

ASPERGILLUS NIDULANS GROUP: ASPERGILLUS NAVAHOENSIS, AND A REVISED SYNOPTIC KEY

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ABSTRACT

A new species in the *Aspergillus nidulans* group is described and compared to related taxa. *Aspergillus navahoensis*, from arid lands belonging to the Navajo Tribe in northern Arizona, resembles *A. recurvatus* and *A. fruticosus* in having crystal-encrusted hyphae and basally curved or coiled conidiophores, but differs in dimensions of the conidium-bearing structures and in characteristics of the cleistothecial stage. The revised and expanded synoptic key to 34 taxa (29 species) uses readily observable features as an aid to identification and comparison of taxa.

Key Words: *Aspergillus*, *Aspergillus nidulans* group, soil fungi, *Emericella*, desert micro-fungi, synoptic key.

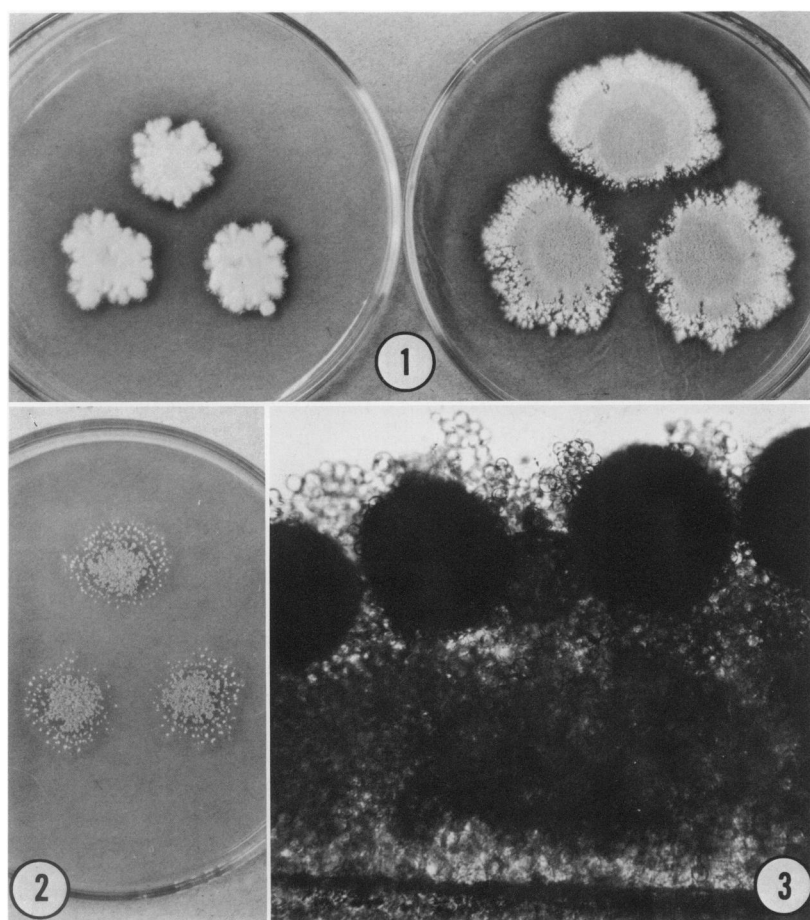
Representatives of the species described below were isolated from soil samples collected in northern Arizona in connection with an ecological study for the Navajo and Kaiparowits Generating Stations (10). The species is characterized particularly by its pale yellow, crystal-encrusted flexuous hyphae, continuous crust of loosely-piled Hülle cells, short conidiophores with recurved bases, and its large, rapidly maturing cleistothecia.

***Aspergillus navahoensis* Christensen & States, sp. nov. status perfectus sit judicatus** ***Emericella navahoensis* Christensen & States, sp. nov.** FIGS. 1–9

