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ADDITIONAL NEW AND UNREPORTED SPECIES OF MYCORRHIZAL FUNGI (ENDOGONACEAE) FROM FLORIDA[1]

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ABSTRACT

The occurrence of five species of Endogonaceae previously unreported from Florida is noted and seven new species (six in *Glomus*) are described. *Glomus aggregatum* is the only new species from Florida which forms sporocarps in and around roots and is similar in appearance to the previously described taxon *G. fasciculatum*. *Glomus intraradices* forms yellow-brown spores almost exclusively in the root. *Glomus claroideum* has hyaline to yellow spores which are smaller but similar in appearance to the previously described taxon *G. clarum*. *Glomus leptotichum* has relatively large white spores with a thin wall bearing a faint reticulum. Spores of *Glomus fecundisporum* are gray-white, have two walls and are frequently borne in clusters. *Glomus tortuosum* has a sinuous hyphal mantle covering the spore. *Gigaspora albida* has generally smaller spores with slightly thicker walls but is similar in spore shape and color to the previously described taxon *G. gigantea*. A synoptic key to the 34 species of Endogonaceae described in Florida is included.

Key Words: taxonomy, symbiotic fungi, vesicular-arbuscular mycorrhizae.

Several new genera and species of recently described mycorrhizal fungi in the Endogonaceae have been observed in Florida. However, these and several other species have not been reported from Florida. In addition, several new species have been found in Florida since a previous report in 1979 (**12**). The purpose of this paper is to report first observations in Florida of two genera and five species as well as describe six new *Glomus* species and a new species of *Gigaspora* in the Endogonaceae.

FIRST REPORTS OF PREVIOUSLY DESCRIBED SPECIES

Acaulospora bireticulata Rothwell and Trappe (**15**) was recovered at one location only in a nursery of tropical legumes on the campus of the University of Florida. Spore measurements and the bireticulate wall pattern were similar to those described by Rothwell and Trappe. Spores of this species were sparsely associated with soil from around the roots of *Centrosema pubescens* L. No attempt was made to establish pot cultures.

Acaulospora scrobiculata Trappe (**18**) was found in soil of unknown origin near Daytona Beach, Florida, by C. Walker (Walker specimen No. 116). We examined spores taken from this sample and agreed with Walker's determinations but were unsuccessful in our attempts to establish a pot culture with this isolate on soybean [*Glycine max* (L.) Merr.] or bahia grass (*Paspalum notatum* Flugge).

Acaulospora spinosa Walker and Trappe (**21**) was recovered from soil associated with the roots of St. Augustine grass [*Stenotaphrum secundatum* (Walt.) Kuntze] from the Horticultural Farm, University of Florida, Gainesville. Spore measurements and spore wall characteristics were similar to those described by Walker and Trappe.

Entrophospora infrequens Ames and Schneider (**2**) was recovered from soil

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associated with *Macroptilium* sp. from the Agricultural Research Center at Ft. Pierce, Florida. Azygospores were globose, 98–130 μm in diameter, orange-brown to brown, and frequently attached to an empty vesicle. This isolate was established in pot culture with bahia grass and sporulated abundantly. However, these pot cultures contained other species of Endogonaceae and a pure pot culture of *E. infrequens* was never established.

Complexipes moniliformis Walker (**19**) was recovered from sand pine [*Pinus clausa* (Engelm.) Vasey] in northeast Florida near Green Cove Springs by E. L. Barnard. Spore diameters ranged from 42 to 70 μm, somewhat smaller than the minimum listed by Walker (55 μm). Spores were globose, red brown, with spines or papillae somewhat curved. Subtending hyphae were moniliform up to four cells below the spore and attached to thick-walled, brown, nonseptate hyphae. Some spores had two adjacent subtending hyphae.

DESCRIPTIONS OF NEW SPECIES

Six new species in the genus *Glomus* and one new species of *Gigaspora* were found in Florida and are described for the first time.

Glomus intraradices Schenck & Smith, sp. nov. FIG. 1a–d

Chlamydosporae singulatae vel aggregatae in radici raro exteriore radici efformatae; sporae globosae 40.5–190.5 μm diam, raro subglobosae, 93–119 × 112–131 μm diam; tunica sporarum 3–15 μm crassa, lutea vel viridifusca; sporae cum una vel duo, raro quatuor tunicae laminatae; sporae immaturae cum tunica separabilis, hyalinae, caducae, exteriore, 1–2 μm crassa; tunica sporarum ad tunicas hyphae subtendentae tendent. Hyphae subtendentes 9–33 μm diam, tunicae 1.5–5.2 μm crassae, ad sporem basem. Hyphae extramatrices 2–15 μm diam. Mycorrhizae vesicular-arbusculares formans.

