMI 136778 = QM 6835 = WB 1858 = IBT 32730 = DTO 327-F3.

*ITS barcode*: EF652426. (Alternative markers: *BenA* = EF652250; *CaM* = EF652338; *RPB2* = EF652162).

*Colony diam, 7 d (mm)*: CYA 26–35; CYA 37 °C 21–34; CYA 40 °C No growth; MEA 32–46; MEA 37 °C 18–35; OA 22–35; YES 38–53; CREA 7–10; CYAS 19–30; DG18 11–22.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white and buff; texture velvety; sporulation moderately dense, conidia *en masse* olive green; soluble pigments absent; exudates clear droplets; reverse dark olive fading into buff. Ascumata present after 1 wk. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture velvety; sporulation dense, conidia *en masse* yellow green to dark green; soluble pigments absent; exudates clear droplets; reverse yellowish brown with brown ring. Ascumata present after 1 wk. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture velvety to granular due to ascumata production; sporulation dense, conidia *en masse* dark green; soluble pigments absent; exudates absent; reverse brown at centre, yellowish brown at edge. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture velvety; sporulation dense; conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse pale yellow green. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white and light yellow; texture floccose; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates clear droplets; reverse yellowish brown. CREA 25 °C, 7 d: Acid production absent.

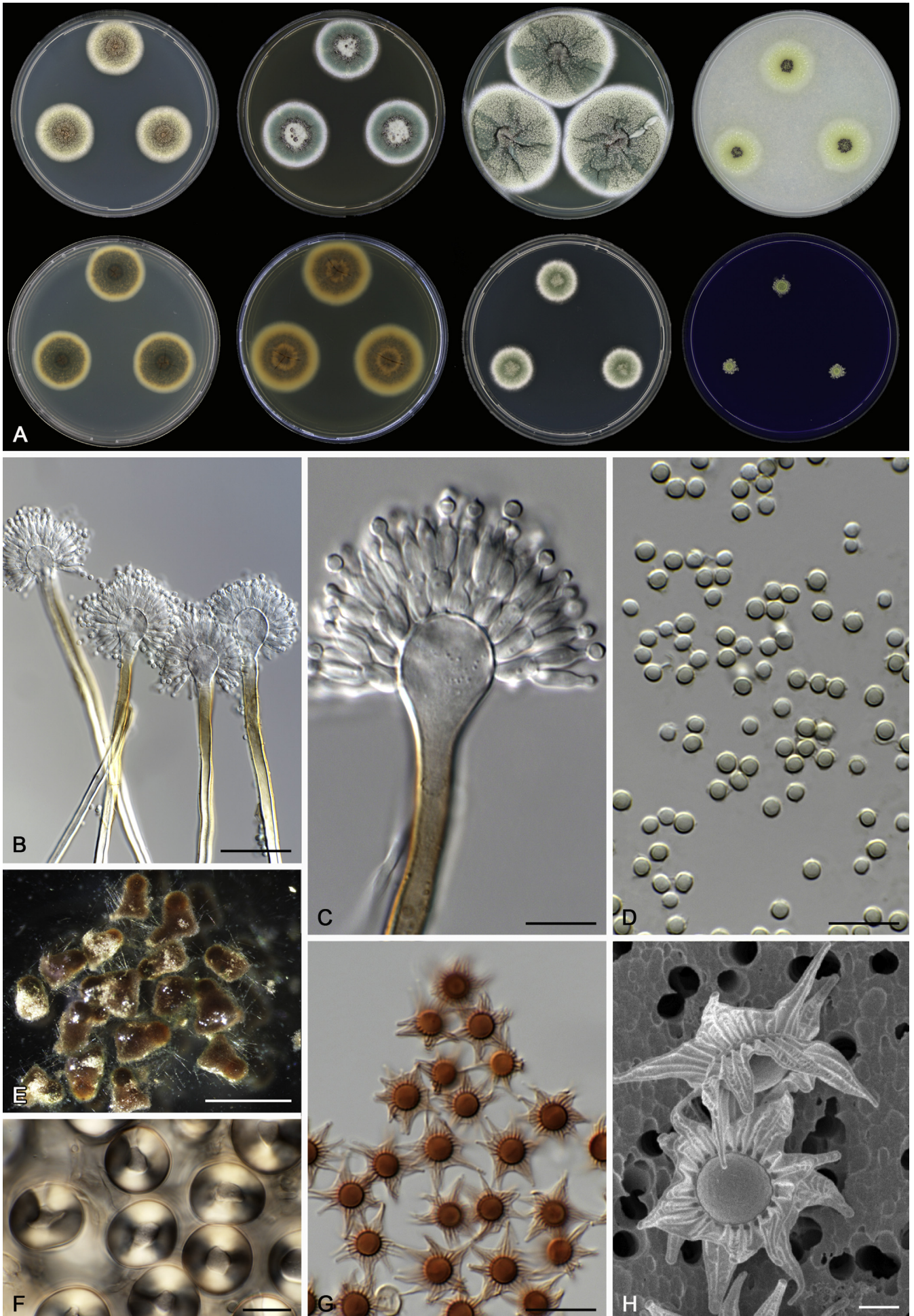
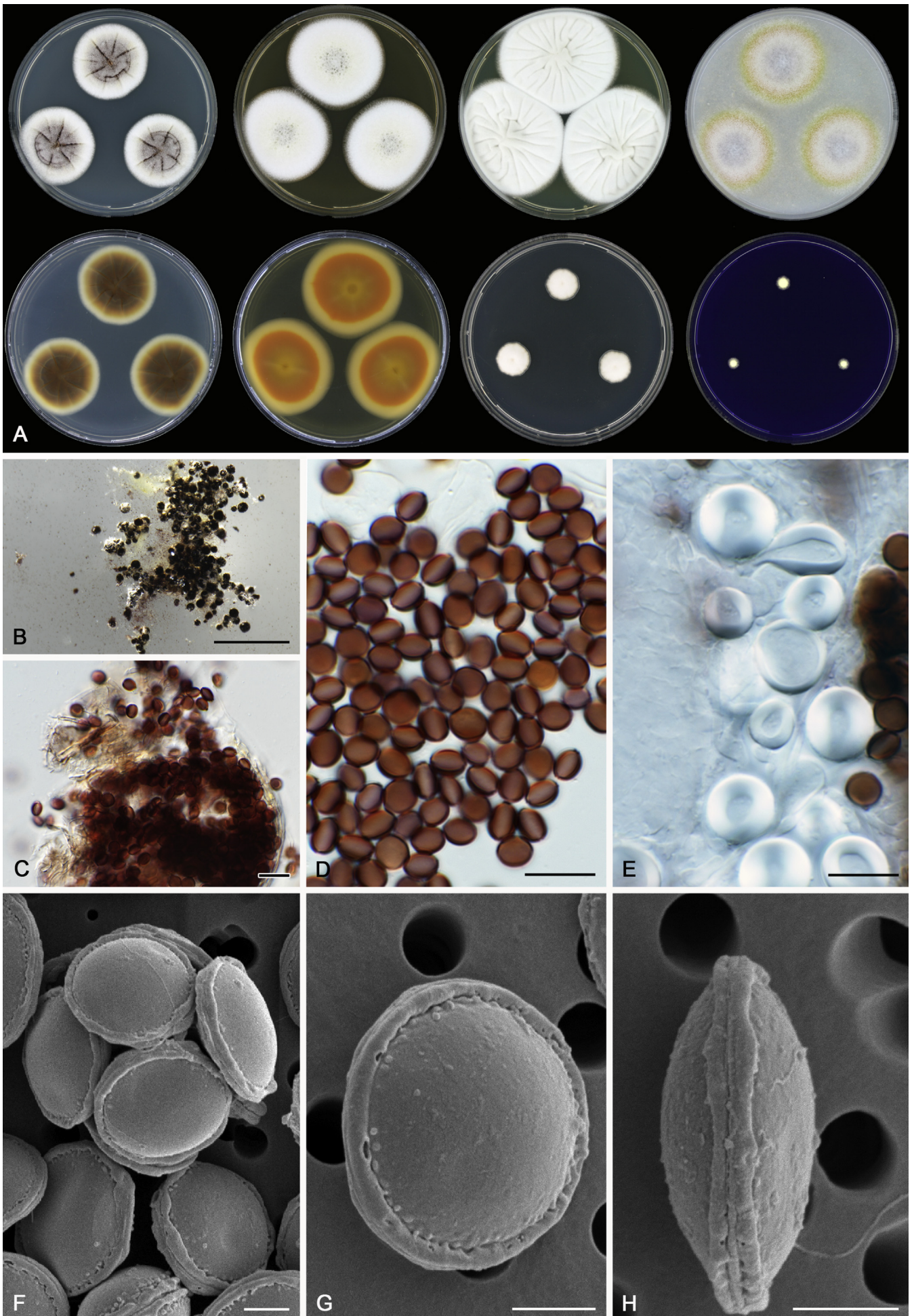


Fig. 49. *Aspergillus stellatus* CBS 598.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascogonia. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.