Coloniae in agar maltoso post dies 15–17, 24–26 C, usque ad 2.5–4.6 cm diam attingentes, griseo-chlorinae (7, XXX 25" d), floccosae, hyphis crystallis incrustatis; facies reversa et agar circumdato ferrugineis (7, XIV 9' k). Capitula conidica pistacea r(7, XLI 29''' i), columnaria ($\times 35\text{--}60\ \mu\text{m}$), bis-erata; conidiophorae saepe ex hyphis crystallis incrustatis emergentes, curvatae vel detortae prope radicem, $15\text{--}120 \times 3\text{--}5\ \mu\text{m}$, aliquando e substrato emergentes et deinde ad $400\ \mu\text{m}$ longitudine, enodes, aequaliter flavo-brunneae; vesiculae lagena formatae, $6\text{--}10\ \mu\text{m}$ crassis; metulae $5\text{--}9 \times 3\text{--}4.5\ \mu\text{m}$; phialides $5.5\text{--}9 \times 2.5\text{--}3.3\ \mu\text{m}$; conidia globosa vel subglobosa, eleganter rugosa, $3\text{--}4\ \mu\text{m}$ diam. "Hülle" cellulae plurimae in agar maltoso, persicinae (raro subviolaceae) cum in massis productae sunt, plerumque globosa vel subglobosae et $16\text{--}22\ \mu\text{m}$ diam, formantes crustam spongiosam $200\text{--}475\ \mu\text{m}$ crassam sub cleistotheciis. Cleistothecia conspicua sicut sphaerae atroviolaceae, paene nudata, $112\text{--}250\ \mu\text{m}$ diam, post dies 10 matura; asci octospori, $10\text{--}12 \times 9\text{--}10\ \mu\text{m}$; ascosporae lenticulares, badiae, cristis aequatorialibus $2, 0.6\text{--}1\ \mu\text{m}$ latis, rugibus radiantibus ornatis, superficies ascosporarum enodes, corpora earum $3.5\text{--}4.2 \times 3\text{--}3.5\ \mu\text{m}$.

Cultura typica: SD-5, isolata e solo colliculi arenariae, in quo innascitur *Gutierrezia sarothrae* (Pursh) Britt. & Rusby, *Vanceleva stylosa* (Eastw.) Greene, *Yucca angustissima* Engelm., *Ephedra viridis* Coville et *Erigeron* sp., prope Page, Arizona, USA; in herbario NY deposita.

Colonies on Czapek's solution agar (FIG. 1) growing restrictedly, 1–3.5 cm in diam after 15–17 da at room temperature, with margins irregular; surface felt-like, uncolored to pale yellow-green near yellowish glaucous to corydalis green or sea-



FIGS. 1-3. *Aspergillus navahoensis* SD-5. 1. Colonies on Czapek and malt agars, respectively, grown for 16 da at room temperature. 2. Colonies on half-strength hay infusion agar (6) after 16 da at room temperature. 3. Vertical section ('profile,' synoptic key set 14) through a colony grown on malt agar showing cleistothecia distributed over a loose crust of Hülle cells, $\times 250$.

foam green to chrysolite green (7, XLI and XXXI), becoming near picric yellow (7, IV) in age in most isolates and with a slight pink or red-orange tinge; reverse bright brown near liver to carob brown (7, XIV) or Morocco red to claret brown (7, I) and with that pigment diffusing in some isolates; conidial structures absent to few at 14 da, not affecting colony color, mostly sparsely produced at 1-2 months and colonies then green-tinged near mytho green to pois green (7, XLI); cleistothecia irregularly formed in a loose basal crust of Hülle cells in some isolates, lacking or abortive in others.

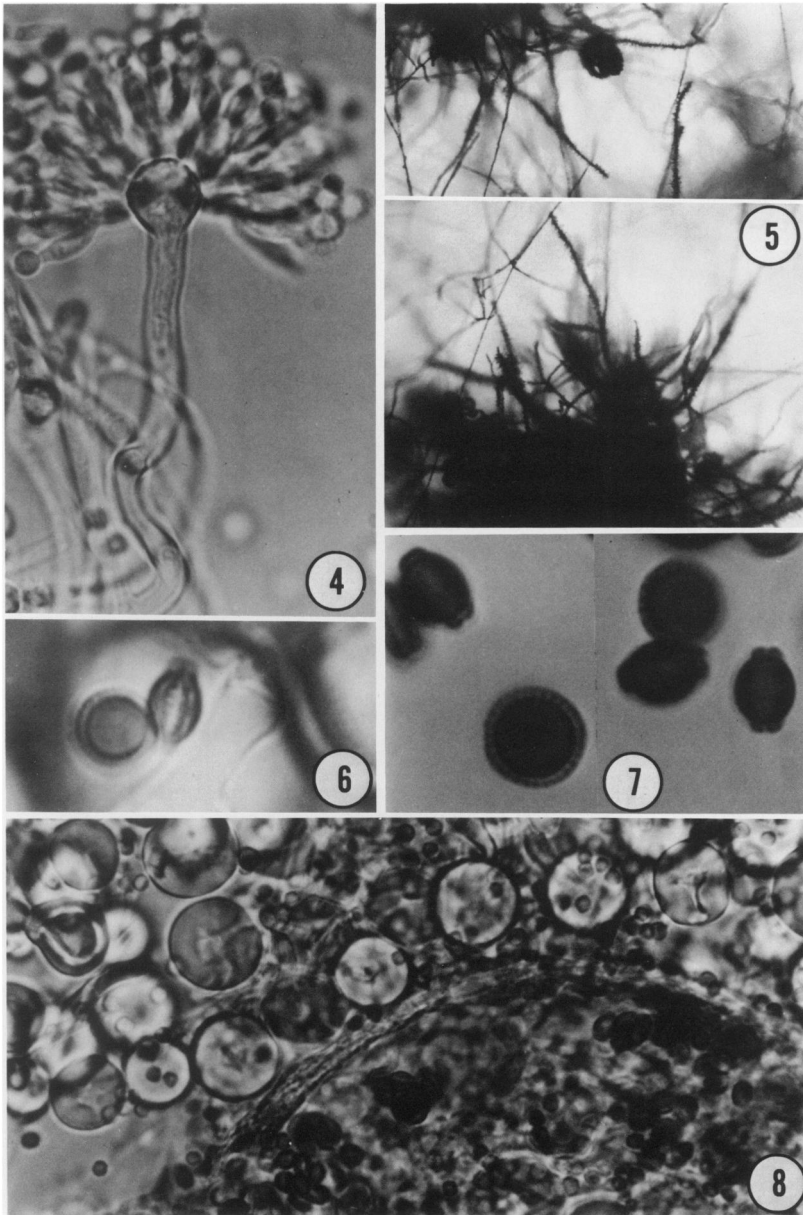
Colonies on malt agar (FIG. 1) 2.2-6.5 cm in diam after growth for 15-17 da at room temperature, pale yellow green near citron yellow or chartreuse yellow to citron green (7, XVI and XXXI) with heavily sporulating areas becoming light bice green or deep grape green or pistachio green (7, XVII and XLI), lightly floccose, commonly with a surficial growth of yellow crystal-encrusted flexuous hyphae; reverse and surrounding agar golden to bright orange-brown near orange rufous to burnt sienna becoming Kaiser brown to auburn in age (7, II and XIV);

