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Notes on indoor fungi I: New records and noteworthy fungi from indoor environments

DE-WEI LI* & CHIN S. YANG

dli@stl-inc.com cyang@stl-inc.com
P & K Microbiology Services, Inc.
Cherry Hill, New Jersey, 08003

Abstract—Seven fungal species isolated from indoor environments, including four new records for the United States and three other noteworthy taxa, are described and illustrated. The new U.S. records are: *Ascotricha erinacea*, *Sporoschisma saccardoi*, *Stachybotrys microspora*, and *Stachybotrys nephrospora*. The noteworthy fungi are *Ascotricha chartarum*, *Memnoniella echinata,* and *Zygosporium masonii*.

Key words—ascomycetes, hyphomycetes

Introduction

Indoor fungal contamination has recently become a major issue for homeowners, building owners, business owners and the insurance industry, because public awareness of potential detrimental effects of indoor fungi has increased dramatically in the last decade. Morgan-Jones and Jacobsen (1988) described several darkly pigmented moulds, including two new species of *Cladosporium*, associated with biodeterioration of carpet, plaster and wallpaper from hotels in the southern U.S. Samson et al. (2000) described many common airborne fungi from indoors. Flannigan et al. (2001) provided a list of common and important indoor fungi, with brief descriptions. We note that fungi identified from indoor environments are rather diverse and over 600 species have been identified in our laboratory. Over the last fifteen years, we have isolated many unusual fungi from air and from water-damaged building materials. This paper reports four species new to the USA. *Ascotricha chartarum*, *Zygosporium masonii*, and an isolate of *Memnoniella echinata* producing dimorphic conidia are also described.

* Correspondence author; address after June 28, 2004: Valley Laboratory, The Connecticut Agricultural Experiment Station, 153 Cook Hill Road, Box 248, Windsor, CT 06095

Materials and methods

The isolates used in this study were isolated and purified from samples submitted to P & K Microbiology Services for fungal identification and enumeration. The isolates were grown on 2% Malt Extract, 1.5% Agar (MEA), Corn Meal Agar (CMA), or dicholran glycerol agar (DG18) for 1 to 2 weeks at 25 C. Dimension ranges given are based on 30 measurements. If fewer than 30 structures were available, the actual number measured is noted. United States postal abbreviations of State names are used in the distributional records of fungi reported from the United States.

Taxonomy

Ascotricha chartarum Berk. (Figure 1)

Anamorph: *Dicyma ampullifera* Boulanger

Description: Colonies slow-growing, 25-35 mm diam in 36 days on MEA at 25C, dark blue green with a yellowish edge; aerial mycelium yellow. Perithecia dark brown to black, pear-shaped, ostiolate, 94-150 × 60-105 μm (mean = 123 × 87 μm), developing olivaceous to black, geniculate, rigid, erect setae with thin-walled vesicles at geniculate nodes. Asci 8-spored, cylindrical, thin-walled, deliquescing after ascospores mature. Ascospores uniseriate, dark brown to black when mature, smooth, discoid with a distinct equatorial slit, 5.9-8.4 × 4.2-6.4 μm (mean = 7.5 × 5.5 μm).

Conidiophores straight, stiff, profusely branched, up to 1 mm long, 3.5-5.5 μm wide with pale, thin-walled vesicles at the bends. Conidiogenous cells lateral and terminal, cylindrical, sympodial, developing conidia on denticles. Conidia lightly rough, subspherical to ellipsoidal, colorless when young, becoming light brown when mature, 4.5-7.4 × 2.4-3.7 μm (mean = 5.4 × 3.5 μm).

Habitat: plant materials, paper, linoleum, plaster, cardboard, cloth, cork, skin, seeds, soil, and lignum (Hawksworth 1971, Hanlin 1990). Culture 030130-012 was isolated from water-damaged drywall and wood structures from FL.

Distribution: Brazil, China, Denmark, England, France, Germany, India, Italy, New Zealand, Tanzania and USA (FL, NH., MA) (Hawksworth 1971). It was found in indoor environments in AZ, NY and SC.

Remarks: the fungus is a cellulolytic saprobe. It also causes maxillary sinusitis (de Hoog et al, 2000). *Ascotricha chartarum* var. *orientalis* Castell.

& Jacon. was considered to cause dermatoid infection (paracladiosis) (Hawksworth 1971). A dried specimen derived from the culture 030130-012 is deposited in BPI and CBS. Living cultures are deposited in ATCC.