Sporocarps unknown. Chlamydospores formed singly or in clusters in the root, rarely formed outside the root; chlamydospores predominantly globose, (40.5–)98.5(–190.5) μm diam but frequently subglobose 93–119 × 112–131 μm diam; spore walls 3–15 μm thick, yellow to gray-brown, appearing greenish brown with transmitted light; spores with 1 or 2, occasionally up to 4 laminated walls on larger spores; inner walls darker than outer walls; on young spores an additional, hyaline, ephemeral outer wall (1–2 μm) which occasionally extends down the hyphal attachment 5–10 μm, generally separates from the inner wall(s) under moderate pressure in squash mounts. Spore contents globular, yellow to light brown. Walls of the spore extending into the hyphal attachment forming an apparent tubaeform flare at the juncture with the hyphal attachment; hyphal attachment 9–33 μm wide with a wall thickness of 1.5–5.2 μm at the base of the spore; hyphal attachment occasionally constricted 2–3 μm at the base of the spore. Extramatrical hyphae varying from 2–15 μm in diam. Forming typical vesicular-arbuscular mycorrhizae.

ETYMOLOGY: Latin (*intra* = within, *radices* = roots) referring to the almost exclusive formation of chlamydospores by this species in the root.

TYPE: A pot culture of bahia grass initiated from a sample obtained from S. Nemec; USDA Horticultural Research Laboratory, Orlando, Florida, which he originally isolated from citrus roots. TYPE OSC No. 40,255; ISOTYPES FH; FLAS No. F52578.

DISTRIBUTION: This species is one of the most common *Glomus* species occurring in Florida. It has been recovered from or associated with the roots and soil of papaya (*Carica papaya* L.) and tomato (*Lycopersicon esculentum* Mill.) at Homestead; from tomato at the Agricultural Research Center at Immokalee; from celery [*Apium graveolens* (L.) var. *dulce* DC.] at Belle Glade; from citrus