odor not distinctive. Young colonies and colony margins characteristically producing erect, curling, crystal-encrusted hyphae, cream or pale greenish yellow in color, as an overgrowth above the developing loose crust of Hülle cells (FIG. 5); older colonies with conidiophore production from encrusted hyphae overlying and intermixed with cleistothecia on a bed of Hülle cells (FIGS. 3, 9). *Conidial heads* green, after 20–30 da becoming short columns 35–60 μm wide in most isolates; *conidiophores* predominantly from aerial hyphae, (15–)35–78(–120) $\times$ 3–3.8(–5) μm , with recurved or sinuous bases (FIG. 4), occasionally from the substrate and then up to 160–500 μm tall, smooth, uniformly brown-pigmented and with the vesicle similarly colored; *vesicles* flask-shaped, often appearing to be only slight expansions of conidiophore apices, 6–10 μm wide, fertile over the upper three-fourths, consistently with biseriate appendages; *metulae* compactly arranged, numerous, wedge-shaped, 5–9 $\times$ 3–4.5 μm ; *phialides* (5.5–)6–8(–9) $\times$ (2.7–)2.8(–3.3) μm ; *conidia* (FIG. 4) globose to subglobose, delicately roughened, uniformly 3–4 μm in diam. *Hülle cells* (FIG. 8) mostly globose to subglobose, rarely somewhat elongate to irregular, thick-walled, (12–)16–22(–25) μm in diam, hyaline to pale orange-red in mass by reflected light but pinkish violet in one isolate and violet-tinged areas occasional in other isolates, in clusters or rarely chains, loosely arranged in a layer 200–475 μm thick that subtends the cleistothecia (FIGS. 3, 9). *Cleistothecia* conspicuous as dark violet spheres mostly single layered on a continuous loose mass of Hülle cells and only scantily covered by Hülle cells and the ornamented flexuous hyphae (FIGS. 3, 9), globose, (112–)170–200(–250) μm in diam; *cleistothecial wall* (FIG. 8) 2.5–4 μm and several cells thick with the outermost layer having the appearance of a mosaic of flattened, lobed-interlocking cells similar to the wall in *A. spectabilis* Chris. & Raper, *A. bicolor* Chris. & States, *A. foveolatus* Horie, and others; *asci* 8-spored, 10–12 $\times$ 9–10 μm ; *ascospores* (FIGS. 6, 7) maturing rapidly (10 da or less, all isolates), vinaceous red-orange (in neutral and acid mounting media; violet in dilute NaOH) by transmitted light, lenticular with smooth convex walls and two equatorial crests 0.6–1 μm wide which are incurved, entire (ragged marginally in one isolate), with uniformly-spaced radiate ridges on the inner surfaces (FIG. 6), spore body 3.5–4.2 $\times$ 3–3.5 μm mostly 3.8–4 μm broad. Colony profile on malt agar (FIG. 9) is an expanded type 3 profile (1, fig. 3), just as type 2a in Christensen and Raper's scheme is an expanded form of type 2b.

