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New species and records of saprophytic ascomycetes (Myxotrichaceae) from decaying logs in the boreal forest

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Decayed wood from fallen white spruce (*Picea glauca*) and trembling aspen (*Populus tremuloides*) collected in northeastern Alberta, Canada, was the source of new isolates of species in the ascomycete genera *Gymnostellatospora* and *Pseudogymnoascus*. In addition to new reports of *G. japonica*, *G. frigida* and *P. roseus*, two new species are described. *Gymnostellatospora canadensis* sp. nov. resembles *G. japonica* but differs in producing brown ascomata and in the formation of an arthroconidial anamorph. *Gymnostellatospora subnuda* sp. nov. is distinct in lacking differentiated peridial hyphae. *Gymnostellatospora alpina* was not found in decayed wood but is reviewed based on extralimital material. A dichotomous key to the five species of *Gymnostellatospora* is provided.

Key Words——*Gymnostellatospora*; *Malbranchea*; Myxotrichaceae; *Pseudogymnoascus*.

The Myxotrichaceae was described by Currah (1985) within the order Onygenales for cellulolytic ascomycetes having reddish to dark brown peridial hyphae, fusoid ascospores, and arthroconidial anamorphs. Later, Currah (1994) suggested that the Myxotrichaceae may be phylogenetically unrelated to other members of the Onygenales, and this hypothesis has been supported by recent molecular studies that place members of the family in a separate lineage and closer to members of the Leotiales (inoperculate discomycetes) (Currah, 1994; Hambleton, 1998; Leclerc et al., 1994; Sugiyama et al., 1999). Currah's circumscription included the genera *Myxotrichum* Kuntze, *Byssoascus* Arx and *Pseudogymnoascus* Raillo. *Myxotrichum* and *Byssoascus*, represented by the single species *B. striatisporus* (G.L. Barron & C. Booth) Arx, have striate ascospores but differ in ascomatal complexity. *Pseudogymnoascus* ascomata are discrete and composed of yellowish or reddish brown hyphae often with short echinulate thin-walled appendages. The type species, *P. roseus*, has smooth ascospores and a *Geomyces* anamorph. However, species have been added to the genus that differ in having ornamented ascospores, and some lack the anamorph.

In 1993, Udagawa et al. added a fourth genus, *Gymnostellatospora*, with a single species, *G. japonica* Udagawa, Uchiy. & Kamiya, distinguished by fusiform ascospores having longitudinal wing-like crests and irregular ridges. They noted affinities to *Myxotrichum* and *Byssoascus* in the ridged ascospores, but affinity to *Pseudogymnoascus* in the ascoma color and peridium morphology. Because the type species of *Pseudogymnoascus* has smooth ascospores, they considered their taxon distinct. Uchiyama et al. (1995) described *G. frigida* Uchiy., Kamiya & Udagawa as having ascospores ornamented with somewhat irregular longitudinal ridges but lacking wing-like crests. Both species, then known only from collections from soil in Japan, were similar in lacking anamorphs, but *G. frigida* differed from the type species in being psychrophilic. Udagawa (1997) reevaluated *Gymnostellatospora* and included *Pseudogymnoascus alpinus* E. Müller & Arx [as *G. alpina* (E. Müller & Arx) Udagawa] and *P. dendroideus* Locquin-Linard [as *G. dendroidea* (Locquin-Linard) Udagawa]. *Gymnostellatospora alpina* ascospores have longitudinal rims or crests, similar to the type species, *G. japonica*. Udagawa redescribed *G. dendroidea* from new collections as having striate ascospores with a longitudinal band, somewhat intermediate between *Gymnostellatospora* and *Myxotrichum.*

Members of the genera *Gymnostellatospora* and *Pseudogymnoascus* are cellulolytic and commonly psychrophilic, and they occupy similar habitats in soil, roots or plant debris, especially in the boreal forest. There are few reports of *Gymnostellatospora* species and most species are represented by one or two isolates. A study of microfungi from decaying wood collected in the boreal regions of Alberta, Canada (Lumley et al., 2000), yielded new records of *G. japonica*, and two new species, *G. canadensis*, having an arthroconidial anamorph, and *G. subnuda*, lacking an anamorph. Among the currently accepted species, only *G. dendroidea* has been described with an anamorph. Locquin-Linard (1982) suggested that it might belong to *Geomyces* Traaen; however, her drawing of a solitary lateral hypha forming arthroconidia was not conclusive. The morphology seems more similar to

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the anamorph of *G. canadensis*, which is here placed in *Malbranchea* Sacc. because it lacks the erect conidiophores with acute, verticillate fertile branches typical of *Geomyces* species. The new species are compared with *G. frigida* and *G. alpina*, and we report the presence of a few arthroconidia in old cultures of the ex-type culture of *G. frigida* and in a Japanese isolate identified by Dr. Udagawa as *G. alpina* (Udagawa, 1997). A new record of *P. roseus* is reported and the reliability of characters distinguishing the genera is discussed.

Materials and Methods

Samples of wood (approximately 1 g each) from decayed logs of white spruce (*Picea glauca* (Moench) Voss) were surface-sterilized by briefly flaming, and then spread onto cornmeal agar (CMA, Difco Laboratories, Detroit, MI) and malt extract agar (MEA, 1.5% (w/v) Difco malt extract, 1.5% (w/v) Difco agar). Plates were incubated at room temperature (RT) in the dark and transfers of hyphae growing from the wood fragments were made as appropriate over a period of 18 mo. Subcultures were examined initially on MEA incubated at RT (approx. 21°C) and 15°C for 6 wk. Selected isolates were examined also on CMA and cereal agar (CER, Kane et al., 1997) incubated at RT. Isolates were then regrown on oatmeal agar (OAT, Kane et al., 1997) and growth characteristics recorded weekly for 40 d at 18°C and 25°C. Colony colors are according to Kornerup and Wanscher (1978). All isolates are maintained as living cultures and dried specimens at the University of Alberta Microfungus Collection and Herbarium (UAMH) (Sigler and Flis, 1998).