**Fig. 50.** *Aspergillus stercorearius* CBS 428.93<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B. Ascogmata. C. Asci. D,F–H. Ascospores. E. Hülle cells. Scale bars: B = 1000 µm; C–E = 10 µm; F–H = 2 µm.

**Micromorphology:** Ascomata cleistothecial, superficial, violet to reddish brown, globose to subglobose, 300–600 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale yellowish brown, globose to ovoid, 11.5–25.5 µm. Asci 8 spored, subglobose to polygonal or stellate. Ascospores orange to reddish brown, in surface view stellate, 10–14 µm; spore bodies smooth, globose to subglobose, 3.5–4 × 3–4 µm; in side view broadly lenticular, with two stellate equatorial crests; undissected part of crests 0.5–1 µm broad, with 2.5–4 µm long extensions; crests ornamented with longitudinal, 0.3–0.4 µm wide pleats. Conidiophores with smooth stipes, yellowish brown, 320–610 × 4.5–6.5 µm; vesicles hyaline to pale yellowish brown, globose to subclavate, 13.5–18.5 µm wide, fertile over the upper half to two thirds; metulae hyaline, 4–7.5 × 3.5–4 µm; phialides hyaline, flask-shaped, 6–8.5 × 2.5–3.5 µm. Conidia echinulate, globose to subglobose, 2.5–3 µm.

**Extrolites:** asperthecin, asperugins, astellolide, asteltoxin, austinol, a desertorin, emericellin, 2-ω-hydroxyemodin, Mer-NF8054X, shamixanthones, varitriol, violaceols.

**Distinguishing characters:** The stellate ascospores of *Aspergillus stellatus* resemble those of *A. stella-maris* and *A. dromiae*, but it differs from *A. dromiae* by smaller conidia, differs from *A. stella-maris* by non-septate conidiophores.

***Aspergillus stercorarius*** A.J. Chen, Frisvad & Samson, **sp. nov.** MycoBank MB816094. Fig. 50.

**Etymology:** The name refers to the dung (from *Uromastix acanthinurus*) habitat.

**Diagnosis:** Brown, smooth ascospores measuring 4.5–6 × 3.5–4.5 µm, with two low equatorial crests measuring 0.3–0.4 µm wide.

**Typus:** Algeria, Sahara, *Uromastix acanthinurus* dung, 1993, isolated by M. Locquin-Linard (holotype CBS H-22496, culture ex-type: CBS 428.93 = IBT 28024 = DTO 320-B3).

**ITS barcode:** KU866625. (Alternative markers: *BenA* = KU866865; *CaM* = KU866763; *RPB2* = KU867026).

**Colony diam, 7 d (mm):** CYA 30–40; CYA 37 °C 53–56; CYA 40 °C 47–48; MEA 42–46; MEA 37 °C >60; OA 35–42; YES 52–60; CREA 5–7; CYAS 26–27; DG18 15–16.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white and buff; texture velvety; sporulation absent; soluble pigments absent; exudates light brown droplets; reverse dark brown fading into yellowish brown. Ascomata present after 1 wk. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white and light yellow; texture floccose; sporulation absent; soluble pigments absent; exudates clear droplets; reverse orange brown fading into yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white and light yellow; texture velvety; sporulation absent; soluble pigments absent; exudates clear droplets; reverse yellowish brown. DG18 25 °C, 7 d: Colonies deep, plane; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse light yellow. OA 25 °C, 7 d: Colonies low, plane;

margins entire; mycelium white and light yellow; texture floccose; sporulation absent; light yellow to light orange pigments; exudates clear droplets; reverse luteous, ascomata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, superficial, purple to dark brown, globose to subglobose, 70–150 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 8–14.5 µm. Asci 8 spored, globose to subglobose. Ascospores brown, in surface view globose to subglobose, spore bodies smooth, 4.5–6 × 3.5–4.5 µm; in side view lenticular, with two low equatorial crests measuring 0.3–0.4 µm wide. Anamorph absent.

**Extrolites:** cf. asperthecin, calbistrins, desertorins, emindols, paspaline, paspalinine, paxillin, terrequinone A.

**Distinguishing characters:** *Aspergillus stercorarius* is close to *A. latilabiatum* and *A. desertorum*, but differs in smaller, smooth ascospores.

***Aspergillus striatus*** J.N. Rai, J.P. Tewari & Mukerji, *Can. J. Bot.* 42: 1521. 1964. MycoBank MB326659. Fig. 51.

≡ *Emericella striata* (J.N. Rai, J.P. Tewari & Mukerji) Malloch & Cain, *Can. J. Bot.* 50: 62. 1972. ≡ *Aspergillus striatulus* Samson & W. Gams, *Adv. Pen. Asp. Syst.*: 50. 1985.

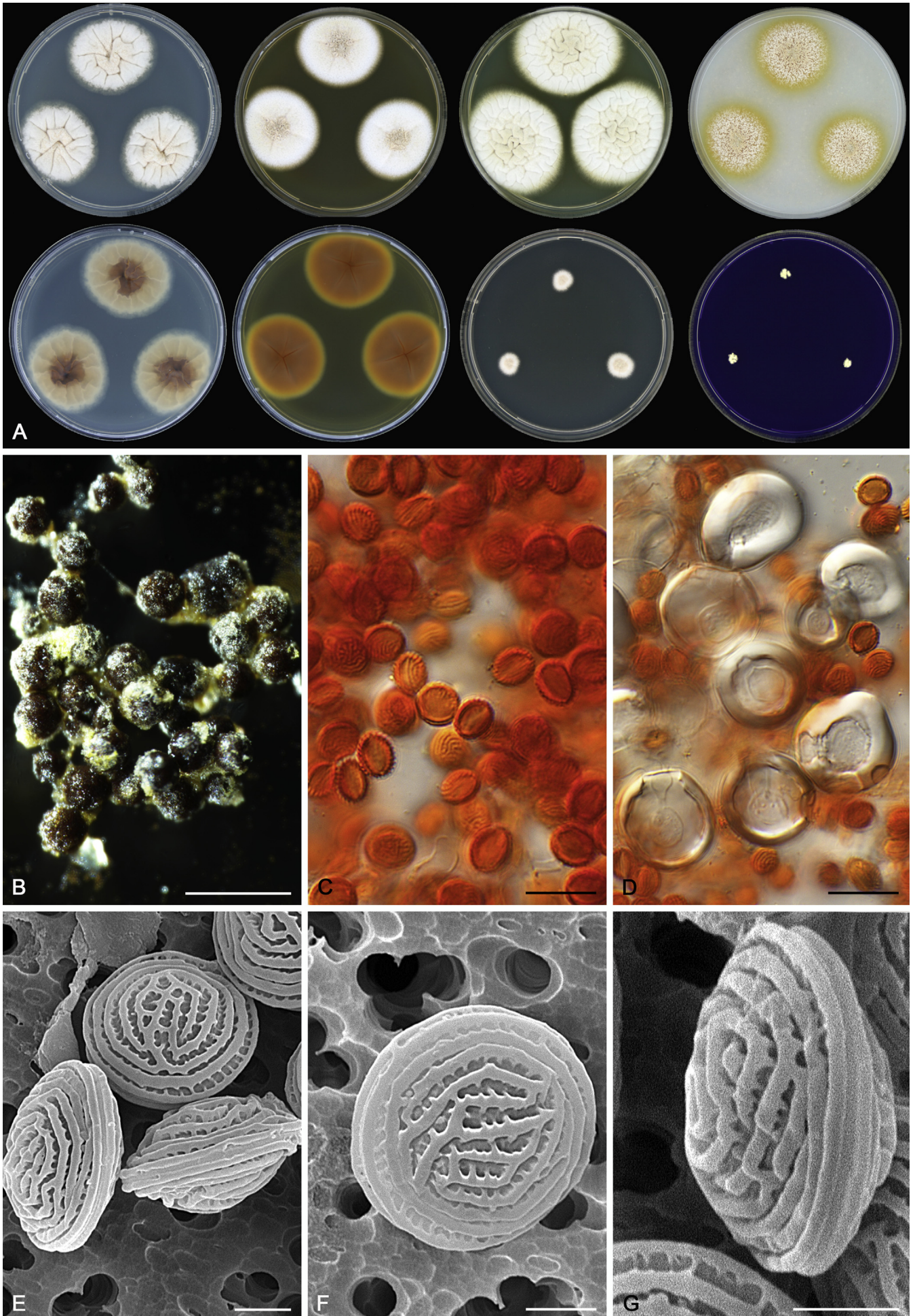
**Typus:** IMI 96679. Culture ex-type: CBS 283.67 = CBS 592.65 = NRRL 4699 = ATCC 16815 = IMI 96679 = QM 8901 = WB 4699 = DTO 320-D3.