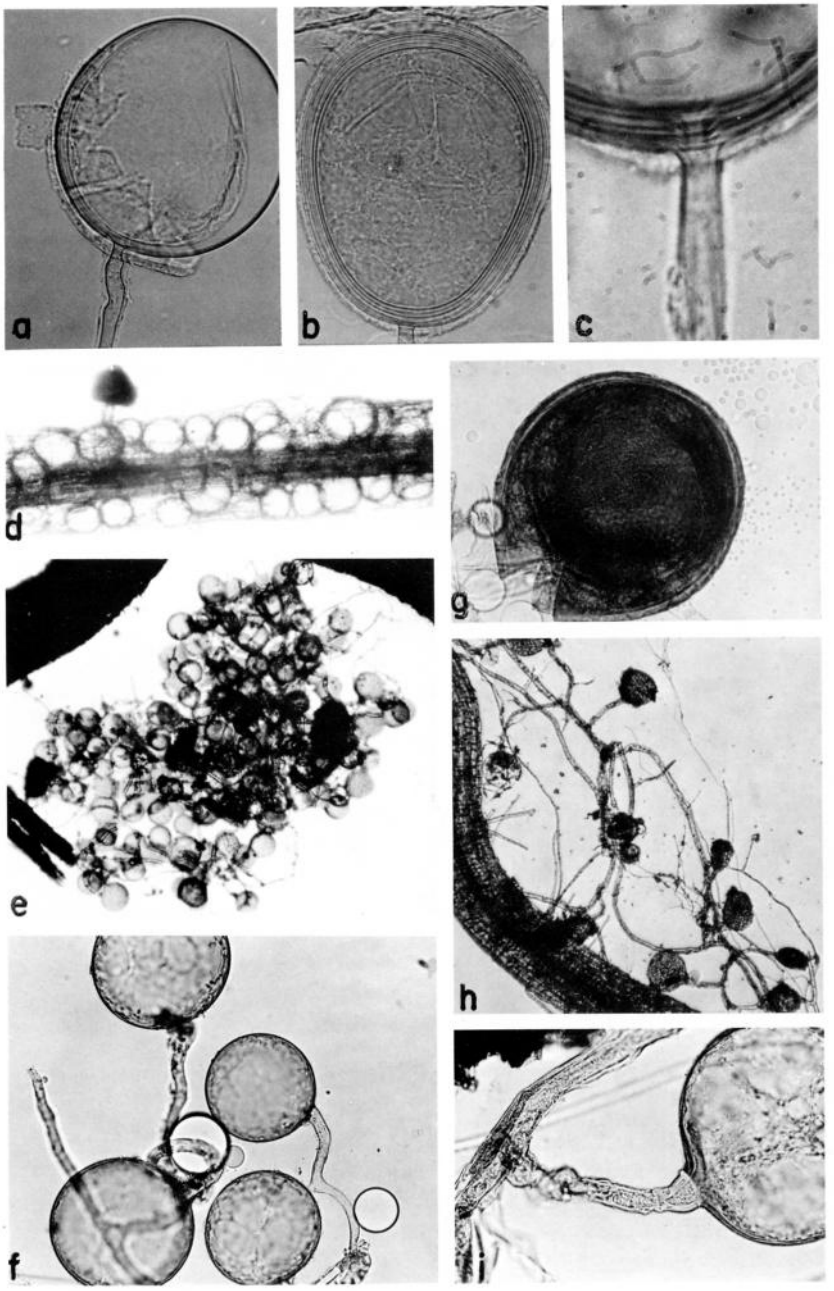

FIG. 1a–d. *Glomus intraradices*. a. Young chlamydospore with outer fragile wall broken, ×400. b. Chlamydospore showing the multiple wall and intact hyaline outer wall, ×400. c. Base of mature spore with the tubaeform flare on the hyphal attachment apparent, ×1000. d. Root containing many chlamydospores of *G. intraradices*, ×60. FIG. e, f. *Glomus aggregatum*. e. Small sporocarp beside root, ×28. f. Individual spores, ×400. FIG. g–i. *Glomus fecundisporum*. g. Chlamydospore broken to show inner and outer wall, ×400. h. Chlamydospores attached to hyphae and root, ×56. i. Individual spore with hyphae, ×400.

(*Citrus* sp.), rhizoma peanut (*Arachis glabrata* Benth.), and *Stylosanthes* sp. at the Agricultural Research Center at Ft. Pierce; from corn (*Zea mays* L.), snap bean (*Phaseolus vulgaris* L.), and strawberry (*Fragaria chiloensis* Duch. var. *ananassa* Bail.) at the Agricultural Research Center at Dover; from celery and carrot (*Daucus carota* L. var. *sativa* DC.) at Zellwood; from potato (*Solanum tuberosum* L.) at the Agricultural Research Center at Hastings; from barley (*Hordeum vulgare* L.), oats (*Avena sativum* L.), wheat (*Triticum vulgare* L.) and corn at the Agricultural Research and Education Center at Quincy.

Glomus intraradices is the only described species of *Glomus* which has yellow to brown spores forming predominantly in the root. As individual spores are rarely recovered in soil sievings, it is more frequently observed in fresh or stained roots. The chlamydospore size range is intermediate between *G. fasciculatum* (Thax. sensu Gerd.) Gerd. & Trappe and *G. clarum* Nicol. & Schenck, distinguishing it from these two species which also form spores within roots. Individual chlamydospores resemble *G. aggregatum* Schen. & Smith, *G. etunicatum* Beck. & Gerd., and *G. macrocarpum* Tul. & Tul. but can be distinguished from these as well as other *Glomus* species by the tubaeform flare (FIG. 1c) on the spore walls where they join the subtending hyphal attachment and the outer ephemeral wall which usually cracks under light pressure.

Glomus aggregatum Schenck & Smith, sp. nov. FIG. 1e–f

Chlamydosporae laxae gregaria vel in sporocarpis sine peridio efformatae; sporocarpi 660–1800 × 330–1400 μm; primi externam radicem posterior vesiculae et sporae in radici efformates. Sporocarpi hyalini vel lutei, viridulo suffusi. Chlamydosporae bitunicatae, hyalinae vel luteae, globosae, 50–91 μm, vel subglobosae, obovatae, cylindricae, irregulares 67–110 × 58–79 μm. Tunicae separabiles, luteae vel fulvae, 1.2–2.4 μm crassae; tunica externa quam interno clariora et crassiora. Hyphae subtendentes 4.8–12 μm diam, poro non claudit; hyphae extramatrices 4.8–7.2 μm diam. Formans vesicular-arbusculares mycorrhizas.

Chlamydospores formed in loose clusters or in sporocarps without a peridium; earliest sporocarps forming outside the root, in as early as 60 da in pot culture; vesicles and spores in roots formed after 100 da, eventually developing into sporocarps that rupture the root cortex and epidermis. Sporocarps of variable size ranging from 660–1800 × 330–1400 μm after five months in pot culture. Sporocarps hyaline to light yellow with a greenish tint in transmitted light, becoming yellow with age. Chlamydospores globose, subglobose, obovate, cylindrical to irregular; spore diam average (50.4–)72.5(–91.2) μm when globose and (67.2–)87(–110.4) × (57.6–)72(–79.2) μm when subglobose. Spores hyaline to yellow; spore walls yellow to yellow-brown, varying from 1.2–2.4 μm thick consisting of an outer wall slightly thicker and lighter in color than the inner wall; walls separable with slight pressure and most apparent in stained preparations. Hyphae at the point of spore attachment 4.8–12 μm wide. Spore contents confluent with hyphal contents on young spores but separated from hyphae on older spores by inner spore wall; pore not occluded by hyphal wall thickening. Hyphal attachment straight or recurved sharply at the spore base. Most hyphae 4.8–7.2 μm diam. Forming typical vesicular-arbuscular mycorrhizae.