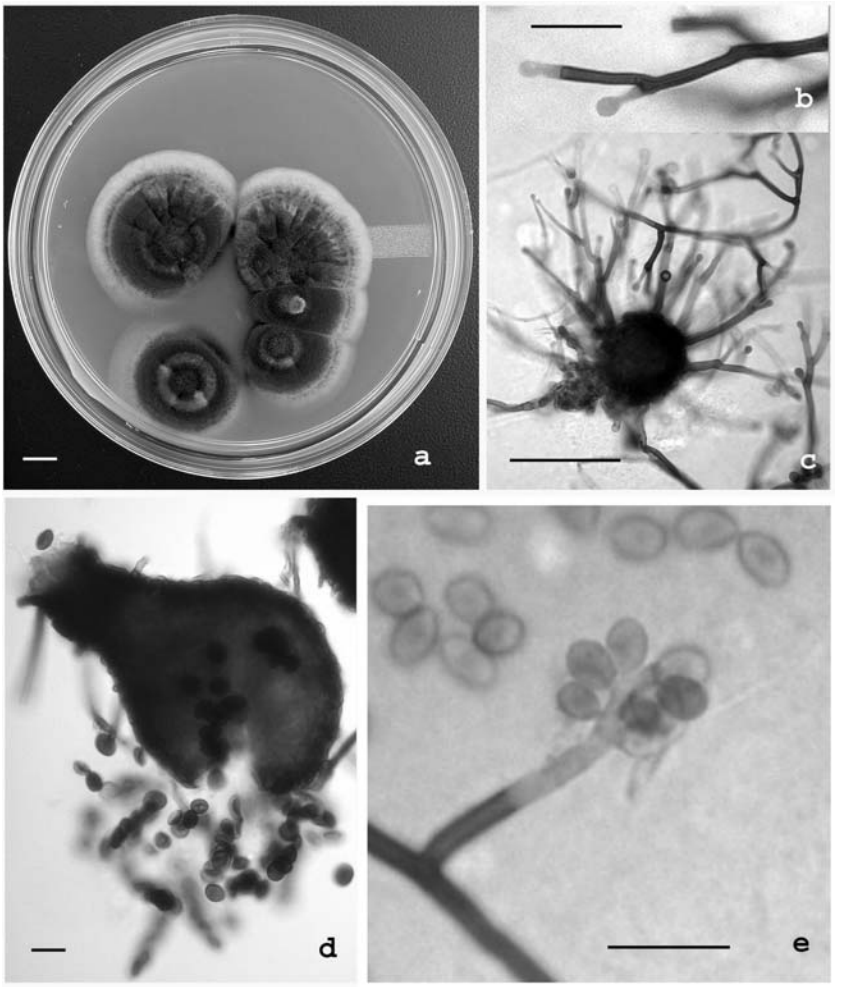

Figure 1. *Ascotricha chartarum* (030130-012). a. Colonies on MEA after 36 days. b. Appendages. c. Perithecia and appendages. d. Perithecia and ascopsores. e. Conidiophores and conidia. Bars: a = 10 mm, b, d, e = 10 μm, c = 100 μm, respectively.

Ascotricha erinacea Zambett. (Figure 2)

Description: Colonies 17-22 mm diam in 7 days on MEA at 25C, green with a raised white center and wavy light brown edge. Conidiophores 44-92 × 2.2-4.8 μm (mean = 60 × 2.9 μm). Conidia 3.7-5.9 × 2.4-3.7 μm (mean = 5.1 × 3.5 μm). Perithecia black, developing among the conidiophores, ostiolate, globose to subglobose, 99-165 × 66-115 μm (mean = 135 × 88 μm). Terminal hairs erect, brown to black, geniculate, often dichotomously and trichotomously branched, remotely septate, narrowing to pointed apices, 4.5-8 μm wide at the base. Lateral hairs sparse or absent, similar to the terminal hairs. Asci 33-72 × 7.8-11 μm (mean = 57 × 8.6 μm). Ascospores 9.4-13 × 5.6-7.4 μm (mean = 12 × 6.5 μm).

Habitat: on paper of water-damaged drywall and wood structures. Culture 021219-026 isolated from indoors in MN.

Distribution: France (Hawksworth 1971) and USA (AZ MD, MN, and NY). It is a new record for the U.S.A.

Remarks: this species was isolated from paper by Zambettakis in 1955. Hawksworth described it in his revision of the genus *Ascotricha*. It appears to be a rare species. We have occasionally encountered it on water damaged paper products or on wood. A dried specimen derived from culture 021219-026 is deposited in BPI and CBS. Living cultures are deposited in ATCC.

Memnoniella echinata (Riv.) Galloway (Figure 3)

Description: Colonies 34 – 37 mm in 21 days on MEA at 25C, gray to dark gray, granular, radially sulcate with irregular edge, reverse light brown. Conidiophores unbranched, colorless at first, olivaceous later, 42-103 μm (mean = 78 μm) long and 2.8-5.6 μm (4.5 μm) wide, branched portion 22-53 μm (mean = 39 μm) smooth to minutely rough. Phialides unicellular, obovoid or ellipsoidal, pale olivaceous, smooth, of two kinds: (1) phialides producing globose conidia 5.6-9.3 × 2.2-3.9 μm (mean = 8 × 3.4 μm), in groups of 3 to 8 (mostly 5); (2) phialides developing oblong conidia 7-9.3 × 3.2-4.3 μm (7.8 × 3.7 μm) in groups of 3 to 4 (mostly 3); terminal, or intercalary because of extension of phialide. Conidia of two kinds: (1) globose, in dry basipetal chains, colorless and smooth-walled at first, later dark olivaceous, coarsely warted, subglobose to globose, 3.2-4.4 × 2.4-4.3 μm (mean = 3.8 × 3.6 μm); (2) oblong to pyriform, smooth to rough, dark olivaceous 5.7-9.3 × 3.3-4.7 μm (mean = 7.9 × 3.7 μm).