Cellulolytic ability was assayed using the method of Smith (1977) but modified by using Murashige and Skoog's (Sigma M6899) basal salts medium. Molten basal salts medium (10 ml) was poured into 50-ml screw-cap test tubes and the tubes were autoclaved for 12 min at 121°C. One millilitre of a molten 2% suspension (w/v) of cellulose azure (Difco) in basal salts medium was added to each of the cooled test tubes. Test tubes were inoculated with small blocks of mycelium taken from the perimeters of colonies growing on MEA and incubated in the dark at RT for 12 wk. Cellulolytic activity was reported as negative, weakly positive (some diffusion of azure into medium), or strongly positive (most of the azure released in the agar).

Taxonomy

Key to five species of *Gymnostellatospora*

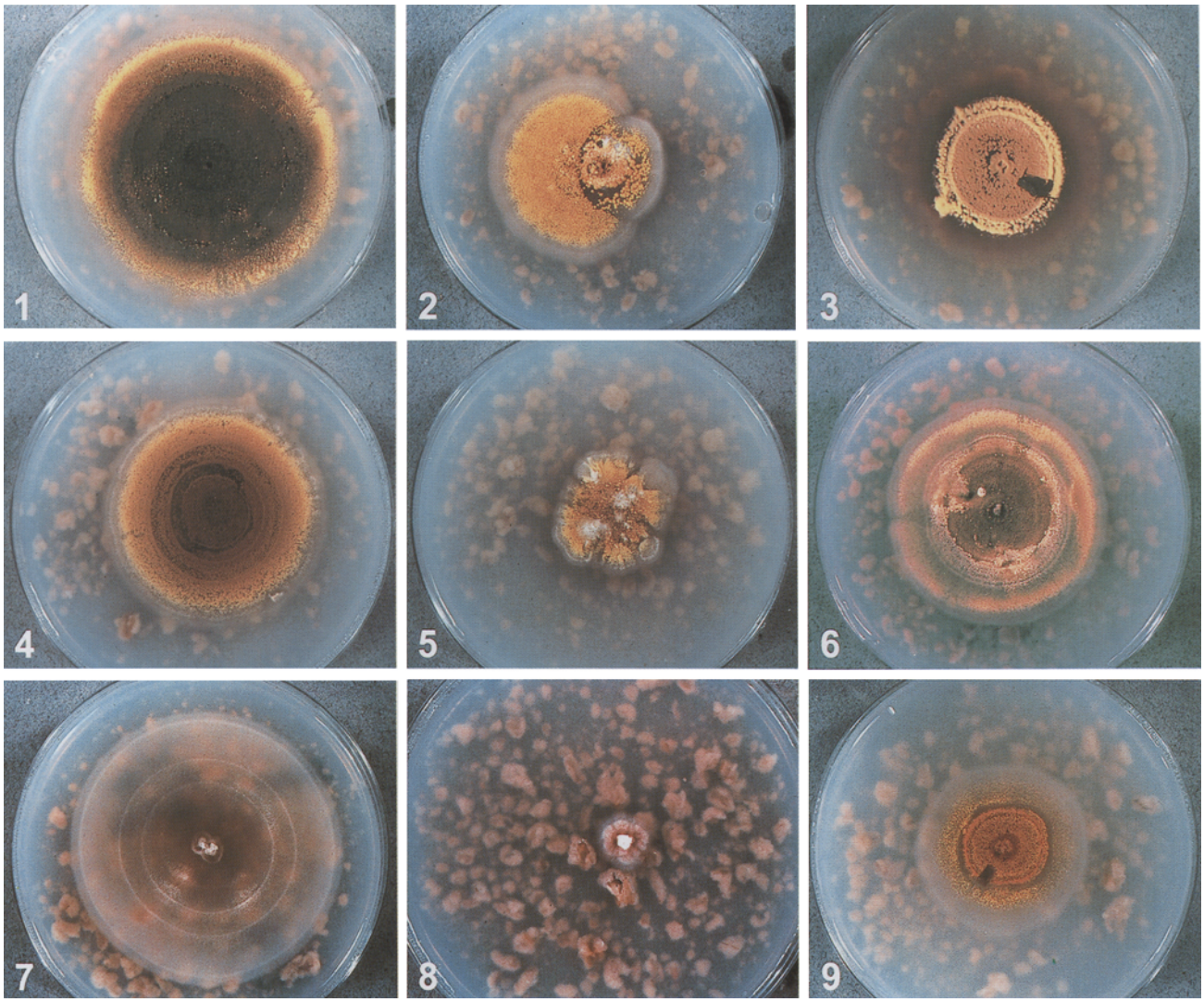
1. Ascomata lacking a distinct peridium, ascospores <3 μm long ..... *G. subnuda*
1. Ascomata with a peridium of distinctive and thick-walled hyphae, ascospores >3 μm long 2
   2. Ascospores with inconspicuous longitudinal furrows but lacking wing-like bands or ridges ..... *G. frigida*
   2. Ascospores with distinct longitudinal bands or ridges, appearing stellate in end view 3
3. Ascomata white to pale yellow or yellowish brown; at 25°C, colonies on OAT <5 mm after 14 d ..... *G. alpina*
3. Ascomata yellowish orange to olive brown, colonies >5 mm after 14 d 4
   4. Ascomata brown, conidial state of alternate arthroconidia ..... *G. canadensis*
   4. Ascomata yellowish, conidial state absent ..... *G. japonica*