Colonies on half-strength hay infusion agar (6) 1.5–3.5 cm in diam after growth for 15 da at room temperature, thin, spreading, with tufts consisting of encrusted hyphae, conidiophores, and a single cleistothecium with Hülle cells (FIG. 2); cleistothecia, ascospores and conidial structures morphologically equal to those produced on malt agar; ascospores mature at 10 da.

Colonies on malt agar at 37 C growing rapidly, 5.8–6.8 cm in diam after 8 da, lightly floccose, buff-colored, sterile or nearly so; reverse dark brown at center.

Anascosporic strains of three of the original soil isolates were obtained through isolation of colonies arising from single conidia. The variants, precisely similar to one another, are restricted on malt and Czapek's agars (1.8–4 cm and 1.8–3.4 cm in diam, respectively, after 16 da at room temperature), have crowded radiate conidial heads on malt agar and form sparse wefts of yellow hyphae centrally in age, but have few or no Hülle cells and are without cleistothecia; morphology of the conidial state in the variants differs from that in the parent cultures in that conidiophores are up to 580 μm long with vesicles 10–26 μm wide; additionally in contrast to the parent cultures, the anascosporic strains do not grow at 37 C. The anascosporic strains are represented by SD-5 var. (ATCC 44664).



FIGS. 4-8. *Aspergillus navahoensis* SD-5. 4. Typical conidiophore, arising from an aerial hypha and coiled at the base, $\times 1100$. 5. View of pale yellow aerial hyphae encrusted with distinctive, needle-like crystals that may project outward 6-8 μm ; malt agar, direct examination, $\times 110$. 6, 7. Ascospores in face and edge view to show lenticular form and incurved equatorial flanges with tooth-like ridges on their inner surfaces, $\times 2250$ and $\times 2500$, respectively. 8. Hülle cells, asci, ascospores, and cleistothecium wall in cross section, $\times 670$.

The perfect state may be referred to as *Emericella navahoensis* Christensen & States.

The outstanding characteristics of this species are 1) crystal-encrusted, pale yellow, flexuous hyphae similar in appearance to the crystal-bearing hyphae in *A.*

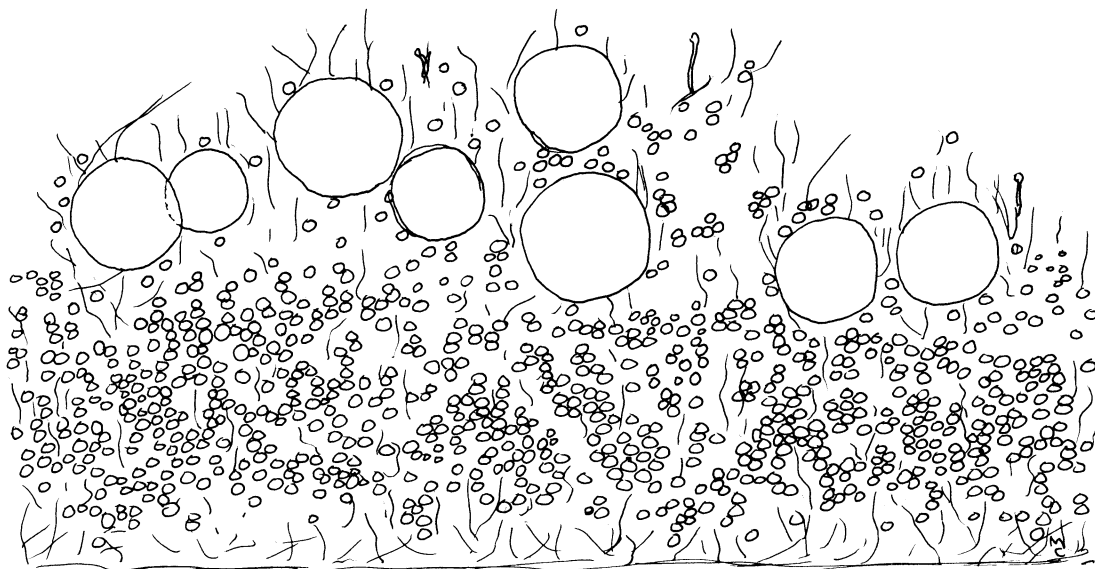
0 200 μm 

FIG. 9. Cross section of *Aspergillus navahoensis* colony on malt agar showing cleistothecial distribution in relation to Hülle cells, characteristic occurrence of vegetative hyphae throughout the profile, and conidiophores borne from aerial hyphae. Semidiagrammatic; scale approximate.

fruticulosus Raper & Fennell and *A. recurvatus* Raper & Fennell; 2) short, brown conidiophores borne from aerial hyphae and characteristically with recurved bases; 3) production of large (200–250 μm diam), rapidly maturing cleistothecia and red to red-orange ascospores mostly 3.8–4 μm broad with conspicuously ribbed equatorial crests about 1 μm wide, and 4) formation on malt agar of a continuous mass of peach-colored Hülle cells, loosely arranged, that elevate the cleistothecia to 200–475 μm above the agar surface.