Habitat: Indoor air, paper products, textiles, wood (*Hevea brasiliensis*) (Ellis 1971, Florence *et al*. 1998), ginger (Srivastava *et al*. 1998). Culture 021220-067 was isolated from MI.

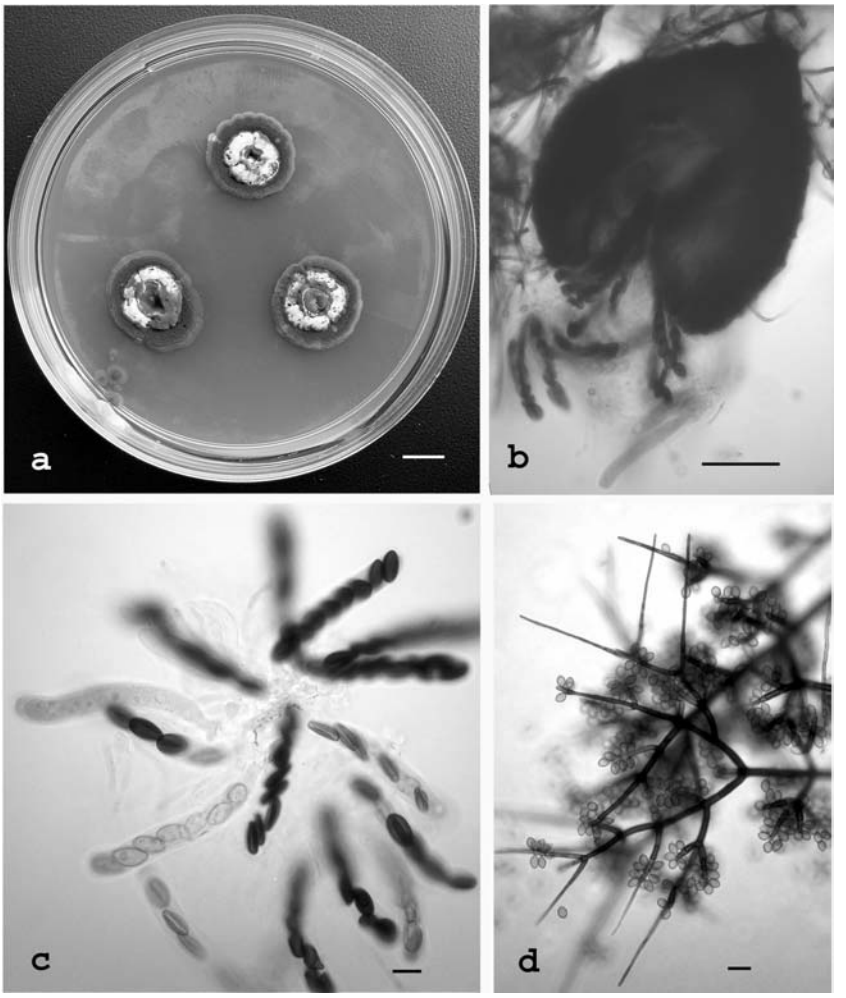

Figure 2. *Ascotricha erinacea* (021219-026). a. Colonies on MEA after 7 days. b. Perithecia. c. Asci and ascospores. d. conidiophores and conidia. Bars: a = 10 mm, b = 40 μm, c, d = 10 μm, respectively.

Distribution: cosmopolitan, but mainly from tropical areas (Domsch *et al*. 1993, Ellis 1971, Jong and Davis 1976). We have identified this fungus from

indoor environments in U.S.A. (AZ, CA, FL, HI, IL, LA, MN, NJ, NY, OH, PA, SC, TN, TX, VA, WA, and WI). It was found more often in NJ, NY, and PA.