Gymnostellatospora canadensis Lumley, Sigler & Currah, sp. nov. Figs. 1, 2, 10–12, 22

Coloniae in OAT 7 cm diam post 40 dies ad 18°C, densae, primum flavae, dein flavo-brunneae vel olivaceo-brunneae. Coloniae in MEA 3.5–4.5 cm diam post 42 dies ad 15°C, tenues, ex mycelio vegetativo submerso constans, centro ascomatibus abundantibus formantes, flavae vel olivaceo-brunneae; reversum flavum, ad centrum brunneum. Ascomata discreta vel saepe confluentia, globosa vel subglobosa, 150–250 μm diam, primum alba, dein flavo-brunnea vel olivaceo-brunnea. Hyphae peridii ramosae et intertextae, laeves vel asperulatae et incrassatae, septatae, dilute brunneae, 2–3 μm diam; appendices indistinctae, breves, tenues, asperulatae, aseptatae, rectae vel curvae, 4–35 μm longae. Asci 8-spori, subglobosi vel ovoidei, 8×6 μm, breviter stipitati, evanescentes. Ascosporae fusiformes, $3–4\times1.8–2.5$ μm, hyalinae vel dilute flavae in massa, sub SEM 1 cristam longitudinalem et striam irregulares visae. Anamorphosis: *Malbranchea*. Arthroconidia intercalaria, levia, cylindrica, flava, 3.5×2.5 μm. Cellulolytica.

Colonies on OAT at 18°C attaining diam of 7 cm after 40 d, forming dense mat of ascomata, yellowish to olivaceous brown in the centre (4D5-5F4/5), light yellow toward the periphery (3A4), thin at the margin, reverse uncolored. Growth slower at 25°C, with colonies reaching diam of 2.7-4 cm, but otherwise similar. Colonies on MEA at RT and at 15°C similar at 6 wk, 3.5–4.5 cm in diam, mycelium mostly submerged but with some aerial growth, reverse yellow, brown in the centre. Ascomata abundant, discrete to rarely aggregated in clusters of 2 to 4, olive-green to olive-brown when mature, maturing within 2–4 wk. CER colonies 6–7 cm diam, mycelium hyaline, margin submerged, more aerial growth near the centre, reverse darkening near the centre, ascomata sparse, maturing very slowly and occurring as bright yellow patches, immature after 6 wk. CMA colonies 3–4 cm in diam, mycelium dark yellow-brown, mostly submerged with some yellow aerial patches, reverse dark yellow-brown, ascomata abundant but diffuse, maturing within 4 wk.

Ascomata white when young, turning bright yellow, then yellowish-brown to olivaceous-brown when mature, 150–250 μm in diam. Peridium of branched network of thick-walled, smooth to asperulate hyphae, 2–3 μm in diam, slightly swollen at the nodes (sometimes up to 6



Figs. 1–9. Colonies of *Gymnostellatospora* species on OAT after 40 d. 1. *G. canadensis* at 18°C. (UAMH 8899, ex-type). 2. *G. canadensis* at 25°C (UAMH 8899, ex-type). 3. *G. subnuda* at 18°C (UAMH 9241, ex-type). 4. *G. japonica* at 18°C (UAMH 9240). 5. *G. japonica* at 25°C (UAMH 9240). 6. *G. frigida* at 18°C (UAMH 9304, ex-type). 7. *G. alpina* at 18°C (UAMH 9430, ex-type). 8. *G. alpina* at 25°C (UAMH 9430, ex-type). 9. *G. alpina* at 18°C (UAMH 9339).

μm wide); appendages simple, thin-walled, slightly asperulate, aseptate, straight or slightly curved, emanating as free ends from peridial hyphae, 4–35 μm long. Asci 8-spored, subglobose to ovoid, 8 × 6 μm, short-stipitate, evanescent. Ascospores fusiform, 3–4 × 1.8–2.5 μm, hyaline to yellow in mass, with a longitudinal rim and with several irregular longitudinal ridges visible under SEM, appearing stellate in end view. *Malbranchea* anamorph consisting of alternate arthroconidia produced on fertile hyphae that are straight or, rarely, slightly curved. Arthroconidia smooth, cylindrical, yellowish, 3.5 × 2.5 μm. Strongly cellulolytic.