**ITS barcode:** EF652470. (Alternative markers: *BenA* = EF652294; *CaM* = EF652382; *RPB2* = EF652206).

**Colony diam, 7 d (mm):** CYA 38–41; CYA 37 °C 47–60; CYA 40 °C 48–55; MEA 38–45; MEA 37 °C >60; OA 32–35; YES 50–57; CREA 3–5; CYAS 12–22; DG18 11–15.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white and saffron; texture velvety; sporulation absent; soluble pigments absent; exudates clear droplets; reverse brown fading into saffron. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium saffron at centre, white at edge; texture floccose; sporulation absent; soluble pigments absent; exudates clear droplets; reverse yellowish brown to reddish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white and light yellow; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse yellowish brown. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium saffron at centre, white at edge; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse cream white to yellow. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white and saffron; texture floccose; sporulation absent; soluble pigments yellowish brown to light brown; exudates clear droplets; reverse yellowish brown. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, superficial, blackish to dark brown, globose to subglobose, 180–500 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale brown, globose to ovoid, 14–23 µm. Asci 8 spored, globose to ovoid. Ascospores



**Fig. 51.** *Aspergillus striatus* CBS 592.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B. Ascospores. C,E–G. Ascospores. D. Hülle cells. Scale bars: B = 1000 µm; C–D = 10 µm; E–G = 2 µm.

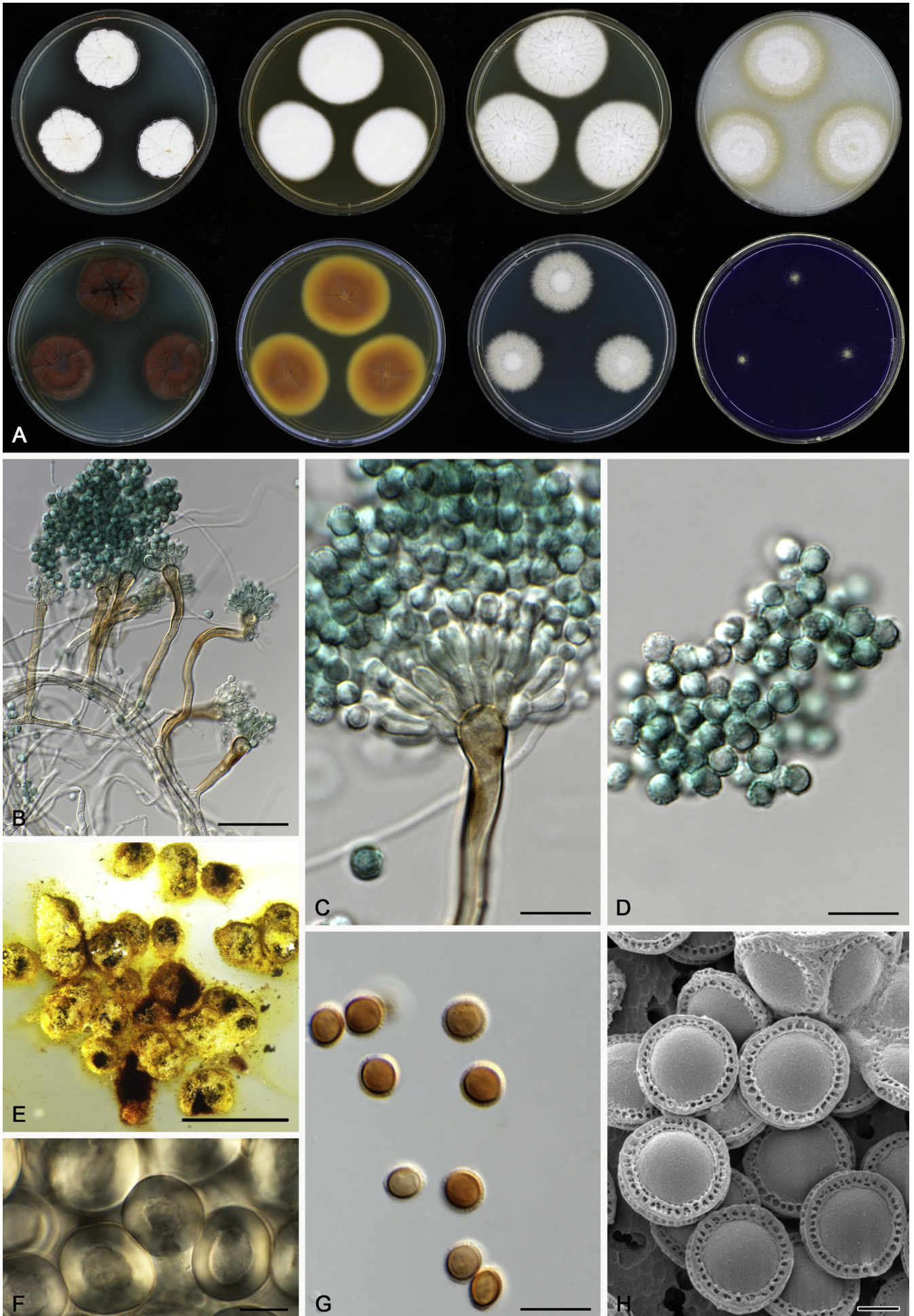


Fig. 52. *Aspergillus sulphureoviridis* CBS 140626<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30 µm; C,D,F,G = 10 µm; E = 1000 µm; H = 2 µm.

orange, in surface view globose to subglobose; spore bodies roughened, convex surface bearing simple or anastomosing thickenings arranged in more or less concentric rings, 6–7 × 5–5.5 µm; in side view broadly lenticular. Anamorph absent.

*Extrolites*: asperthecin, emericellin, emestrin, emindol SA, paxillin, shamixanthones, sterigmatocystin, versicolorins, violaceols.

*Distinguishing characters*: Morphologically this species is close to *A. rugulosus* and *A. violaceus*, but differs in orange ascospores with fingerprint like ornamentation.

***Aspergillus sulphureoviridis*** A.J. Chen, Frisvad & Samson, **sp. nov.** MycoBank MB816097. Fig. 52.

*Etymology*: Name refers to its bluish green conidia mass.

*Diagnosis*: Large ascospores measuring 4.5–5.5 × 3.5–4.5 µm and bluish green conidia measuring 3.5–5 µm.

*Typus*: Denmark, factory, indoor air, 1999, isolated by J.C. Frisvad (holotype CBS H-22497, culture ex-type CBS 140626 = IBT 21868 = DTO 325-D1).

*ITS barcode*: KU866673. (Alternative markers: *BenA* = KU866911; *CaM* = KU866793; *RPB2* = KU867058).

*Colony diam, 7 d (mm)*: CYA 30–31; CYA 37 °C 55–56; CYA 40 °C 40–41; MEA 39–41; MEA 37 °C >60; OA 42–43; YES 43–45; CREA 12–13; CYAS 28–29; DG18 28–29.

*Colony characters*: CYA 25 °C, 7 d: Colonies deep, sulcate; margins slightly irregular; mycelium white and saffron; texture floccose; sporulation sparse; soluble pigments absent; exudates clear droplets; reverse dark brown. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse reddish brown fading into orange and yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse buff. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation sparse; soluble pigments absent; exudates absent; reverse yellow. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white and buff; texture floccose; sporulation sparse, conidia *en masse* pale green; soluble pigments light brown; exudates clear droplets; reverse buff. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata cleistothecial, superficial, reddish brown to brown, globose to subglobose, 350–600 µm, surrounded by numerous Hülle cells; Hülle cells hyaline, globose to ovoid, 10–22.5 µm. Asci 8 spored, globose to subglobose. Ascospores orange to reddish brown, in surface view globose to subglobose, spore bodies smooth, 4.5–5.5 × 3.5–4.5 µm; in side view lenticular, with two equatorial crests measuring 0.8–1.2 µm. Conidiophores with smooth stipes, pale brown, 30–80 × 3–5 µm; vesicles pale brown, subglobose to subclavate, 7–10 µm wide, fertile over the upper half to two thirds; metulae hyaline, 6.5–8.5 × 2.5–3.5 µm; phialides hyaline, flask-shaped, 6.5–7.5 × 3–4 µm. Conidia tuberculate, globose to subglobose, 3.5–5 µm, bluish green in mass.

*Distinguishing characters*: The ornamentation on the ascospore crests (holes measuring 0.2–0.5 µm) resembles those of *A. foveolatus* and *A. aurantiobrunneus*, but *A. foveolatus* produces pitted ascospores and *A. aurantiobrunneus* produces smaller conidia (2.5–3.5 µm).

***Aspergillus undulatus*** H.Z. Kong & Z.T. Qi, Acta Mycol. Sin. 5: 211. 1986. MycoBank MB129004. Fig. 53.

≡ *Emericella undulata* H.Z. Kong & Z.T. Qi, Acta Mycol. Sin. 5: 211. 1986.