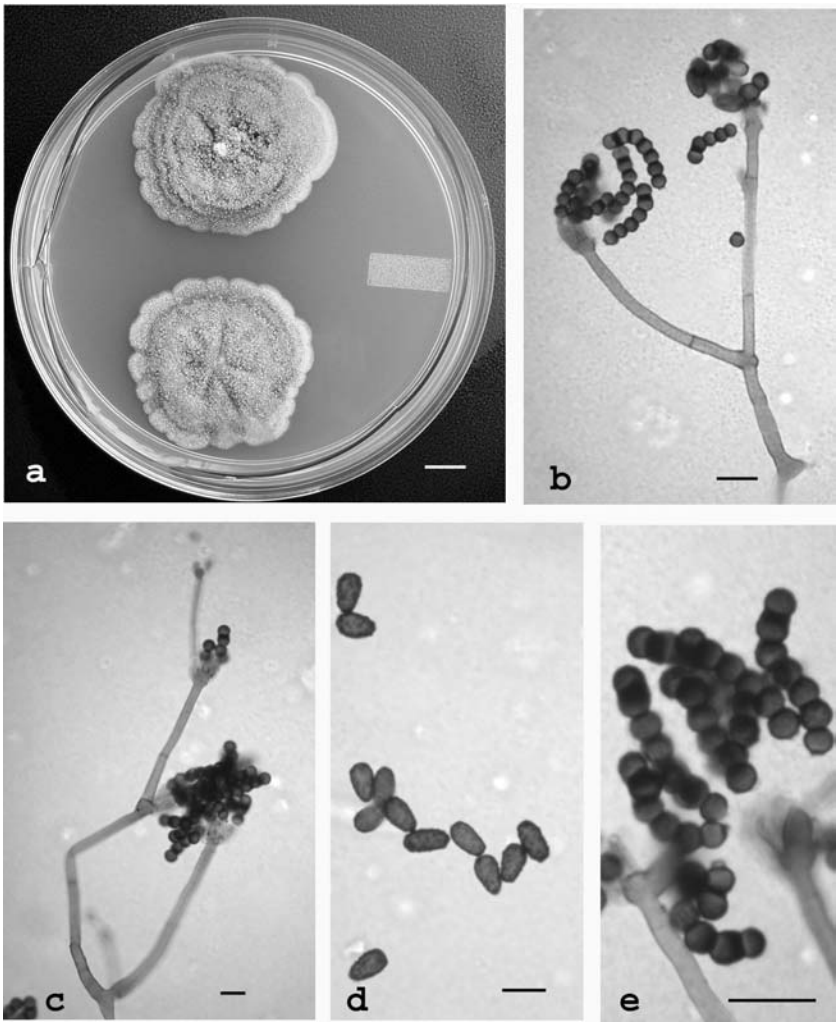

Figure 3. *Memnoniella echinata* (021220-067). a. Colonies on MEA after 7 days. b. Conidiophore with 2 kinds of conidia. c. Proliferation of conidiophore through phialides. d. *Stachybotrys*-type conidia. e. *Memnoniella*-type conidia. Bars: a = 10 mm, b-e = 10 μm, respectively.

Remarks: the fungus produces several mycotoxins: trichodermol, trichodermin, dechlorogriseofulvins, memnobotrins A and B, memenoconol, memnoconone (Jarvis *et al.* 1996). A dried specimen derived from the culture 021220-067 is deposited in BPI and CBS. Living cultures are deposited in ATCC.

Sporoschisma saccardoi Mason & Hughes apud Hughes (Figure 4)

Holomorph: *Melanochaeta hemipsila* (Berk. & Broome) Müller, Harr et Sulmont, Revue de Mycologie 33: 377 (1969).

Description: Colonies restricted, 5 - 8 mm diam in 7 days on MEA at 25C, dark brown to black, covered with grayish aerial mycelium, velvety; reverse dark brown. Conidiophores with terminal phialides, dark brown, smooth, erect, straight, solitary or in groups of 2 to 4, developing very sparsely at center, more profusely at the edge of colonies, 130 – 200 μm (mean = 170 μm) long, 1-septate. Venter of phialides somewhat inflated, 14-20 μm wide (mean =15.6 μm) at inflated portion, apices 11-14 μm wide (mean = 13.5 μm), base 8.4-14 μm wide (mean = 10.8 μm). Conidia in long chains, cylindrical with truncate ends, smooth, dark brown, very dark at the septa, majority 5-septate, the two end cells much shorter and lighter, 32-53 × 11-13 μm (mean = 43 × 11.5 μm), mean conidium length/width ratio = 3.78:1. Developing conidia can be observed through the phialide walls. Capitate hyphae 92-170 × 4.2-5.9 μm (mean = 135 × 5.5 μm), erect, straight, or slightly bent, 2-4-septate, solitary or in pairs, developed in mucilaginous envelopes, mixed with conidiophores; the tips of capitate hyphae are inflated, 7.4-13 × 7.4-13 μm (mean = 10 × 9.5 μm). This fungus sporulates poorly on MEA, but very well on CMA.

Habitat: on wood, especially wet or submerged (Goh *et al.* 1997). Culture 020703-043 was isolated from water-damaged wood structures indoors.

Distribution: Australia, Brunei, Canada, Italy, Hong Kong, Indonesia, Japan, Malaysia, South Africa, South America, Taiwan (Goh *et al.* 1997, Nag Rag and Kendrick 1975, Watanabe 2002), and USA (FL, IL). It is a new record for the U.S.A.

A dried specimen derived from the culture 020703-043 is deposited in BPI and CBS. Living cultures are deposited in ATCC.