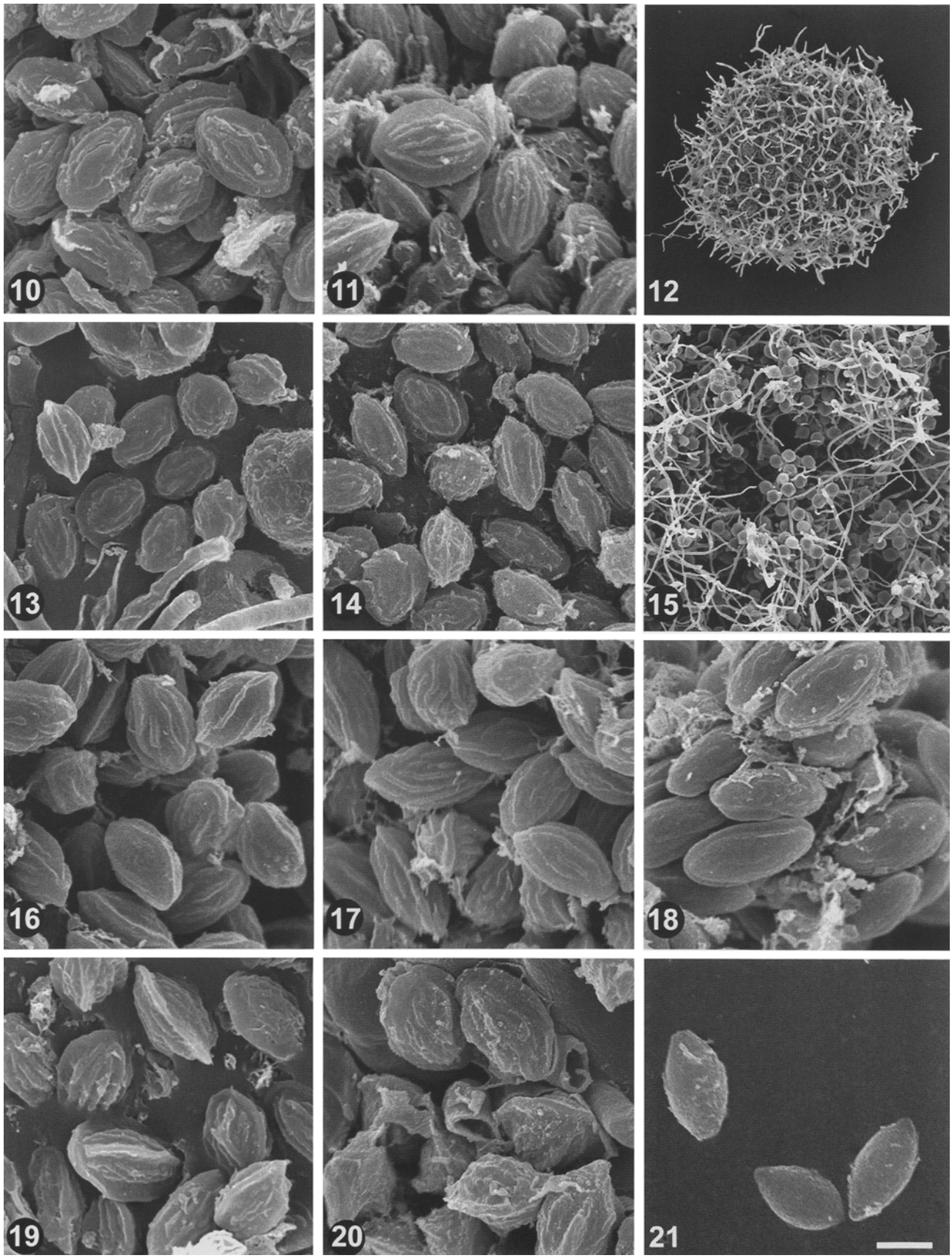
Holotype: CANADA. ALBERTA: ca 50 km N of Mariana Lake, 25-yr-old fire site, as dried colony derived from culture obtained from well-rotted log of *Picea glauca*, some charring, 26 July 1996, T. Lumley (UAMH 8899).

Paratype: CANADA, ALBERTA: 100 km N of Mariana Lake, well-decomposed log of *Picea glauca*, August 1996, T. Lumley (UAMH 9238).

Comments Ascospores of *G. canadensis* and *G. japonica* are similar in wall ornamentation and size, 3–4 × 1.8–2.5 μm for the former, and 3–4 × 1.5–2 μm for the latter (from the original description); however, the mature ascomata of *G. canadensis* are olive-brown rather than brownish yellow. Additionally, no anamorph was reported for *G. japonica*, nor did we observe one in the two Alberta isolates reported here as belonging to that species.

Gymnostellatospora subnuda Sigler, Lumley & Currah, sp. nov. Figs. 3, 13–15

Coloniae in OAT 4–4.5 cm diam post 40 dies ad 18°C, densae, primum pallide flavae, dein fuscato-aureae vel aurantio-brunneae, margine tenues et ca. 8 mm latae submersae; reversum incoloratum vel bubali-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num. Coloniae in OAT ad 25°C restrictae, minus quam l cm diam post 40 dies. Coloniae in MEA 2.5–3 mm diam post 42 dies ad 15°C, ex mycelio submerso; reversum incoloratum. Ascomata confluentia, flava vel aurantiobrunnea, tarde maturescentia. Hyphae peridii hyalinae vel dilute flavae, tenues et leves, septatae, 1–2 μm diam. Asci subnudi, 8-spori, subglobosi, 3.5–5 μm diam, evanescentes. Ascosporae fusiformes, 2.5–3 × 1.5–2 μm, hyalinae vel dilute flavae in massa, sub SEM 1 cristam longitudinalem et striam irregulares visae. Cellulolytica. Anamorphosis abest.

Colonies on OAT at 18°C attaining diam of 4–4.5 cm after 40 d, forming dense mat of confluent ascomata, dark gold to greyish orange (5B3) in centre to pale yellow at periphery (3A4), margin thin, about 8 mm wide, submerged, reverse uncolored to tan. Growth on OAT at 25°C after 40 d restricted, < 1 cm in diam. Colonies on MEA at 15°C reaching diam of 2.5–3 cm after 6 wk, mycelium mostly submerged, reverse uncolored.