The type culture, SD-5, was isolated from the soil of a native sand-dune shrub community in northern Arizona (10, site 15) with primarily *Gutierrezia sarothrae* (Pursh.) Britt. & Rusby, *Vancleavea stylosa* (Eastw.) Greene, *Yucca angustissima* Engelm., *Ephedra viridis* Coville, and *Erigeron* sp. at very low densities. The species description has been based upon the type culture and four additional isolates which are very similar to SD-5 culturally and morphologically. Isolates 24, 26, RPJA, and ASF (006)-2 were obtained from soil samples collected at sand dune, grassland, and pinyon-juniper [*Pinus edulis* Engelm. *Juniperus osteosperma* (Torr.) Little] woodland sites in northern Arizona (10, sites 2, 5, 14).

The holotype for the species, a dried plate culture of SD-5, has been placed in the Cryptogamic Herbarium of The New York Botanical Garden. Living cultures of *A. navahoensis* SD-5 are on deposit in the American Type Culture Collection, Rockville, Maryland (ATCC 44663), at the Commonwealth Mycological Institute, Kew, Surrey, England (IMI 259771), and with the Centraalbureau voor Schimmelcultures, Baarn, Netherlands (CBS 351.81).

Aspergillus navahoensis resembles *A. fruticulosus* and *A. recurvatus* culturally in its development of a striking overgrowth of crystal-encrusted hyphae. Additionally, in all three species short, brown conidiophores arise primarily from the ornamented aerial hyphae and characteristically have curved or coiled bases.

The three species differ in that *A. recurvatus* (1, 6, 9) lacks a cleistothecial stage and often does not form Hülle cells, and in comparison with *A. navahoensis* it has shorter conidiophores (up to 45–100 μm vs. 160–400 μm), and shorter metulae and phialides (5–6.2 μm and 4.5–6.5 μm vs. 5–9 μm and 5.5–9 μm). *Aspergillus fruticosus* (1, 6, 9) resembles *A. recurvatus* and differs from *A. navahoensis* in the dimensions of its conidium-bearing elements. It differs further from the new species in having separate cleistothecia surrounded by Hülle cells, and in the dimensions of its cleistothecia and ascospores.

SYNOPTIC KEY TO SPECIES IN THE ASPERGILLUS NIDULANS GROUP AND RELATED EMERICELLA SPECIES

Since 1978 (1), five species interpreted as belonging to the *Aspergillus nidulans* group have been newly described. They are *Aspergillus corrugatus* Udagawa & Horie (11), *A. foeniculicola* Udagawa (12), *A. foveolatus* Horie (3), *A. mellinus* Novobranova (5), and *A. navahoensis*. According to Samson (8), however, *A. mellinus* represents a non-ascosporic strain of *A. unguis* (Emile-Weil & Gaudin) Thom & Raper; on the basis of examination of NRRL 6328, derived from the type culture of *A. mellinus*, we concur. NRRL 6328 has cultural features, spicular hyphae, and conidial state features that render it indistinguishable from *A. unguis*. The remaining four species, noted above, produce both conidial (*Aspergillus*) and cleistothecial (*Emericella*) stages.

The synoptic key which follows provides a means for distinguishing 34 taxa (TABLE I) in the *Aspergillus nidulans*–*Emericella* assemblage of species. The key is a revision, primarily to accommodate the four new species, of the key that appeared in 1978 (1), and the reader may want to see that reference for discussions of unifying features in the group, cultural methods, and choice of features and use of the key—discussions which have not been affected by modification of the key. Brief descriptions for species 1–25 (TABLE I) also can be found in that earlier paper (1). Similar descriptions for the recently erected species are given here as an aid to comparison and to guide the reader to detailed technical descriptions. Scanning electron photomicrographs showing ascospore ornamentation in 22 taxa belonging to this assemblage have been published recently (4) together with certain colony features which may also facilitate recognition of taxa.

Isolates suspected of belonging to this group should be grown for 14 da at room temperature with ambient light on malt extract, Czapek's, and half-strength hay infusion agars (6).