*Typus*: HMAS 47644. Culture ex-type: CBS 261.88 = AS 3.4510 = IBT 28027 = DTO 011-H1.

*ITS barcode*: EU448275. (Alternative markers: *BenA* = EF428363; *CaM* = EU443989; *RPB2* = KU866928).

*Colony diam, 7 d (mm)*: CYA 13–14; CYA 37 °C 10–15; CYA 40 °C No growth; MEA 25–26; MEA 37 °C 14–18; OA 33–34; YES 29–30; CREA 3–5; CYAS 17–18; DG18 15–17.

*Colony characters*: CYA 25 °C, 7 d: Colonies deep, plane; margins entire; mycelium saffron and white; texture granular due to abundant ascomata production; sporulation absent; soluble pigments absent; exudates absent; reverse dark brown at centre, fading into light brown. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture granular due to abundant ascomata production; sporulation sparse; soluble pigments absent; exudates clear droplets; reverse dark brown. YES 25 °C, 7 d: Colonies moderately deep, plane; margins slightly irregular; mycelium white; texture granular due to abundant ascomata production; sporulation absent; soluble pigments absent; exudates absent; reverse dark brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins slightly irregular; mycelium white; texture velvety to floccose; sporulation dense, conidia *en masse* pale green; soluble pigments absent; exudates absent; reverse yellow green. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white at centre, light yellow at edge; texture granular due to abundant ascomata production; sporulation absent; soluble pigments light brown; exudates clear droplets; reverse dull greenish yellow. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata cleistothecial, superficial, dark reddish brown, globose, 300–500 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale brown, globose to ovoid, 14–26 µm. Asci 8 spored, globose to subglobose. Ascospores brown, in surface view globose to subglobose, spore bodies tuberculate, 4–4.5 × 3.5–4 µm; in side view lenticular, with two waved equatorial crests, low part measuring 0.3–0.7 µm, high part measuring 0.8–1.3 µm. Conidiophores with smooth stipes, hyaline, 80–150 × 3–4.5 µm; vesicles hyaline to pale brown, hemisphere to subclavate, 7–11 µm wide, fertile over the upper half to two thirds; metulae hyaline, 5.5–7.5 × 2.5–3 µm; phialides hyaline to pale brown, flask-shaped, 6.5–7.5 × 2–2.5 µm. Conidia echinulate, globose to subglobose, 3–4 µm.

*Extrolites*: a gregatin, a varitriol.

*Distinguishing characters*: The wave-crested ascospores with tuberculate convex can easily distinguish *Aspergillus undulatus* from other species.

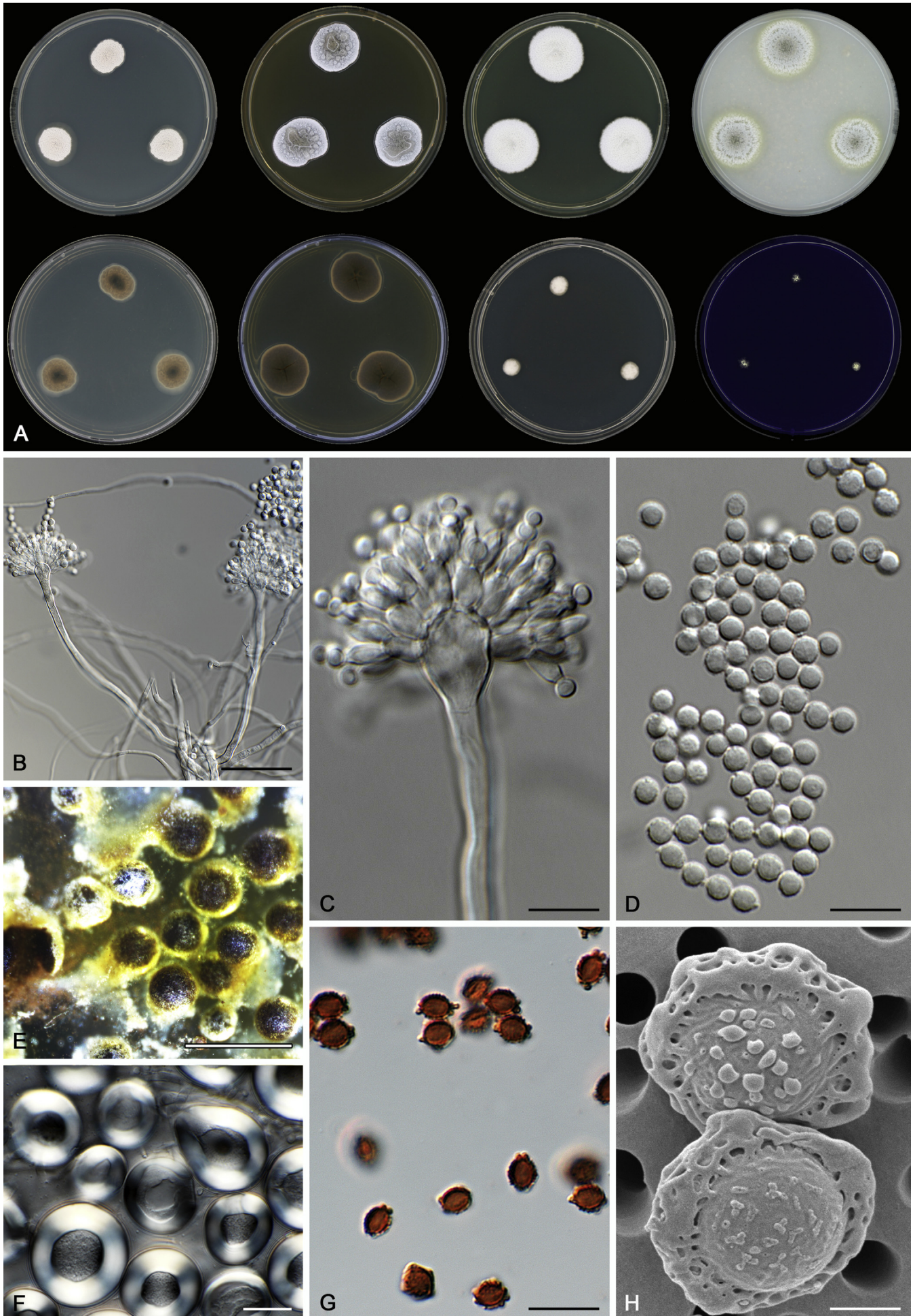
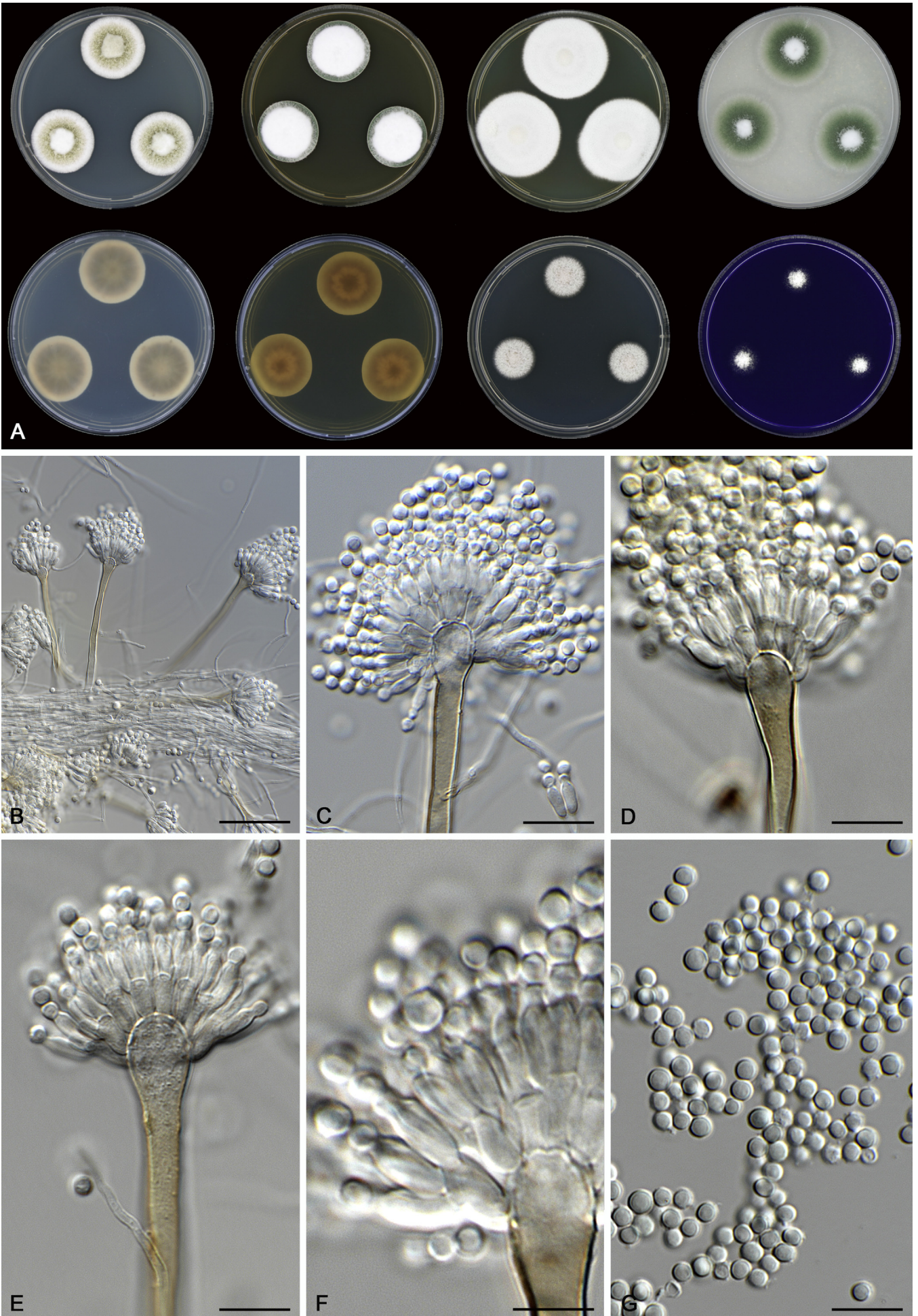