Ascomata forming in yellow-brown patches at the centre, dense, confluent, initially white or bright yellow, forming asci within 3–4 wk, but maturing slowly. Ascomata consisting of loose aggregations of almost naked asci surrounded by strands of undifferentiated hyaline to pale yellow, thin-walled, narrow (1–2 μm wide) hyphae. Asci 8-spored, subglobose, 3.5–5 μm, evanescent. Ascospores fusiform, 2.5–3 × 1.5–2 μm, hyaline to pale yellow in mass, with one longitudinal rim and several irregular ridges visible under SEM, appearing sigmoid with light microscopy. Anamorph not observed. Weakly cellulolytic.

Holotype: CANADA. ALBERTA: 100 km N of Mariana Lake, nearly humified log of *Picea glauca*, July 1996, T. Lumley (UAMH 9241).

Paratype: CANADA, ALBERTA: well-rotted log of *Picea glauca*, July 1996, T. Lumley (UAMH 9242).

Etymology: *sub*=near, *nuda*=naked, referring to its almost naked asci.

Gymnostellatospora japonica Udagawa, Uchiy. & Kamiya, Mycotaxon **58**: 159. 1993. Figs. 4, 5, 16, 17

Description based on Alberta isolates. Colonies on OAT at 18°C attaining diam of 5–5.2 cm after 40 d, dark brownish orange to brownish yellow (5C8) at the centre to light yellow (3A5) at periphery, reverse pale tan, slightly zonate, flat, dense. On OAT at 25°C, colonies slower growing (2–2.8 cm after 40 d) but otherwise similar. On MEA at 15°C and RT, colonies similar, 4–4.5 cm in diam after 6 wk, mycelium mostly submerged with some patches of aerial growth, darker yellow or yellowish brown at the centre, reverse pale yellow. Ascomata abundant on most media, discrete, yellowish orange maturing to orange-brown, usually maturing within 2–4 wk.

Ascomata pale yellow becoming yellowish orange when mature, 100–200μm in diam. Peridium of branched, thick-walled, smooth to asperulate hyphae 1.5–2.5 μm diam, nodes slightly swollen; free ends of peridial hyphae terminating in indistinct thin-walled, asperulate, occasionally undulate appendages, up to 12 μm long. Asci 8-spored, subglobose to pyriform, 7–8 × 5–5.5 μm, short-stipitate, evanescent. Ascospores fusiform, 3–4 × 2–2.5 μm (3–4 × 1.5–2 μm, original description), yellow to orange in mass, with one longitudinal band and several irregular ridges apparent under SEM. Anamorph not observed. Weakly cellulolytic.

Cultures examined: CANADA, ALBERTA: 100 km N of Mariana Lake, well rotted wood of *Picea glauca*, July 1996, T. Lumley (UAMH 9239; UAMH 9240. Specimen examined. JAPAN: cultura exsiccata from forest soil, February 1990, S. Udagawa BF 24290 (Holotype).

Comments Ascospores of *G. japonica*, *G. alpina* and *G. canadensis* are similar in having one longitudinal band and several low ridges on the convex surface. *G. alpina* has white to pale yellow ascomata and is psychrophilic with growth strongly inhibited at 25°C. *G. canadensis* grows better at 18°C than at 25°C and is further distinguished by its arthroconidial anamorph. Although *G. japonica* was described as mesophilic (Udagawa et al., 1993), we were unable to evaluate its growth characteristics because a living strain was not available for comparison. The Alberta strains grew better at 18°C but otherwise appear to fit the description of *G. japonica.*

Gymnostellatospora alpina (E. Müller & Arx) Udagawa, Trans. Mycol. Soc. Japan **38**: 154. 1997. Figs. 7–9, 19, 20

≡*Pseudogymnoascus alpinus* E. Müller & Arx, Sydowia **35**: 135. 1982.

This species is represented by two isolates that differ slightly. Colonies of the ex-type culture (CBS 620.81=UAMH 9430) on OAT at 18°C attained 6 cm diam after 40 d, and were thin with scant aerial mycelium, slightly zonate, forming scant, discrete, white ascomata. Colonies on OAT of a second isolate (SUM 3062; UAMH 9339) attained diam of 3.8 cm, and were dark orange in the centre (5A8) with yellowish submerged margin, reverse uncolored, forming dense mat of discrete yellowish-brown ascomata. Both isolates showed scant growth at 25°C (< 1 cm in 40 d).

Ascomata discrete, remaining white or turning pale yellow to yellowish-brown, peridium of loose network of branched, hyaline to yellow, thin-walled, narrow (1–1.5 μm wide) hyphae that are curved at the apices. Asci 8-spored, subglobose, 8 × 6 μm, short-stipitate, evanescent. Ascospores fusiform, 3–4.5 × 1.5–2.5 (–3) μm,

Figs. 10–21. *Gymnostellatospora* species and *Pseudogymnoascus roseus.* 10–12. *G. canadensis.* 10, 11. Ascospores (UAMH 8899, ex-type, and UAMH 9238). 12. Ascomata composed of branched hyphae (UAMH 9238). 13–15. *G. subnuda.* 13, 14. Ascospores (UAMH 9241, ex-type). 15. Asci within undifferentiated hyphae (UAMH 9241). 16, 17. *G. japonica* ascospores (Alberta isolates UAMH 9239 and 9240). 18. *G. frigida* ascospores (UAMH 9304, ex-type). 19, 20. *G. alpina* ascospores (UAMH 9430 (ex-type) and 9339). 21. *P. roseus* ascospores (UAMH 3337). Scale bar: Figs. 10, 11, 13, 14, 16–21=1.5 μm; Fig. 12=45 μm; Fig. 15=15 μm.

hyaline or yellow, with one longitudinal rim and several irregular ridges visible under SEM, appearing sigmoid with light microscopy. Anamorph not observed in the ex-type culture but a few arthroconidia were observed in UAMH 9339 in a 40-d-old OAT plate reexamined after 8 wk of refrigeration.