Colony features

1. Restricted growth on malt extract agar: colony diam 2 cm or less after 14 da at 23–27 C. 2, 3, 6, 16, 19
Growth not restricted on malt. 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12?, 13, 14 (all), 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29
2. Colony on malt characterized by formation of pale brown, encrusted, spicular hyphae. 23
Colony on malt characterized by formation of an overgrowth of white, encrusted, flexuous or erect hyphae. 6, 8, 9, 10, 23
Colony on malt characterized by formation of an overgrowth of yellow, encrusted, flexuous or erect hyphae. 10, 18, 26, 29
Colony on malt with reverse and surrounding agar red to scarlet. 27
Colony on Czapek's agar and malt agar with conspicuous marginal stolons forming fine lateral branches and, on malt, short erect conidiophores. 15
Some strains with putrid odor on Czapek's agar. 10
3. Colony reverse on Czapek's agar brilliant orange. 1, 3, 8, 22
Colony reverse on Czapek's agar yellow. 4, 11, 12, 22, 25

TABLE I
SPECIES TREATED IN THE SYNOPTIC KEY AND THEIR REFERENCE NUMBERS IN THAT KEY*

1. <i>Aspergillus aeneus</i> Sappa	14d. <i>A. nidulans</i> var. <i>latus</i> Thom & Raper
2. <i>A. aurantiobrunneus</i> Raper & Fennell	14e. <i>A. nidulans</i> (Eidam) Wint. var. <i>nidulans</i>
3. <i>A. aureolatus</i> Munt.-Cvet. & Bata	15. <i>A. parvathecius</i> Raper & Fennell
4. <i>A. bicolor</i> Christensen & States	16. <i>Emericella purpurea</i> Samson & Mouchacca
5. <i>Emericella cleistominuta</i> Mehrotra & Prasad	17. <i>Aspergillus quadrilineatus</i> Thom & Raper
6. <i>Aspergillus crustosus</i> Raper & Fennell	18. <i>A. recurvatus</i> Raper & Fennell
7. <i>Emericella desertorum</i> Samson & Mouchacca	19. <i>A. rugulosus</i> Thom & Raper
8. <i>Aspergillus eburneocremeus</i> Sappa	20. <i>A. spectabilis</i> Christensen & Raper
9. <i>A. egyptiacus</i> Moubasher & Moustafa	21. <i>A. striatus</i> Rai, Tewari & Mukerji
10. <i>A. fruticosus</i> Raper & Fennell	22. <i>A. subsessilis</i> Raper & Fennell
11. <i>A. heterothallicus</i> Kwon, Fennell & Raper	23. <i>A. unguis</i> (E.-W. & G.) Thom & Raper
12. <i>A. kassunensis</i> Baghdadi	24a. <i>A. varicolor</i> var. <i>astellatus</i> Fennell & Raper
13. <i>A. multicolor</i> Sappa	24b. <i>A. varicolor</i> var. <i>varicolor</i> (Berk. & Br.) Thom & Raper
14a. <i>A. nidulans</i> var. <i>acristatus</i> Fennell & Raper	25. <i>A. violaceus</i> Fennell & Raper
14b. <i>A. nidulans</i> var. <i>dentatus</i> Sandhu & Sandhu	26. <i>A. corrugatus</i> Udagawa & Horie
14c. <i>A. nidulans</i> var. <i>echinulatus</i> Fennell & Raper	27. <i>A. foeniculicola</i> Udagawa
	28. <i>A. foveolatus</i> Horie
	29. <i>A. navahoensis</i> Christensen & States

* *Emericella sublata* Horie (Horie, Y. 1979. New or interesting *Emericella* from herbal drugs. *Trans. Mycol. Soc. Japan* 20: 481-491) came to our attention after completion of the manuscript. Its ascospores, which distinguish it from *A. corrugatus*, *A. foeniculicola* and *A. foveolatus*, resemble those in *A. heterothallicus*, *A. nidulans* var. *nidulans* and *A. nidulans* var. *latus* (4). It differs from *A. heterothallicus* in conidiophore length ("up to 210 μm " vs. 250-410 μm in *A. heterothallicus*) and apparent homothallism; it differs from the varieties of *A. nidulans* in having much larger cleistothecia ("200-380 μm in diam") and taller conidiophores (1, 6).