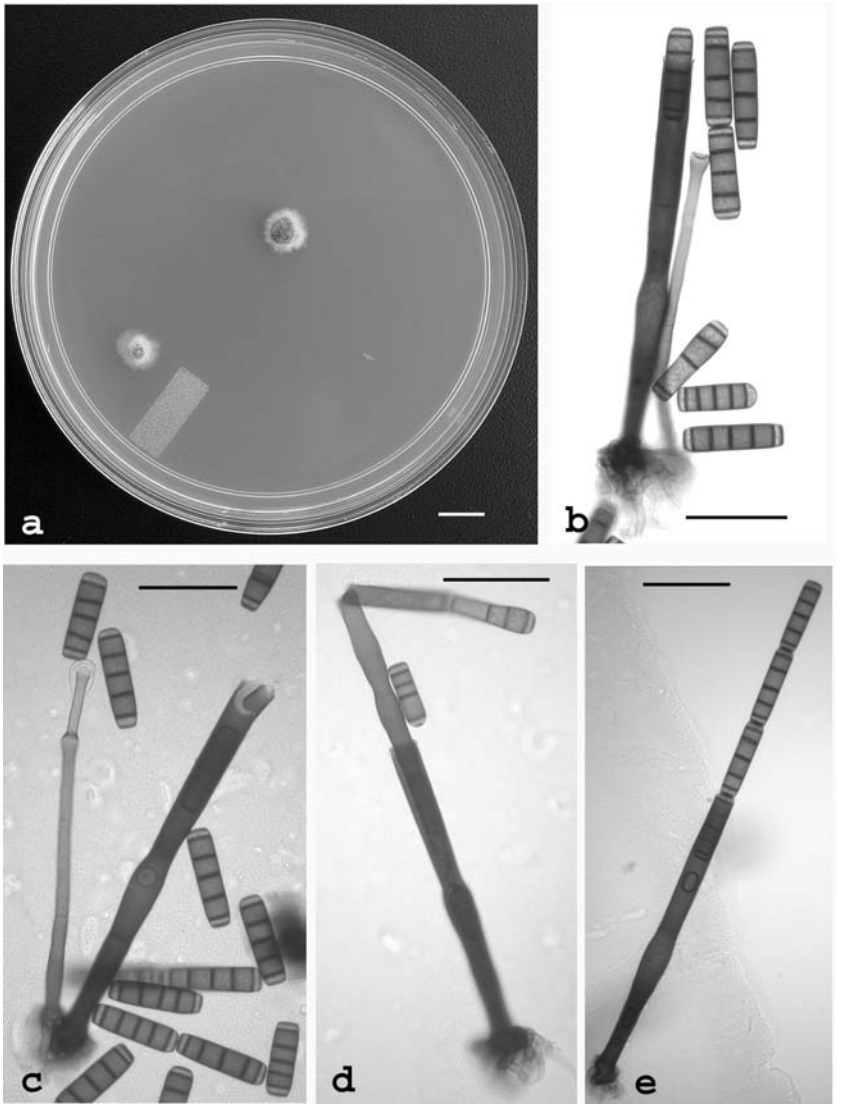

Figure 4. *Sporoschisma saccardoi* (020703-043). a. Colonies on MEA after 17 days. b. Conidiophore, conidia and capitate hypha. c. Percurrent extension of capitate hypha with conidiophore and conidia. d. Extension of conidiophore. e. Conidophores and conidia without vesicles. Bars: a = 10 mm, b-e = 40 μm, respectively.

Stachybotrys microspora (Mathur & Sankhla) Jong & Davis (Figure 5)

Description: Colonies slow growing 16.5 – 19 mm diam in 14 days on MEA at 25C, white with a pink tint; reverse brown; aerial mycelium white; the edges of the colonies irregular. In three weeks the colonies become light gray, still with a light pink tint; clear amber exudates start to develop. After four weeks, the colonies become dark gray to black. Conidiophores differentiated, single, determinate, simple, colorless and smooth, erect, straight, colorless to light brown, smooth, 44-92 × 2.2-4.8 μm (mean = 60 × 2.9 μm). Phialides 7-11 × 3.3-7.4 μm (mean = 8.8 × 4.6 μm) with conspicuous collarettes, in groups of 5-6. Conidia ellipsoidal, olivaceous, smooth to rough, 4.3 - 6.1 × 3.7 – 4.6 μm (mean = 5.4 × 4 μm).

Habitat: paper, soil, seeds, textiles and dead plants (Ellis 1971). It was isolated from paper of water-damaged drywall, and wallpaper, from WA.

Distribution: Canada, Cuba, India, Nigeria, and Pakistan (Ellis 1971). Culture 021020-084 is the first record for the U.S.A.

A dried specimen derived from the culture 021020-084 is deposited in BPI and CBS. Living cultures are deposited in ATCC.

Stachybotrys nephrospora Hansford (Figure 6)

Description: Colonies olivaceous to black, 37 – 42 mm diam in 22 days on MEA at 25C; reverse brown; aerial mycelium white; the edge of the colonies slightly irregular. Conidiophores differentiated, single, determinate, simple, occasionally branched, colorless and smooth, erect, straight or curved (flexuous), 60-150 × 2.5-3.3 μm (mostly 93.6 × 3.2 μm). Phialides obovoid or ellipsoidal, 8-10 × 4.2-6.6 μm (mean = 9 × 5 μm) in group of 2-4 (mostly 3) with conspicuous collarettes. Conidia reniform, colorless at first, becoming olivaceous to nearly black at maturity, smooth to rough, 8.3 – 13 × 5 – 8.3 μm (mean = 10.4 × 6.5 μm).

Habitat: on wood. Culture 021213-012 was isolated from water-damaged wallboard in Florida.

Distribution: Solomon Islands, India, Jamaica, Sierra Leone, Uganda (Ellis 1971). This species is newly recorded for North America. We have seen this fungus three times, from FL and AZ.