Fig. 53. *Aspergillus undulatus* CBS 261.88<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.





**Fig. 54.** *Aspergillus unguis* CBS 132.55<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–F. Conidiophores. G. Conidia. Scale bars: B = 30  $\mu$ m; C–E, G = 10  $\mu$ m; F = 8  $\mu$ m.

***Aspergillus unguis*** (Emile-Weill & L. Gaudin) Thom & Raper, *Mycologia* 31: 667. 1939. MycoBank MB255264. Fig. 54.

≡ *Sterigmatocystis unguis* Emile-Weill & L. Gaudin, Arch. Med. Exp. Anat. Pathol. 28:

463. 1918. ≡ *Emericella unguis* Malloch & Cain, Can. J. Bot. 50: 62. 1972.

*Typus*: IMI 136526. Culture ex-type: CBS 132.55 = NRRL 2393 = ATCC 16812 = IMI 136526 = NRRL A-2391 = NRRLA-445 = QM 25B = WB 2393 = DTO 047-I5.

*ITS barcode*: EF652443. (Alternative markers: *BenA* = EF652267; *CaM* = EF652355; *RPB2* = EF652179).

*Colony diam, 7 d (mm)*: CYA 22–35; CYA 37 °C 19–27; CYA 40 °C no growth or 1–2; MEA 23–35; MEA 37 °C 22–25; OA 30–35; YES 34–45; CREA 10–17; CYAS 32–35; DG18 18–22.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, plane to slightly sulcate; margins entire; mycelium white and light yellow; texture floccose to velvety; sporulation sparse to moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse vinaceous buff. MEA 25 °C, 7 d: Colonies moderately deep to deep, plane to slightly sulcate; margins entire; mycelium white; texture floccose to velvety; sporulation moderately dense, conidia *en masse* greyish green; soluble pigments absent; exudates absent or clear droplets; reverse brown fading into yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, plane to sulcate; margins entire; mycelium white; texture velvety to floccose; sporulation sparse to moderately dense, conidia *en masse* greyish olive to olive green; soluble pigments absent; exudates absent; reverse light brown to vinaceous buff. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation sparse to moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse vinaceous buff. OA 25 °C, 7 d: Colonies low, plane; margins entire; texture velvety to floccose; sporulation sparse to moderately dense, conidia *en masse* dark green; soluble pigments absent; exudates absent; reverse pale green. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata not observed. Conidiophores with smooth stipes, pale brown, 50–100 × 3–5 µm; vesicles hyaline to pale brown, subclavate, 8–10 µm wide, fertile over the upper half; metulae hyaline to pale brown, 5–7 × 2.5–3.5 µm; phialides hyaline, flask-shaped, 5–9 × 2–2.5 µm. Conidia globose to subglobose, echinulate, 2.5–4 µm.

*Extrolites*: asperugins, nidulin, nornidulin, unguisin, unguisinol, ustilagonoidin C.

*Distinguishing characters*: *Aspergillus unguis* is close to *A. asperescens* and *A. aureolatus*, but *A. asperescens* produces longer conidiophores (200–400 × 6–8 µm) and large, ellipsoidal conidia (4–7 × 3–5 µm); *A. aureolatus* is characterized by orange marginal zone of colonies. In addition *A. asperescens* and *A. aureolatus* cannot grow at 37 °C, while *A. unguis* grows well at this temperature.

***Aspergillus varians*** Wehmer, Bot. Centralbl. 80: 460. 1899. MycoBank: MB172782. Fig. 55.

*Typus*: IMI 172297. Culture ex-type: CBS 505.65 = NRRL 4793 = ATCC 16836 = IFO

4114 = IMI 172297 = WB 4793 = IBT 22568 = DTO 073-B5.

*ITS barcode*: EF652479. (Alternative markers: *BenA* = EF652303; *CaM* = EF652391; *RPB2* = EF652215).

*Colony diam, 7 d (mm)*: CYA 20–30; CYA 37 °C No growth; CYA 40 °C No growth; MEA 21–22; MEA 37 °C No growth; OA 25–26; YES 25–26; CREA 28–30; CYAS 24–25; DG18 14–15.

*Colony characters*: CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium white and gray; texture floccose; sporulation moderately dense, conidia *en masse* greyish green; soluble pigments absent; exudates absent; reverse orange at centre, dark brown at edge. MEA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* glaucous; soluble pigments absent; exudates absent; reverse orange. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium yellow at centre, white at edge; texture floccose to velvety; sporulation moderately dense, conidia *en masse* dull green to greyish green; soluble pigments absent; exudates absent; reverse light yellow to light brown. DG18 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium light yellow; texture floccose; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse yellow ochre. OA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium white; texture floccose; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse pale green. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology*: Ascomata not observed. Conidiophores with smooth stipes, hyaline to pale brown, 600–1200 × 7–12 µm; vesicles hyaline, hemispherical to subclavate, 20–30 µm wide, fertile over the upper half to two thirds; metulae hyaline, 7–10 × 3.5–4.5 µm; phialides hyaline, flask-shaped, 8–12 × 3–4 µm. Conidia subglobose to ellipsoidal, smooth, 4–6 × 3.5–4 µm.

*Extrolites*: 2- $\omega$ -hydroxyemodin, emerlin, epurpurin A, B & C, shamixanones, versicolorins.

*Distinguishing characters*: The long conidiophores (600–1200 µm) and wide vesicles (20–30 µm) can easily distinguish *Aspergillus varians* from other related species.

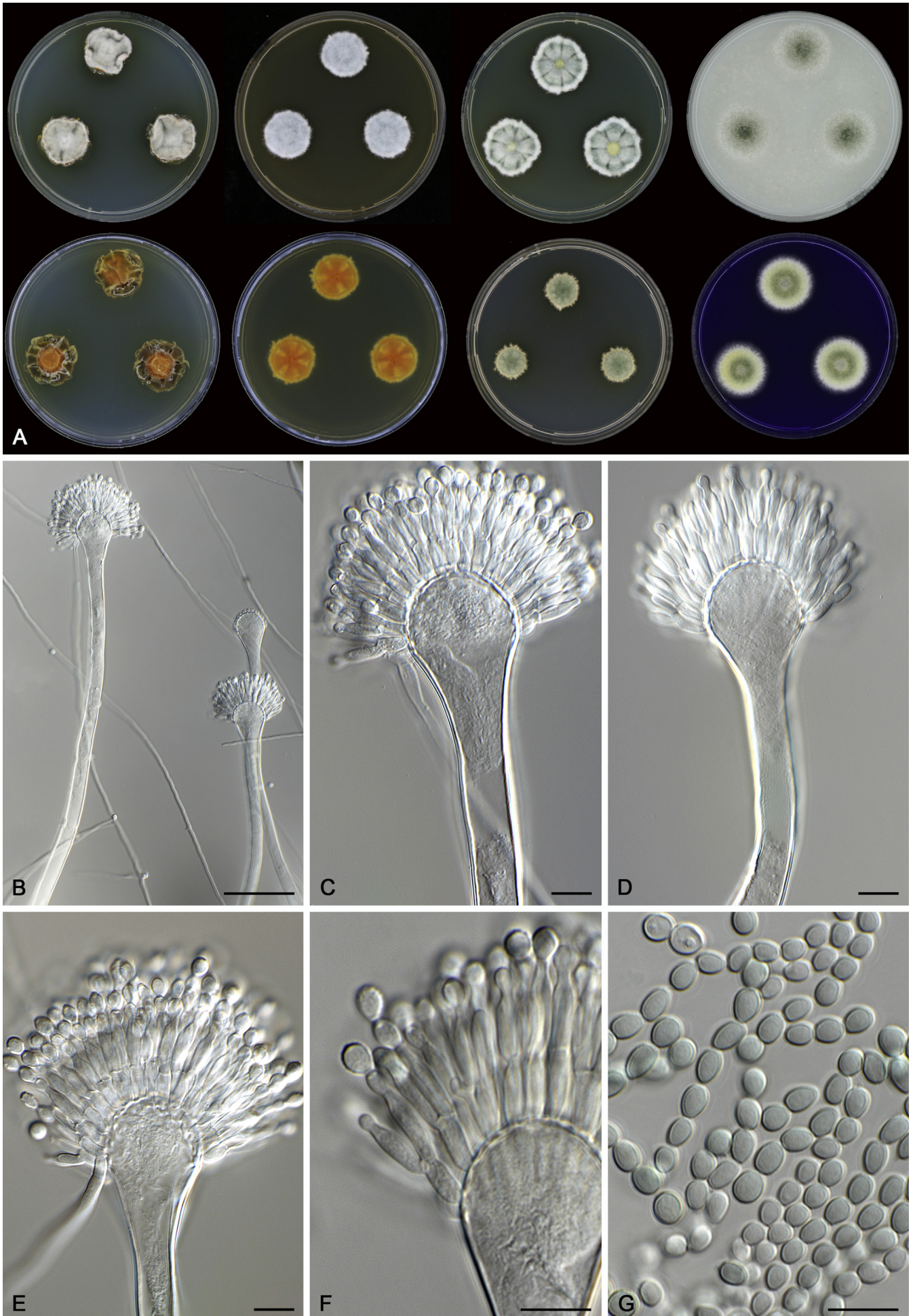
***Aspergillus venezuelensis*** Frisvad & Samson, Syst. Appl. Microbiol. 27: 678. 2004. MycoBank MB368544. Fig. 56.