Colony reverse on Czapek's agar reddish brown to vinaceous. 4, 5, 6, 7, 10, 11, 12, 14 (all), 15, 17, 18, 19, 20, 21, 24, 25, 26, 27, 28, 29

Colony reverse on Czapek's agar uncolored or drab brown, green or dull orange. 2, 6, 9, 10, 12, 13, 16, 18, 21, 22, 23, 24, 25, 26, 29

4. Color of Hülle cells in mass by reflected light some shade of yellow, russet or ocher, rarely greenish yellow. 2, 8, 9, 11, 14 (all), 16, 17, 19, 21, 25, 26, 27, 28, 29

Color of Hülle cells in mass by reflected light lavender, pale blue or vinaceous. 1, 2, 4, 6, 7, 13, 15, 20, 22, 24, 29

Hülle cells hyaline by reflected light or very few in number and color in mass undeterminable. 2, 4, 5, 6, 9, 10, 11, 12?, 15, 18, 22, 23, 25, 29

Hülle cells not present. 3, 18, 23, 29

Conidial state features

5. Conidial state not present. 7, 8, 16, 25

Conidiophores less than 150 μm long. 2, 3, 5, 9, 10, 12, 14 (all), 15, 16, 17, 18, 19, 21, 22, 23, 25, 26, 27, 29

Conidiophores more than 150 μm long. 1, 2, 4, 6, 8, 11, 13, 20, 24, 25, 26, 27, 28, 29

6. Conidial heads white at maturity. 12?, 14, 16

Conidial heads pale yellow, ocher or tan. 1, 2, 3, 8, 24

Conidial heads some shade of green. 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14 (all), 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29

7. Conidial chains in compact columns exceeding 65 μm diam. 1, 4, 8, 11, 13, 20

Conidial chains in compact columns less than 65 μm diam. 3, 5, 6, 9, 10, 14b, 14c, 14d, 14e, 15, 17, 18, 19, 23, 24, 25, 26, 28, 29

Conidial chains radiate, tangled or in loose columns. 2, 3, 9, 12?, 14a, 15, 16, 21, 22, 24, 25, 27, 29

8. Conidiophores becoming brown-pigmented. 1, 2, 3, 4, 5, 6, 8, 10, 11, 13, 14 (all), 15, 17, 18, 19, 20, 23, 24, 26, 27, 28, 29
Conidiophores hyaline. 9, 12?, 13, 16, 21, 22, 25, 27
9. Biseriate, metulae wedge-shaped up to 3.8–4.5 μm wide or more. 1, 2, 3, 4, 6, 9, 11, 15, 20, 21, 24, 26, 28, 29
Biseriate, metulae narrower, mostly 2.5–3.5 μm wide. 1, 2, 3, 5, 8, 9, 10, 11, 12?, 13, 14 (all), 15, 16, 17, 18, 19, 22, 23, 24, 26, 27
Uniseriate heads present. 2, 5, 21, 22, 25

Ascosporic state features

10. Cleistothecia lacking or maturation requiring more than 14–16 da. 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14 (all), 15, 18, 22, 23, 29
Cleistothecia mature at 14–16 da; maximum diam excluding Hülle cells, 50–160 μm . 5, 10, 15
Cleistothecia mature at 14–16 da; maximum diam excluding Hülle cells, 175 μm or more. 2, 7, 11, 14 (all), 16, 17, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29
Heterothallic. 11
11. Ascospore convex wall smooth. 2, 4, 10, 11, 14a, 14b, 14d, 14e, 15, 16, 17, 20, 23, 24, 25, 26, 27, 28, 29
Ascospore convex wall rugulose, echinulate, ridged or pitted, not smooth. 4, 5, 7, 14c, 19, 21, 25, 26, 28
12. Ascospore crests lacking. 4, 14a, 21
Ascospore crests present, two in number. 2, 4, 5, 7, 10, 11, 14 (all), 15, 16, 17, 19, 20, 23, 24, 25, 26, 27, 28, 29
Ascospore crests four, or multiple and irregularly arranged. 15, 17, 21
13. Ascospore crests well-developed, commonly extending 1.7 μm or more outward from spore body. 11, 14d, 24
Ascospore crests incised, spores stellate in pattern. 24b
Ascospore crests up to 0.8 to 1.5 μm wide. 2, 10, 14b, 14c, 14e, 17, 20, 26, 27, 28, 29
Ascospore crests 0.6 μm wide or less. 4, 5, 7, 14a, 14b, 15, 16, 17, 19, 21, 23, 25
14. (Requires examination of colony profile on malt agar; most crust-formers are type 1 on Czapek's agar; see 1)
Cleistothecia several-layered, deeply embedded and often mutually compressed in a compact Hülle cell crust (type 5; 1, fig. 5). 2, 16
Cleistothecia at various elevations in Hülle cell crust or colony profile but not compressed or deeply embedded (type 2; 1, fig. 2). 4, 7, 14a, 19, 25
Cleistothecia single-layered, embedded in upper portion of an elevating Hülle cell crust; depth of Hülle cells beneath cleistothecia up to 400–600 μm (type 3; 1, fig. 3). 20, 21, 29
Cleistothecia individually elevated on separable Hülle cell columns measuring about 500 μm from agar to bottom of cleistothecium (type 4; 1, fig. 4). 24
Cleistothecia mostly separate without an underlying crust, not conspicuously elevated, with Hülle cell envelopes near 20 to 120 μm thick (type 1; 1, fig. 1). 4, 5?, 10?, 11, 14b, 14c, 14d, 14e, 15?, 17, 19, 23, 26, 27, 28