Cultures examined: SWITZERLAND, Graubünden, Flasch, rhizosphere of *Erica carnea* (Ericaceae), E. Müller, CBS 620.81 (UAMH 9430). KENYA: Mt. Kenya (alt. 4200 m), forest soil, S.I. Udagawa (SUM 3062; UAMH 9339).

Comments *Gymnostellatospora alpina* and *G. subnuda* are similar in showing strongly restricted growth at 25°C. *Gymnostellatospora alpina* is distinguished by the discrete ascomata composed of loose, curved hyphae and larger ascospores (3–4.5 × 1.5–2.5(–3) μm vs 2.5–3 × 1.5–2 μm for *G. subnuda*). Ascospores of *G. alpina* are similar to those of *G. japonica* and *G. canadensis* but ascomata of the latter two species are composed of differentiated yellowish orange or olive brown peridial hyphae.

Although UAMH 9339 (SUM 3062) was received as *G. alpina* (Udagawa, 1997), this strain grows more slowly; the ascospores are less distinctly ridged (Fig. 19), and it produces a few arthroconidia. When originally received, the ex-type culture of *G. alpina* appeared degenerate with very sparse aerial hyphae. Fruiting was enhanced in colonies incubated at lower temperatures and on other media such as Takashio agar (Kane et al., 1997) and especially when the medium was overlaid with a cellophane membrane (Sigler and Carmichael, 1976). Under such conditions, ascomata of the ex-type developed a yellow color in age, and then appeared more similar to those of UAMH 9339.

Gymnostellatospora frigida Uchiy., Kamiya & Udagawa, Mycoscience **36**: 3. 1995. Figs. 6, 18

Colonies on OAT at 18°C attaining diam of 5.2 cm after 40 d, light golden brown (6D4) in centre, light yellow (4A5) at periphery, margin thin, reverse pale tan, flat, dense. On OAT at 25°C, colonies slower growing (3.1 cm after 40 d), light yellow (4A5). Ascomata pale yellow becoming golden brown when mature, composed of branched thick-walled, smooth to asperulate, yellowish-brown hyphae 1.5–2.5 μm diam. Asci 8-spored, subglobose to pyriform, 7–8 × 5–5.5 μm, short-stipitate, evanescent. Ascospores fusiform, 3.5–4.5 (–5) × 1.5–2.2 μm, hyaline to pale yellow in mass, slightly irregularly furrowed under SEM. A few arthroconidia were observed in a 40-d-old OAT plate reexamined after 8 wk of refrigeration.

Cultures examined: JAPAN, HOKKAIDO: forest soil, S. Uchiyama BF44675 ex-type culture (UAMH 9304).

Comments *Gymnostellatospora frigida* is known only from forest soil in Hokkaido, Japan. Uchiyama et al. (1995) distinguished this species from *G. japonica* by the psychrophilic habit with growth and production of fertile ascomata enhanced at 15°C rather than 21°C, and by the ascospores ornamented with irregular longitudinal ridges but lacking the longitudinal band.

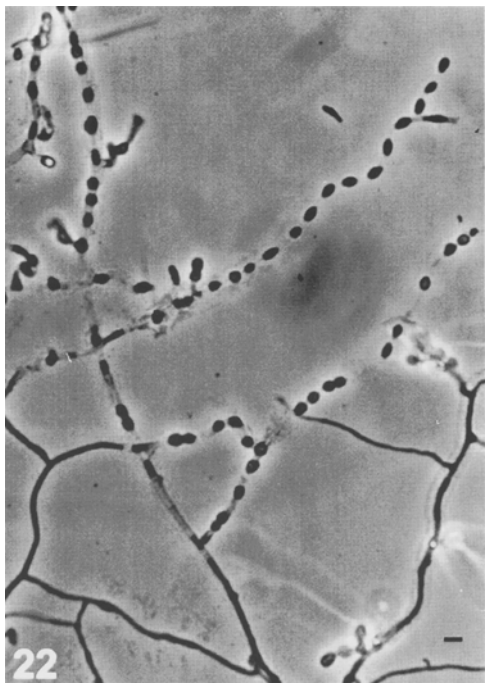

Fig. 22. *Gymnostellatospora canadensis* in slide culture preparation showing alternate arthroconidia of *Malbranchea* state (UAMH 9238). Scale bar = 5 μm.

Pseudogymnoascus roseus Raillo, Zentrbl. Bakteriol. Parasitkde **78**: 250. 1929. Fig. 21

≡*Gymnoascus roseus* (Raillo) Apinis, Mycol. Pap. **96**: 8. 1964.

=*Gymnoascus rhousiogongylinus* Wener & Cain, Can. J. Bot. **48**: 325. 1970.

=*Pseudogymnoascus vinaceus* Raillo, Zentbl. Bakteriol. Parasitkde **78**: 250. 1929.

≡*Gymnoascus vinaceus* (Raillo) Apinis, Mycol. Pap. **96**: 9. 1964.