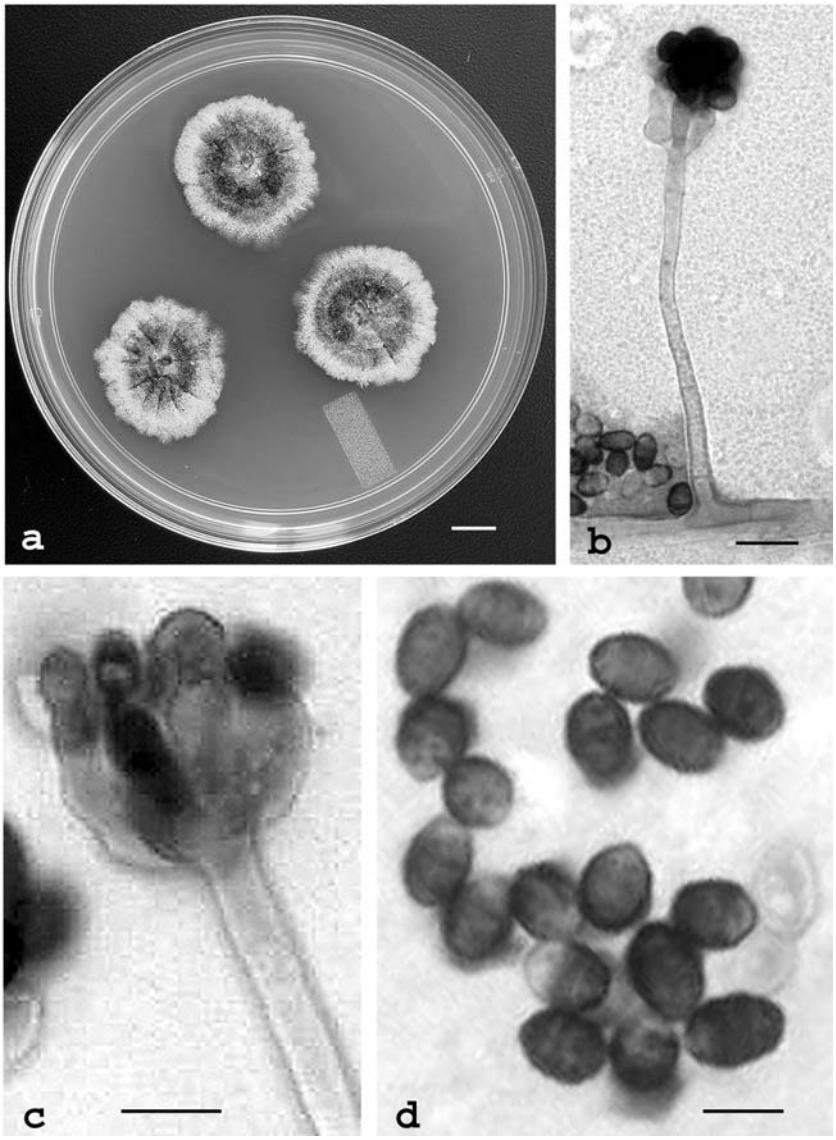

Figure 5. *Stachybotrys microspora* (021030-084). a. Colonies on MEA after 3 weeks. b. Conidiophore and conidia. c. Phialides with immature conidia. d. Conidia. Bars: a = 10 mm, b = 10 μm, c, d = 5 μm, respectively.

A dried specimen derived from the culture 021213-012 is deposited in BPI and CBS. Living cultures are deposited in ATCC.