≡ *Emericella venezuelensis* Frisvad & Samson, Syst. Appl. Microbiol. 27: 678 2004.

*Typus*: CBS 868.97. Culture ex-type: CBS 868.97 = IBT 20956 = DTO 011-A4.

*ITS barcode*: AJ874119. (Alternative markers: *BenA* = AY339998; *CaM* = EU443977; *RPB2* = KU866931).

*Colony diam, 7 d (mm)*: CYA 37–38; CYA 37 °C 3–5; CYA 40 °C No growth; MEA 42–43; MEA 37 °C No growth; OA 31–35; YES 49–50; CREA 18–19; CYAS 37–38; DG18 23–26.



**Fig. 55.** *Aspergillus varians* CBS 505.65<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–F. Conidiophores. G. Conidia. Scale bars: B = 30  $\mu$ m; C–G = 10  $\mu$ m.

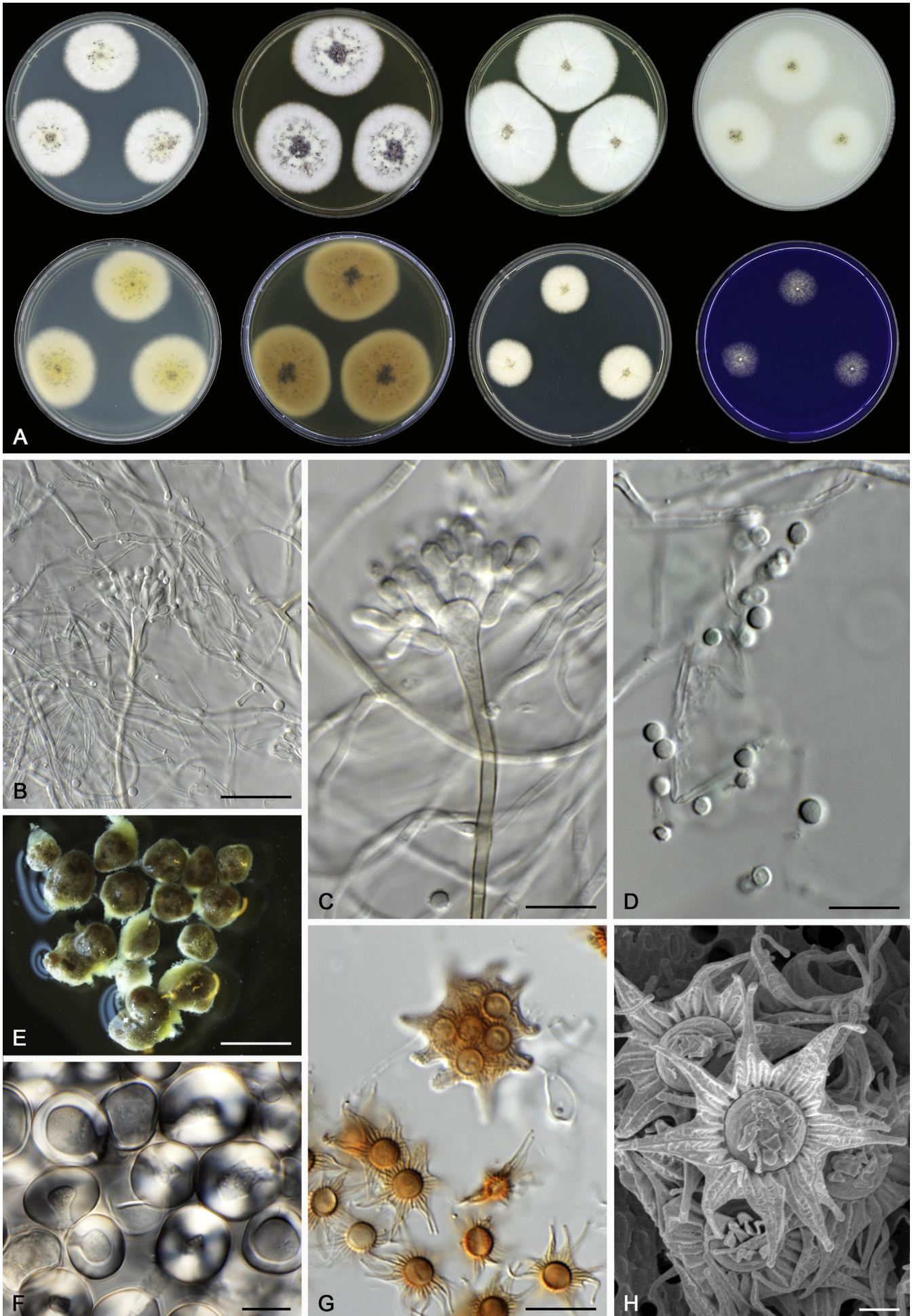


Fig. 56. *Aspergillus venezuelensis* CBS 868.97<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B,C. Conidiophores. D. Conidia. E. Ascomata. F. Hülle cells. G,H. Ascospores. Scale bars: B = 30  $\mu$ m; C,D,F,G = 10  $\mu$ m; E = 1000  $\mu$ m; H = 2  $\mu$ m.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, plane; margins entire; mycelium light yellow at centre, white at edge; texture floccose at centre, velvety at edge; sporulation absent; soluble pigments absent; exudates clear droplets; reverse light yellow fading into cream white; ascomata present after 1 wk. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium light yellow at centre, white at edge; texture floccose at centre, velvety at edge; sporulation absent; soluble pigments absent; exudates clear droplets; reverse dark brown at centre, yellowish brown at edge; ascomata present after 1 wk. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture floccose to velvety; sporulation absent; soluble pigments absent; exudates absent; reverse cream white; ascomata present after 1 wk. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium light yellow at centre, white at edge; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse citron yellow; ascomata present after 1 wk. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium light yellow at centre, white at edge; texture floccose at centre, velvety at edge; sporulation absent; soluble pigments absent; exudates clear droplets; reverse cream white; ascomata present after 1 wk. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, superficial, violet to brown, globose to subglobose, 400–1000 µm, surrounded by numerous Hülle cells; Hülle cells hyaline to pale yellowish brown, globose to ovoid, 12–21.5 µm. Asci 8 spored, stellate. Ascospores orange to reddish brown, in surface view stellate, 12.5–19.5 µm; spore bodies covered with triangular flaps, globose to subglobose, 4–5 × 3.5–4.5 µm; in side view broadly lenticular, with two stellate equatorial; undissected part of crests 1–1.2 µm broad, with 2.5–4 µm long extensions; crests ornamented with longitudinal, 0.3–0.5 µm wide pleats. Conidiophores with smooth stipes, light yellowish brown, 65–130 × 2–3 µm; vesicles hyaline to pale yellowish brown, subclavate, 5.5–7 µm wide, fertile over the upper half to two thirds; metulae hyaline, 4–5 × 2.5–3.5 µm; phialides hyaline, flask-shaped, 6–7 × 2.5–3.5 µm. Conidia echinulate, globose to subglobose, 2.5–4 µm (Anamorphic structures were observed from CYA).