Colonies on OAT at 18°C attaining diam of 7.5–8 cm after 40 d, light brown at centre (6C/D4/5 to 7D6), becoming white at margin, reverse tan to wine red in centre, dense, flat, sometimes slightly zonate. Growth at 25°C on OAT attaining diam of 5 cm, reddish brown (8D4) at centre but with thin aerial mycelium, sometimes forming white, non-sporulating sectors, reverse greyish red. On MEA at 15°C, colonies 3–4 cm in diam after 6 wk, mycelium hyaline, mostly submerged, occasionally with some aerial patches, reverse light brown. MEA colonies at RT 2–3 cm after 6 wk, reverse brown. Ascomata forming abundantly on most media, discrete or confluent, brown or red-brown, maturing within 2–4 wk at lower temperatures.

Ascomata discrete, initially white, turning pink to pink-brown or red-brown with age. Peridium composed of branched, thick-walled, smooth to slightly verrucose hyphae, terminating in thin-walled, clavate, asperulate appendages at apices of dichotomous branches. Asci 8-spored, subglobose, 7–9 × 4–7 μm, evanescent. Ascospores fusiform, occasionally flattened on 1 side,

2.5–4 × 1.5–2.5 μm, smooth (Fig. 21). Anamorph *Geomyces vinaceus* Dal Vesco (Sigler and Carmichael, 1976; Orr, 1979).

Cultures examined: CANADA. ALBERTA: Mariana Lake, extremely well decayed wood (stage 5 decay, Lumley et al., 2000), *Picea glauca*, 29 yr post-fire site, T. Lumley (UAMH 9222). Additional collections from decayed spruce (stage 3 decay), ONTARIO: forest soil near Parry Sound, H.M. Wener (ex-type of *G. rhousiogongylinus* UAMH 3337=CBS 722.69=ATCC 18970). Three additional collections from well-rotted spruce and aspen were examined (Lumley et al., 2000).

Comments Raillo described two species in *Pseudogymnoascus, P. roseus* and *P. vinaceus*, but failed to designate a type species or to deposit material. The distinction between them is tenuous, given that Raillo described them as having different ascomatal colors ("roseis" for *P. roseus* and "flavoroseis" for *P. vinaceus*) but the ascospore size and shape and the original drawings are virtually identical. Kuehn (1958), followed by Orr (1979), considered *P. roseus* and *P. vinaceus* distinct and listed *P. vinaceus* as the type, but provided no justification. However, Samson (1972) chose *P. roseus* as the type species and treated *P. vinaceus* as a synonym and this has been followed by others (Currah, 1985; von Arx, 1987). Although Orr (1979) has noted that Kuehn's (1958) designation of *P. vinaceus* is the earliest and should be followed according to Article 9 of the current International Code of Botanical Nomenclature (Greuter et al. 1994), Samson selected a neotype for *P. roseus*, and the latter species has been more widely accepted as the type species.

Colonies of *P. roseus* vary in color and extent of ascomatal and anamorph development. These color differences have been noted by many authors and have been used in the past to distinguish *P. roseus* from *P. vinaceus*. Colony color is also affected by rate of ascomatal maturity, which is enhanced at lower growth temperatures. Isolates with slowly developing peridia appear light pink and turn red-brown only after many weeks in culture.

The anamorph of *P. roseus* is *Geo. vinaceus* Dal Vesco. Although Carmichael (1962) reduced the genus *Geomyces* to synonymy with *Chrysosporium*, Sigler and Carmichael (1976) reinstated it with three species: *G. pannorum* as type, *Geo. vinaceus* and *Geo. asperulatus* Sigler & Carm. In *Geomyces*, short, narrow conidiophores branch acutely at the tip, sometimes verticillately. Conidia are formed at the tip, on the sides and in an intercalary position to form short chains of cuneiform or barrel-shaped alternate arthroconidia. Although the microscopic morphology is rather uniform among the species, considerable colonial plasticity is observed especially among isolates belonging to *Geo. pannorum*. Nonetheless, teleomorphic isolates are consistently associated with purplish red or reddish brown colonial colors especially on OAT at 18°C. *Geo. vinaceus* has been considered a variety of *Geo. pannorum* (van Oorschot, 1980). *Geomyces* species have a wide distribution in cold temperate soils, are cellulolytic, and are occasionally encountered as contaminants from human cutaneous specimens (Kane et al., 1997).

Discussion

Raillo described the ascospores of *Pseudogymnoascus* as "ovoideis vel globosis." No mention is made of spores being smooth or of an anamorph, two characteristics later used by Udagawa et al. (1993) to separate *Gymnostellatospora*. In their circumscriptions of *Pseudogymnoascus*, Samson (1972), Orr (1979), and later Currah (1985) described the ascospores as smooth and the anamorph as usually present and as arthro- and aleurioconidia (Samson, 1972; Orr, 1979) or as a *Geomyces* state (Currah, 1985). Müller and von Arx (1982) described *P. alpinus* as lacking an anamorph and as having ascospores with one to three longitudinal rims. Von Arx (1987) included species with crested ascospores in his description of *Pseudogymnoascus* and indicated a correlation between the lack of an anamorph and ornamented ascospores. However, previously Locquin-Linard (1982) had described *P. dendroideus* with an arthroconidial anamorph and with large ascospores ("elliptiques-fusiformes, 6–7 × 4.5–5 × 3–3.5 μm") having a longitudinal band and surface striations. The type material came from cow dung collected in Algeria, and thus it is probably not a psychrophile like most species of *Gymnostellatospora* and *Pseudogymnoascus*. Authentic material of *P. dendroideus* received by us several years ago from Prof. Locquin-Linard was scanty and contained neither ascospores nor conidia. Udagawa (1997) transferred the species to *Gymnostellatospora* and illustrated *G. dendroidea* based on a new isolate from soil in China.