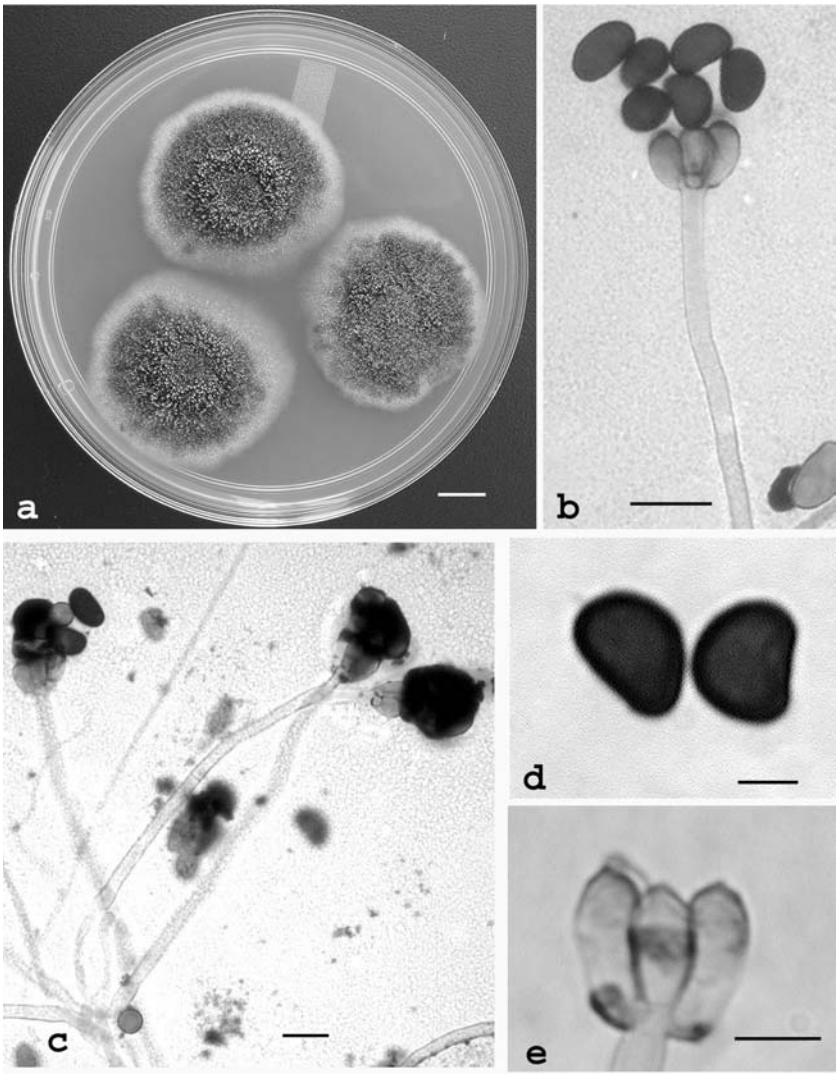

Figure 6. *Stachybotrys nephrospora* (021213-012). a. Colonies on MEA after 7 days. b Conidiophore and conidia. c. Conidia in slimy masses on conidiophores. d. Conidia. e. Phialides. Bars: a = 10 mm, b, c = 10 μm, d, e = 5 μm, respectively.

Zygosporium masonii Hughes (Figure 7)

Description: Colonies slow growing, 4 – 6 mm diam in 7 days on MEA at 25C, raised; aerial mycelium white; reverse brown. Conidiophores differentiated, single, 59-89μm long (mean = 71μm), erect, brown, smooth, with chains of up to 6 integrated vesicles (falces) and a colorless, sterile apical region, which is 15- 39 × 1.1-2.2 μm (mean = 23 × 1.8 μm) and terminates in a small knob. Vesicles (falces) thick-walled, dark brown, reflexed, 7.4-14 × 3.7-7.4 μm (mean = 9.8 × 5.6 μm), each developing 1-3 short, colorless distal conidiogenous cells. Conidiogenous cells monoblastic, discrete, determinate, ellipsoidal, curved, colorless, 3.7- 7.4 × 1.9-3.7 μm (mean = 5.9 × 3.0 μm). Conidia solitary, acrogenous, non-septate, ellipsoidal, colorless, smooth to rough, 3.9- 7.4 × 1.9-3.7 μm (mean = 6.5 × 2.9 μm). Conidiophores develop sparsely on MEA, but more profusely on DG18 medium.

Habitat: dry-wall, wall-paper indoors, air, soil, and dead plant materials. Culture 030201-011 was isolated from AZ.

Distribution: U.S.A. (AZ, southern CA, LA, TX), Assam, Australia, Ghana, Guinea, Hong Kong, India, Jamaica, Japan, Sierra Leone, Tanzania, Venezuela (Barron 1968, Ellis 1971, Matsushima 1975).

Remarks: *Zygosporium* is known to produce cytochalasin, which has cytotoxic effects on membrane function and the contractile mechanisms of cell movement and division (Griffin 1994). It prefers low water activity. A dried specimen derived from the culture 030201-011 is deposited in BPI and CBS. Living cultures are deposited in ATCC.

Discussion

Our observations suggest that *Ascotricha erinacea* is more common than *A. chartarum* in indoor environments, although *A. erinacea* was previously known from France (Hawksworth 1971). Anamorphs of both *Ascotricha chartarum* and *A. erinacea* develop well on MEA and DG18, but their teleomorphs usually fail to develop, or are produced sparsely on the same media. Freshly isolated cultures may develop the teleomorph, but subcultures normally do not produce ascomata.

A number of isolates of *Memnoniella echinata* (021220-067), *M. subsimplex* and *M. longistipitata* were observed to develop both *Stachybotrys*-type and *Memnoniella*-type conidia on the same colonies. *Stachybotrys*-type conidia are more often developed at the edges of colonies. Conidiophores of *Stachybotrys proliferata* Karandikar, Lulkarni & Patwardhan proliferate like those of *M. echinata* (isolate 021220-067) (Karandikar, Lulkarni, and Patwardhan 1992). *Stachybotrys*-type conidia in those isolates of *Memnoniella* spp. developing dimorphic conidia are all more or less oblong.