**Extrolites:** aflatoxin B1, B2, a desertorin, emericellin, an emerin, shamixanthones, sterigmatocystin, versicolorins.

**Distinguishing characters:** Triangular flaps on the ascospore convex surface can distinguish this species from other stellate ascospored species.

**Notes:** The anamorph of *A. venezuelensis* occurs quite late (after 1 month) on unconventional media such as CREA, CYA + 40 % sucrose, while absent on conventional growth media (CYA, MEA, OA) (Frisvad & Samson 2004). During our study, sparse conidiophores are present on CYA after 2 months. The presented conidiophores show typical characters of section *Nidulantes*, but the vesicles are smaller (5.5–7 µm) compared with original description (7–10 µm).

***Aspergillus violaceus*** Fennell & Raper, *Mycologia* 47: 75. 1955. MycoBank MB292863. Fig. 57.

≡ *Emericella violacea* (Fennell & Raper) Malloch & Cain, *Can. J. Bot.* 50: 62. 1972. ≡ *Aspergillus violaceobrunneus* Samson & W. Gams, *Adv. Pen. Asp. Syst.*: 53. 1985.

= *Emericella similis* Y. Horie *et al.*, *Trans. Mycol. Soc. Japan* 31: 425. 1990. = *Aspergillus similis* (Y. Horie *et al.*) Samson, Visagie & Houbraken, *Stud. Mycol.* 78: 157. 2014.

**Typus:** IMI 61449. Culture ex-type: CBS 138.55 = NRRL 2240 = ATCC 16813 = CECT2587 = IFO 8106 = IMI 061449ii = IMI 61449 = LCP 82.3318 = NRRL A-3156 = QM 1905 = UC4511 = WB 2240 = DTO 048-B2.

**ITS barcode:** EF652438. (Alternative markers: *BenA* = EF652262; *CaM* = EF652350; *RPB2* = EF652174).

**Colony diam, 7 d (mm):** CYA 23–33; CYA 37 °C 45–56; CYA 40 °C 41–45; MEA 22–41; MEA 37 °C 58– >60; OA 30–32; YES 38–53; CREA 5–13; CYAS 18–25; DG18 3–16.

**Colony characters:** CYA 25 °C, 7 d: Colonies moderately deep, sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse brown. MEA 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, sulcate; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse yellowish brown. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse cream white to olive brown. OA 25 °C, 7 d: Colonies low, plane; margins entire; mycelium white; texture velvety; sporulation absent; soluble pigments light olive to light brown; exudates clear droplets; reverse light yellowish brown. CREA 25 °C, 7 d: Acid production absent.

**Micromorphology:** Ascomata cleistothecial, blackish to dark brown, globose, 25–50 µm in CBS 138.55<sup>T</sup>, up to 190 µm in CBS 293.93, surrounded by numerous Hülle cells; Hülle cells hyaline to pale yellowish brown, globose to ovoid, 6–26 µm. Asci 8 spored, globose to ovoid. Ascospores violet, in surface view globose to subglobose; spore bodies roughened, with reticulate intertwined ornamentation, 4–6.5 × 3–5 µm; in side view broadly lenticular, with two low equatorial crest, less than 0.3 µm wide. *Fide Fennell & Raper (1955)* the conidial structures on hay-infusion agar scattered, small and commonly fractional, not affecting the colony appearance. Conidiophores arising primarily from aerial hyphae, smooth-walled, very short, 30–50 µm in length by 3–4 µm in diameter, somewhat sinuous, thin-walled, hyaline or nearly so, terminating in rounded and somewhat enlarged vesicular areas mostly 5–6 µm, metulae few in number, borne on the upper part of the vesicle only, variable in dimensions, mostly 6–7.5 × 3–3.5 µm; phialides about 5–6 × 2–2.5 µm, flask-shaped, bearing conidia in short chains; conidia globose or nearly so, light green in colour, smooth or delicately roughened, mostly 2.8–3.3 µm in diameter.

**Extrolites:** asperugin, emestrin, violaceols, emericellin, paxillin.

**Distinguishing characters:** Violet ascospores with reticulate intertwined ornamentation.

**Notes:** According to Fennell & Raper (1955), limited and generally minute conidial heads were produced on hay-infusion

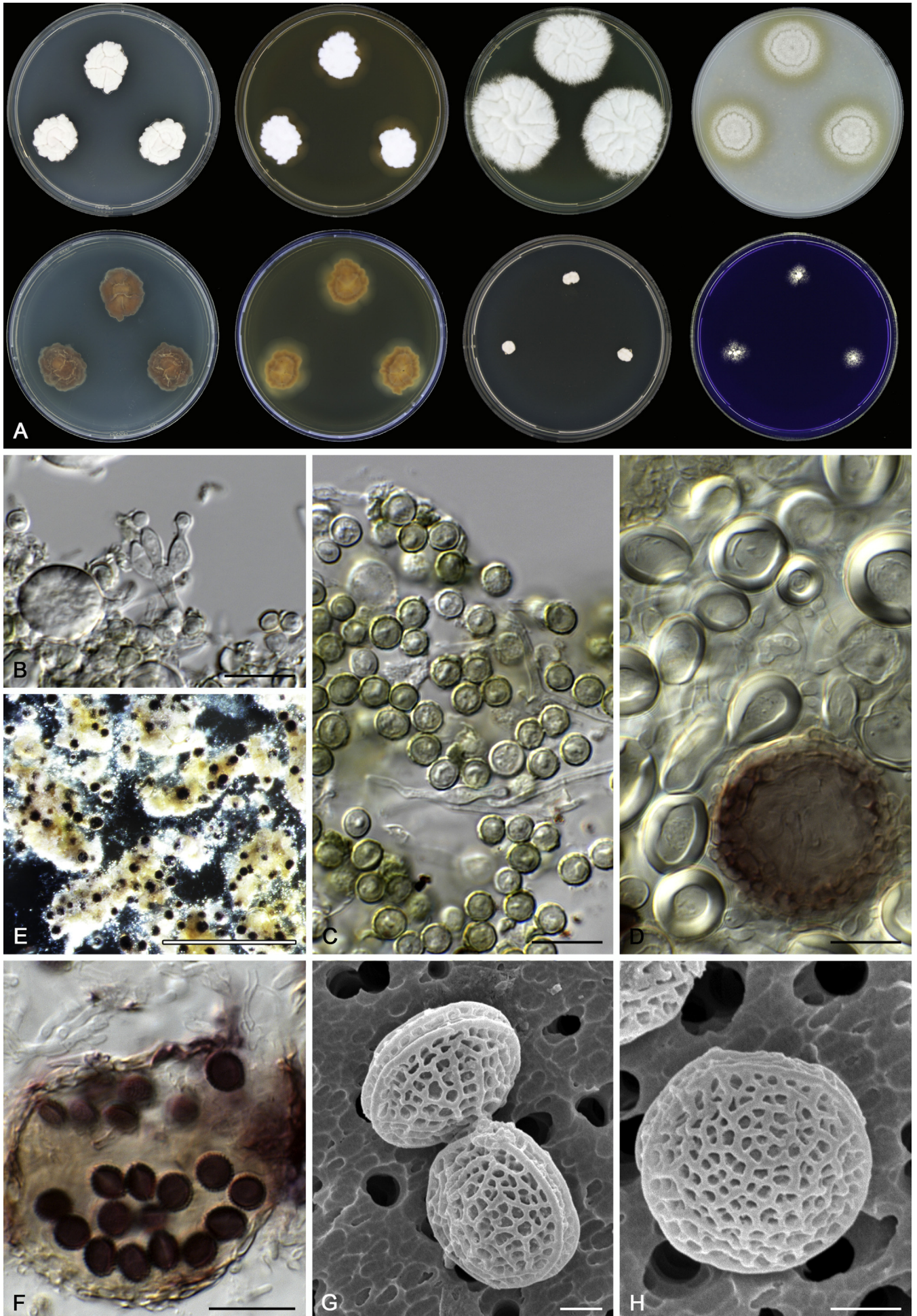
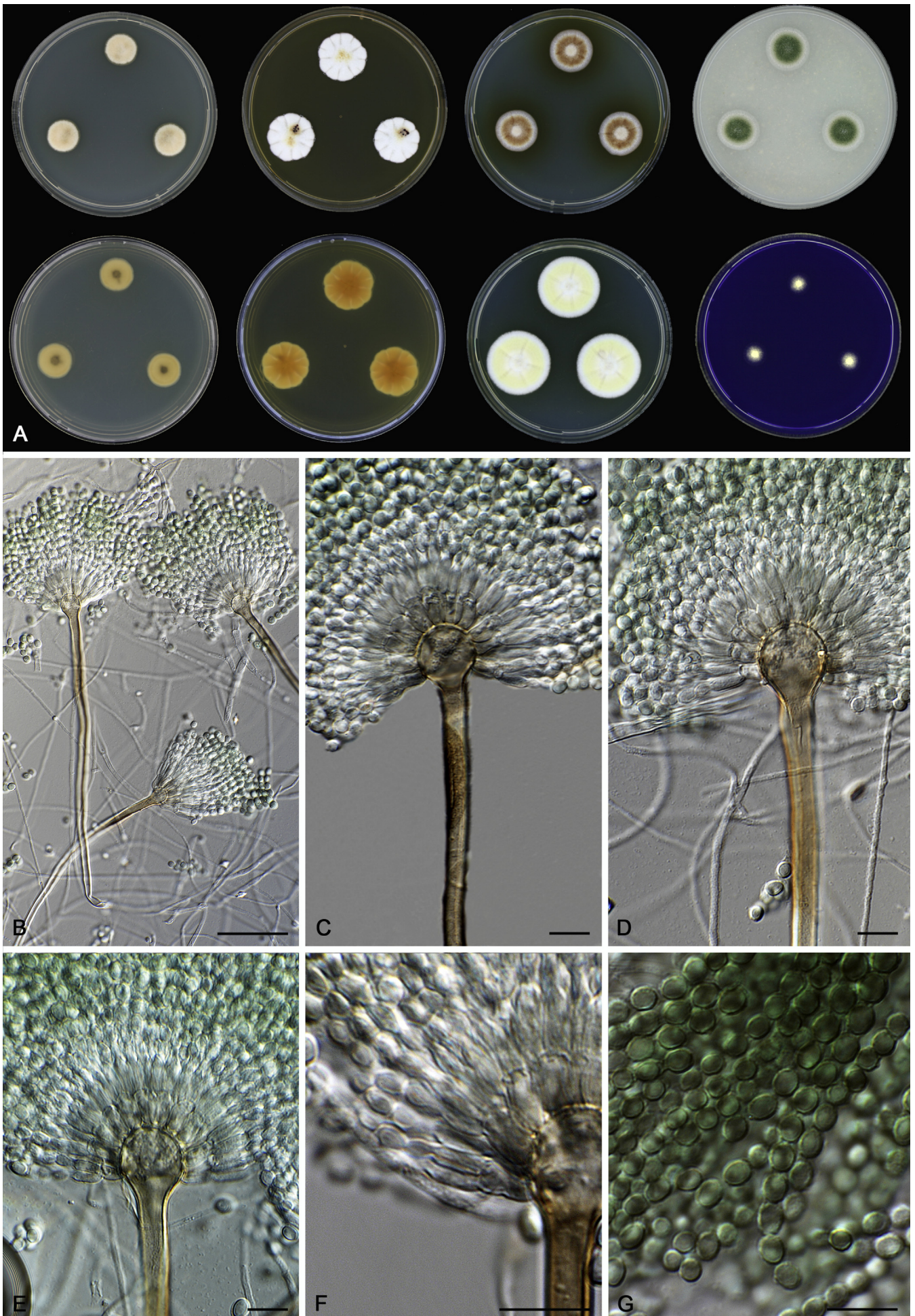