Differences in anamorph and ascospore morphology appear to provide support for Udagawa's decision (1997) to maintain *Gymnostellatospora* and *Pseudogymnoascus* separately. Prior to the transfer of *P. dendroideus* to *Gymnostellatospora*, anamorphs were unknown within the genus. Our study describes the presence of arthroconidial anamorphs in *G. canadensis* and in the extype strain of *G. frigida* and one isolate of *G. alpina*. The anamorph of *G. canadensis* is placed in *Malbranchea* since verticillate branching typical of *Geomyces* was not seen. However, the new variety *Pseudogymnoascus roseus* var. *ornatus* (Udagawa and Uchiyama, 1999) has ascospores very similar in ornamentation to those of *G. frigida* and suggests a continuum that requires further investigation.

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Literature cited

Carmichael, J. W. 1962. *Chrysosporium* and some other aleuriosporic hyphomycetes. Can. J. Bot. **40**: 1137–1173.

Currah, R. S. 1985. Taxonomy of the Onygenales: Arthrodermataceae, Gymnoascaceae, Myxotrichaceae, and Onygenaceae. Mycotaxon **24**: 1–216.

Currah, R. S. 1994. Peridial morphology and evolution in the prototunicate ascomycetes. In: Ascomycete systematics: problems and perspectives in the nineties, (ed. by Hawksworth, D.L.), pp. 281–293. Plenum Press, New York.

Greuter, W., Barrie, F.R., Burdet, H.M., Chaloner, W.G., Demoulin, V., Hawksworth, D.L., Jørgensen, P.M., Nicolson, D.H., Silva, P.C., Trehane, P. and McNeill, J. (Editors). 1994. International Code of Botanical Nomenclature (Tokyo Code). Regnum Vegetabile Vol. 131. Koeltz Scientific Books, Koenigstein, Germany.

Hambleton, S. 1998. Mycorrhizas of the Ericaceae: Diversity and systematics of the mycobionts. PhD thesis, University of Alberta, Edmonton, Alberta.

Kane, J., Summerbell, R., Sigler, L., Krajden, S. and Land, G. 1997. Laboratory handbook of dermatophytes. Star Publ. Co., Belmont, California.

Kornerup, A. and Wanscher, J.H. 1978. Methuen handbook of color, 3rd ed. Methuen, London, U.K.

Kuehn, H. H. 1958. A preliminary survey of the Gymnoascaceae. I. Mycologia **51**: 417–439.

Leclerc, M.C., Philippe, H. and Guèho, E. 1994. Phylogeny of dermatophytes and dimorphic fungi based on large subunit ribosomal RNA sequence comparisons. J. Med. Vet. Mycol. **32**: 331–341.

Locquin-Linard, M. 1982. *Pseudogymnoascus dendroideus* Locquin-Linard, nouvelle espèce de Gymnoascale (Ascomycètes) coprophile d'Afrique du Nord. Cryptog. Mycol. **3**: 409–414.

Lumley, T., Abbott, S. P. and Currah, R.S. 2000. Microscopic ascomycetes isolated from rotting wood in the boreal forest. Mycotaxon **74**: 395–414.

Müller, E. and von Arx, J. A. 1982. *Pseudogymnoascus alpinus*, nov. spec. Sydowia **35**: 135–137.

Orr, G. F. 1979. The genus *Pseudogymnoascus.* Mycotaxon **8**: 165–173.

Samson, R. A. 1972. Notes on *Pseudogymnoascus, Gymnoascus*, and related genera. Acta Bot. Neerl. **21**: 517–527.

Sigler, L. and Carmichael, J.W. 1976. Taxonomy of *Malbranchea* and some other Hyphomycetes with arthroconidia. Mycotaxon **4**: 349–488.

Sigler, L. and Flis, A. 1998. Catalogue of the University of Alberta Microfungus Collection and Herbarium, 3rd ed. University of Alberta, Edmonton, Alberta.

Smith, R. E. 1977. Rapid tube test for detecting fungal cellulase production. Appl. Env. Microbiol. **33**: 980–981.

Sugiyama, M., Ohara, A. and Mikawa, T. 1999. Molecular phylogeny of onygenalean fungi based on small subunit ribosomal DNA (SSU rDNA) sequences. Mycoscience **40**: 251–258.

Uchiyama, S., Kamiya, S. and Udagawa, S. 1995. Five onygenalean fungi from Japan. Mycoscience **36**: 211–220.

Udagawa, S. 1997. Taxonomic studies on Plectomycetes (cleistothecial ascomycetes). Trans. Mycol. Soc. Japan **38**: 143–157.

Udagawa, S., Uchiyama, S. and Kamiya, S. 1993. *Gymnostellatospora*, a new genus of the Myxotrichaceae. Mycotaxon **48**: 157–164.

Udagawa, S. and Uchiyama, S. 1999. Taxonomic studies on new or critical fungi of non-pathogenic Onygenales 1. Mycoscience **40**: 277–290.

Van Oorschot, C. A. N. 1980. A revision of *Chrysosporium* and allied genera. Stud. Mycol. **20**: 1–89.

Von Arx, J. A. 1987. A re-evaluation of the Eurotiales. Persoonia **13**: 273–300.

Note: *Gymnostellatospora parvula* Udagawa & Uchiyama (Mycoscience 41: 217–221) appeared just as this paper was going to press. *Gymnostellatospora parvula* is similar to *G. subnuda* although there are slight differences in ascospore size and in features associated with hyphae surrounding the asci. The relationship between these two taxa will be determined when both type specimens are examined.