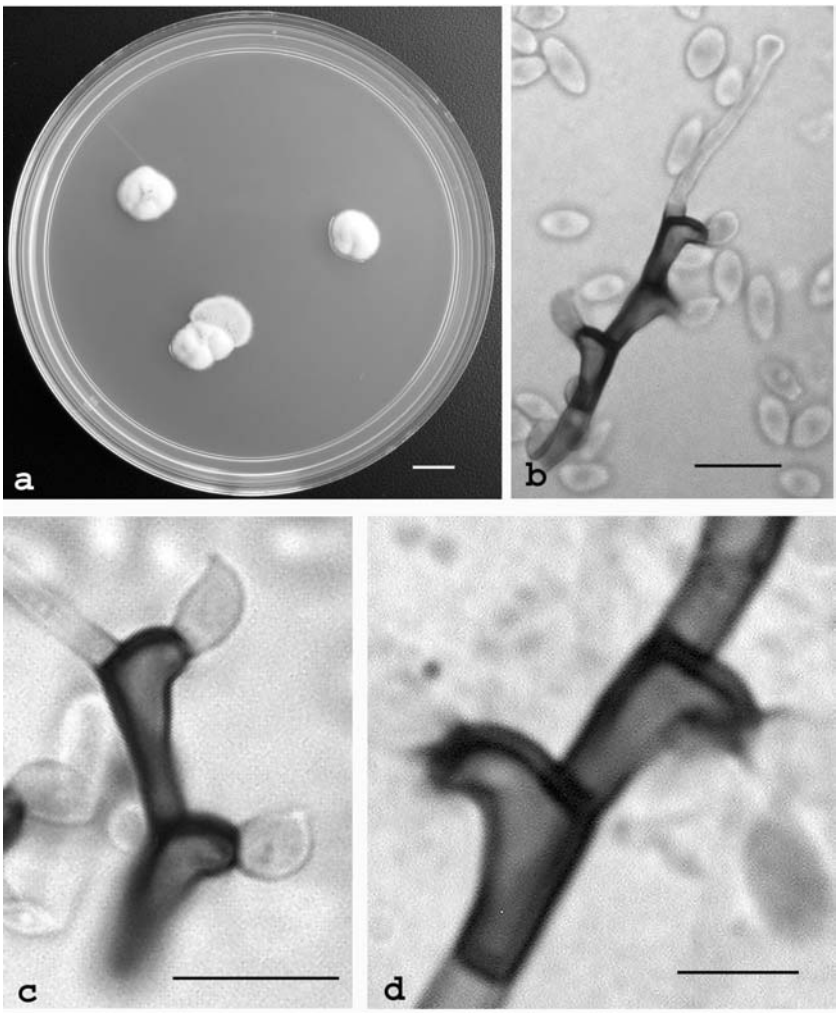

Figure 7. *Zygosporium masonii* (030201-011). a. Colonies on DG 18 after 7 days. b. Conidiophore and conidia. c. Vesicles, conidiogenous cells and conidia. d. Vesicle with collapsed conidiogenous cells. Bars: a = 10 mm, b, c = 10 μm, d = 5 μm, respectively.

But in *M. echinata* (021220-067) while some conidia were oblong or ovoid, a significant portion of the *Stachybotrys*-type conidia were pyriform. This

isolate could be a new taxon, but further studies are needed to determine its disposition.

Sporoschisma saccardoi (020703-043) grown on CMA produced a few conidiophores and capitate hyphae showing percurrent extension. Since the percurrent extension of conidiophores is one of important characters differentiating *Sporoschismopsis* from *Sporoschisma, Sporoschisma saccardoi* (020703-043) appears to be intermediate between *Sporoschisma* and *Sporoschismopsis*. This phenomenon raises two questions: 1) whether *Sporoschisma* and *Sporoschismopsis* should be treated as two separate genera; 2) whether the culture we examined should be a new species. To answer above-mentioned questions, further research is necessary. Watanabe (2002) suggested that the capitate hyphae of *S. saccardoi* are possibly in the process of developing into mature conidiophores, but we were unable to confirm this. During the percurrent extension of the capitate hyphae, they remained non-sporulating.

Both *S. microspora* and *S. nephrospora* are reported for the first time in the U.S.A. Without careful examination, both can be confused with *S. chartarum*. Conidia of *S. microspora* are similar to immature or smaller ones of *S. chartarum*. Ellis agreed with Mathur & Sankhla (1966) and treated it as a variety of *S. chartarum* (*Stachybotrys atra* var. *microspora*) (Ellis 1971). Jong and Davis (1976) elevated it to species rank. The comparative sequence analysis conducted by Haugland *et al*. (2001) showed that Jong and Davis were correct. Since the delimitation of *S. microspora* and *S. chartarum* is mainly based on conidial size, it is crucial to measure conidia precisely. Some conidia of *S. nephrospora* may not be reniform due to orientation or stage of development, which can make them appear similar to those of *S. chartarum*. The ecological significance of these closely related species in indoor environments and their effects on human health need more study.

Zygosporium masonii was commonly reported from Europe. In the U.S., it was a laboratory air contaminant in West Virginia, and was isolated from coastal sands of Oahu, Hawaii (Wang and Baker 1967). Recently it has been isolated from indoor environments in southwestern U.S.A. (AZ, CA, TX). Wang and Baker (1967) interpreted conidiogenesis in *Z. masonii* as being phialidic, with a *Sporothrix*-like synanamorph. However, Wang now considers the collarettes observed were probably collapsed conidiogenous cells and that the mode of conidium ontogeny is blastic (personal communication). Hughes (1951) did not consider the conidiogenous cells of this species to be phialides. Ellis (1971) treated them as monoblastic. In our isolates, monoblastic conidiogenous cells predominated. However one conidiophore was found with collarette-bearing conidiogenous cells where conidia can develop directly on vesicles. Each vesicle usually develops 2 conidiogenous cells (Wang and Baker 1967, Ellis

1971), but vesicles may bear 1-3 conidiogenous cells. This species was found in AZ, CA, TX where there is no previous published record. Conidiophores with conidia still attached were observed in an air sample. Meredith (1962) found that the conidia of *Z. oscheoides* Mont. are violently discharged. This may explain why species of *Zygosporium*, an unusual genus, are found in air samples from time to time.

Acknowledgments

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