Fig. 57. *Aspergillus violaceus* CBS 138.55<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B. Conidiophores. C. Conidia. D. Hülle cells. E. Ascospores. F–H. Ascospores. Scale bars: B–D, F = 10  $\mu$ m; E = 1000  $\mu$ m; G–H = 2  $\mu$ m.



**Fig. 58.** *Aspergillus viridicatenatus* CBS 140629<sup>T</sup>. A. Colonies: top row left to right, obverse CYA, obverse MEA, YES and OA; bottom row left to right, reverse CYA, reverse MEA, DG18 and CREA. B–F. Conidiophores. G. Conidia. Scale bars: B = 30  $\mu$ m; C–G = 10  $\mu$ m.

agar. During our observation, atypical conidiophores and much bigger conidia (3.5–4.5 µm) are produced quite late (after 2 months) on CYA. *Aspergillus similis* (ex-type CBS 293.93) is undifferentiated from *A. violaceus* in ascospore morphology (Fig. 5S, T) and multi-gene phylogeny, thus is considered a synonym of *A. violaceus*.

***Aspergillus viridicatenatus*** A.J. Chen, Frisvad & Samson, **sp. nov.** MycoBank MB816088. Fig. 58.

*Etymology:* Name refers to its long green conidial chains.

*Diagnosis:* Subglobose, ellipsoidal to cylindrical conidia measuring 3–5 × 2.5–4 µm, teleomorph not observed.

*Typus:* Denmark, root of *Gymnadenia conopsea*, 2011, isolated by J.C. Frisvad (holotype CBS H-22498, culture ex-type CBS 140629 = IBT 31492 = DTO 325-F4).

*ITS barcode:* KU866682. (Alternative markers: *BenA* = KX423621; *CaM* = KU866802; *RPB2* = KU867067).

*Colony diam, 7 d (mm):* CYA 15–16; CYA 37 °C No growth; CYA 40 °C No growth; MEA 21–23; MEA 37 °C No growth; OA 19–20; YES 20–21; CREA 10–11; CYAS 12–13; DG18 29–30.

*Colony characters:* CYA 25 °C, 7 d: Colonies deep, plane; margins entire; mycelium buff; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse buff yellow. MEA 25 °C, 7 d: Colonies deep, sulcate; margins slightly irregular; mycelium white; texture floccose; sporulation sparse; soluble pigments absent; exudates dark brown droplets; reverse yellowish brown. YES 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium brown; texture floccose; sporulation moderately dense, conidia *en masse* yellow green; soluble pigments absent; exudates absent; reverse light yellow to light brown. DG18 25 °C, 7 d: Colonies moderately deep, slightly sulcate; margins entire; mycelium light yellow and white; texture floccose; sporulation absent; soluble pigments absent; exudates absent; reverse yellowish brown. OA 25 °C, 7 d: Colonies low, plane; margins entire; texture velvety to floccose; sporulation moderately dense, conidia *en masse* yellow green to dark green; soluble pigments absent; exudates absent; reverse pale green. CREA 25 °C, 7 d: Acid production absent.

*Micromorphology:* Ascomata not observed. Conidiophores with smooth stipes, yellowish brown to brown, 120–270 × 5–6 µm; vesicles hyaline to pale brown, globose to subglobose, 10–15 µm wide, fertile over the two thirds; metulae hyaline to pale brown, 6–9 × 2.5–3.5 µm; phialides hyaline to pale green, flask-shaped, 6–9.5 × 2.5–3.5 µm. Conidia subglobose, ellipsoidal to cylindrical, echinulate, 3–5 × 2.5–4 µm, green in mass.

*Extrolites:* An unidentified extrolite in common with *Penicillium bialowiezense*, which has a UV spectrum with absorption maxima at 220 nm, 312 nm and 324 nm, was present. The extrolite with this UV spectrum has not been found in any other *Aspergillus* species yet.

*Distinguishing characters:* *Aspergillus viridicatenatus* is close to *A. aureolatus* and *A. spelunceus*, but can be distinguished by its ellipsoidal to cylindrical conidia.

***Aspergillus* section *Cavernicolus*** A.J. Chen, Frisvad & Samson, **sect. nov.** MycoBank MB816113.

*Typus:* *Aspergillus cavernicola* Lőrinczi, Contr. Bot. Cluj: 341. 1969.

=*Aspergillus amylovorus* Panas. ex Samson, Stud. Mycol. 18: 28. 1979 =*Aspergillus amylovorus* Panas., Mycologia 56: 58. 1964

*Description:* Conidial heads radiate to columnar, conidiophores biserial, smooth, uncoloured or in brown shades. Vesicles globose to subglobose. Conidia smooth to rough. Hülle cells regularly present.

Five species previously assigned to section *Usti*, namely *A. amylovorus*, *A. californicus*, *A. cavernicola*, *A. egyptiacus*, *A. kassunensis* and *A. subsessilis* are included in this new section mainly based on multigene phylogeny (Fig. 1). Phylogenetically *A. amylovorus* is identical with *A. cavernicola*, although *A. amylovorus* was published at 1964, the name was not validated until 1979 (Samson 1979), thus *A. cavernicola* has priority based on its publication date, *A. amylovorus* is considered as a synonym.

## DOUBTFUL SPECIES LIST

*Aspergillus sub-unguis* Wadhvani, Dudeja & Srivastava Curr. Sci. 53: 443, 1984 (Wadhvani et al. 1984). – *Typus* IMI 254637. ITS barcode: n.a. (Alternative markers: *BenA* = n.a.; *CaM* = n.a.; *RPB2* = n.a.). Type culture is not available anymore and its taxonomic position cannot be determined.

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## APPENDIX A. SUPPLEMENTARY MATERIAL

Supplementary material related to this article can be found at <http://dx.doi.org/10.1016/j.simyco.2016.10.001>.

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