BRIEF DESCRIPTIONS OF RECENT SPECIES

Samson's (8) publication contains discussions of nine recently described species in the *A. nidulans* group (*A. bicolor*, *A. cleistominutus*, *A. corrugatus*, *A. egyptiacus*, *A. kassunensis*, *A. mellinus*, *A. purpureus*, *A. spectabilis*, *Emericella desertorum*). The descriptions to follow have been drawn from published accounts as indicated and from examination of *A. corrugatus* NHL 2763 received from S.-I. Udagawa in 1978. Numbers preceding names are reference numbers continuous with those used earlier (1). The group currently embraces 29 species and 34 varieties.

26. *ASPERGILLUS CORRUGATUS* (NHL 2763). Colonies on Czapek's agar 4.3–4.5 cm diam in 14 da at 25 C, lightly floccose, with delayed development of conidiophores and cleistothecia; cleistothecia in isodiametric masses of Hülle cells; reverse becoming red-brown to purple-brown. Colonies on malt agar 5.4–6 cm diam in 14 da at 25 C, characterized by uniform production of cylindrical,

dark green conidial columns and pale yellowish buff masses of Hülle cells, mostly well-separated and containing single, purple cleistothecia; trailing hyphae often with minute, amber-colored, warty concretions but never crystal-encrusted as in *A. navahoensis* and *A. recurvatus*; conidiophores 20–200 μm long (mostly 80–140 μm), brown, smooth, often sinuous, not basally recurved, with metulae 5–8 $\times$ 2.5–4 μm , phialides 6–8 μm long, and conidia globose to subglobose, echinulate, 2.5–3.5 μm diam; cleistothecia easily rolled free of Hülle cells, mature at 10–14 da, up to 285 μm diam; ascospores purple-red, characteristically with very delicately wrinkled walls and thus appearing to be reticulately or irregularly patterned in face view, lenticular, 3.5–4.5 $\times$ 3.2–4 μm (excluding crests), with 2 equatorial crests 0.5–1 μm wide.

Compare with *A. foveolatus*. *Aspergillus corrugatus* and *A. foveolatus* differ from *A. nidulans* var. *echinulatus* in conidial state features and ornamentation of the ascospore wall; they differ from *A. violaceus* in morphology and size of ascospores, Hülle cell distribution, and conidial state features. (8, 11).

27. *ASPERGILLUS FOENICULICOLA*. According to Udagawa and Muroi (12), conidial state lacking or poorly developed on malt and Czapek's agars, more abundant on cornmeal and M4OY (6); heads gray-green, small, radiate; conidiophores 20–160 $\times$ 2.5–5 μm , smooth, sinuous; vesicles 6–13 μm diam; metulae cylindrical, 5–6 $\times$ 2.5–3.5 μm ; phialides 4.5–7 $\times$ 2–3 μm ; conidia globose to subglobose, 2–3.2 μm diam, smooth. Cleistothecia, in straw-colored masses of hyphae and Hülle cells, maturing rapidly (12 da), up to 185 μm diam and filled with ascospores that are red-purple, lenticular, 3.5–4 $\times$ 2.5–3 μm (excluding crests), smooth, with 2 equatorial crests 0.5–0.8 μm wide.

This species differs markedly from other species in the group in its production of 1) conidia that are smooth and in small, radiate heads, and 2) ascospores that are unusually small and have low equatorial crests (12).

28. *ASPERGILLUS FOVEOLATUS*. Resembles *A. corrugatus* in size, color and morphology of all conidial stage structures, Hülle cell color, size and distribution, and in general appearance of the cleistothecial stage (size of the cleistothecium, relation to Hülle cells, time of maturation). The two species differ in that *A. foveolatus* 1) has slightly larger ascospores (4–5 $\times$ 3.5–4.5 μm vs. 3.5–4.5 $\times$ 3.2–4 μm , excluding crests), with minutely pitted convex walls and less conspicuous equatorial crests (3, fig. 3; 4; 11, fig. 2A), and 2) may be a more rapidly growing form with darker-appearing colonies (3).

29. *ASPERGILLUS NAVAHOENSIS*. Described in previous paragraphs.

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