ETYMOLOGY: Latin (*aggregatum* = grouped) referring to the clustered arrangement of the spores in the sporocarp.

TYPE: From a pot culture obtained from roots of Carrizo citrange (*Citrus sinensis* × *Poncirus trifoliata*) collected at Adam's Citrus Nursery near Haines City. Cultures maintained and increased in pot cultures of bahia grass. TYPE OSC No. 40,254; ISOTYPES FH; FLAS No. F52574.

DISTRIBUTION: This species is known only from a single collection from citrus at the Adam's Citrus Nursery near Haines City, Florida. It has been maintained in bahia grass pot culture for 18 months and retains its original appearance and characteristics.

Glomus aggregatum most resembles *G. fasciculatum*, but it can be distinguished from *G. fasciculatum* by its thinner spore walls, lighter colored spores with a distinct green tint and separable inner and outer wall.

Glomus fecundisporum Schenck & Smith, sp. nov. FIG. 1g–i

Chlamydosporae singulatim vel gregatim in solo efformatae, globosae 60–155 μm diam, longae vel formae irregulares 83–150 × 107–207 μm diam. Tunica sporarum subhyalina vel fulva, 1.5–7.5 (–13) μm crassa; tunica exteriore et interiore inter se aequales; tunica exteriore cum presso levi rumpens, primo glabra deinde cum humo. Spora immatura subhyalina, matura griseola. Apertura pori 6–14 μm diam, sporarum tunicis claudit. Hyphae subtendentes 7–22 μm diam, tunicae 0.5–2 μm crassae. Hyphae extramatrices 12–22 μm diam, asperulae vel 4.5–9 μm diam glabrae. Formans mycorrhizas sed sine vesiculis vel arbusculis.

Sporocarps unknown; chlamydospores formed singly or in loose clusters in the soil and frequently enmeshed and bound to plant roots in profuse hyphae. Chlamydospores globose, (60–)107(–155) μm diam, elongate to irregular spores 83–150 × 107–207 μm in diam. Spore wall sub-hyaline to light yellow on young spores becoming yellow-brown to dark brown or black and laminated when mature, 1.5–7.5(–13) μm wide, averaging 4.5 μm; spore wall smooth on young spores but on mature spores surface frequently roughened with adhering debris; spores consisting of inner and outer walls of approximately equal thickness which can be separated under pressure. Spore contents sub-hyaline in young spores, gray-white when mature; contents and walls on immature spores frequently collapsing in stained specimens. Spore subtending hyphae 7–22 μm, averaging 15 μm diam with thin walls (0.5–2 μm); pore opening 6–14 μm becoming occluded by spore wall on old spores. Extramatrical hyphae frequently 12–22 μm diam with the outer surface roughened with portions of sloughed wall fragments and adhering debris; narrow, thin-walled hyphae (4.5–9 μm diam) with smooth walls. Forming mycorrhizal associations with plant roots but not forming typical vesicles or arbuscules; coiling hyphae formed in outer cortical cells with hyphal walls becoming indistinct and weakly staining with trypan blue after growth through 2 to 3 cortical cells; hyphal contents frequently enlarging to fill cell lumen.

ETYMOLOGY: Latin (*fecundum* = fertile; *sporum* = spore) referring to the prolific production of spores by this species.

TYPE: Spores from a bahia grass pot culture obtained from soil around soybean roots on the Agronomy Farm, University of Florida, Gainesville. TYPE OSC No. 40,250; ISOTYPES FH; FLAS No. F52579.

DISTRIBUTION: Collected from soybean rhizosphere soil on the Agronomy Farm, University of Florida, Gainesville, and identified in a sample of spores from molasses grass (*Melines minutiflora* Beauv.) collected by G. M. Chaves, Viçosa, Minas Gerais, BRAZIL.

Glomus fecundisporum is a hyaline to dirty-white spored species with spores frequently borne in clusters. The spores of *G. fecundisporum* are generally larger than *G. pallidum* Hall (**9**) and are never formed in sporocarps as described for *G. pallidum*. The walls of *G. fecundisporum* are generally thinner than *G. claroideum* Schen. & Smith and *G. clarum* and are never formed in the roots like *G. clarum*. Chlamydospores of *G. fecundisporum* are generally smaller and do not have an alveolate reticulum like spores of *G. leptotichum* Schen. & Smith.

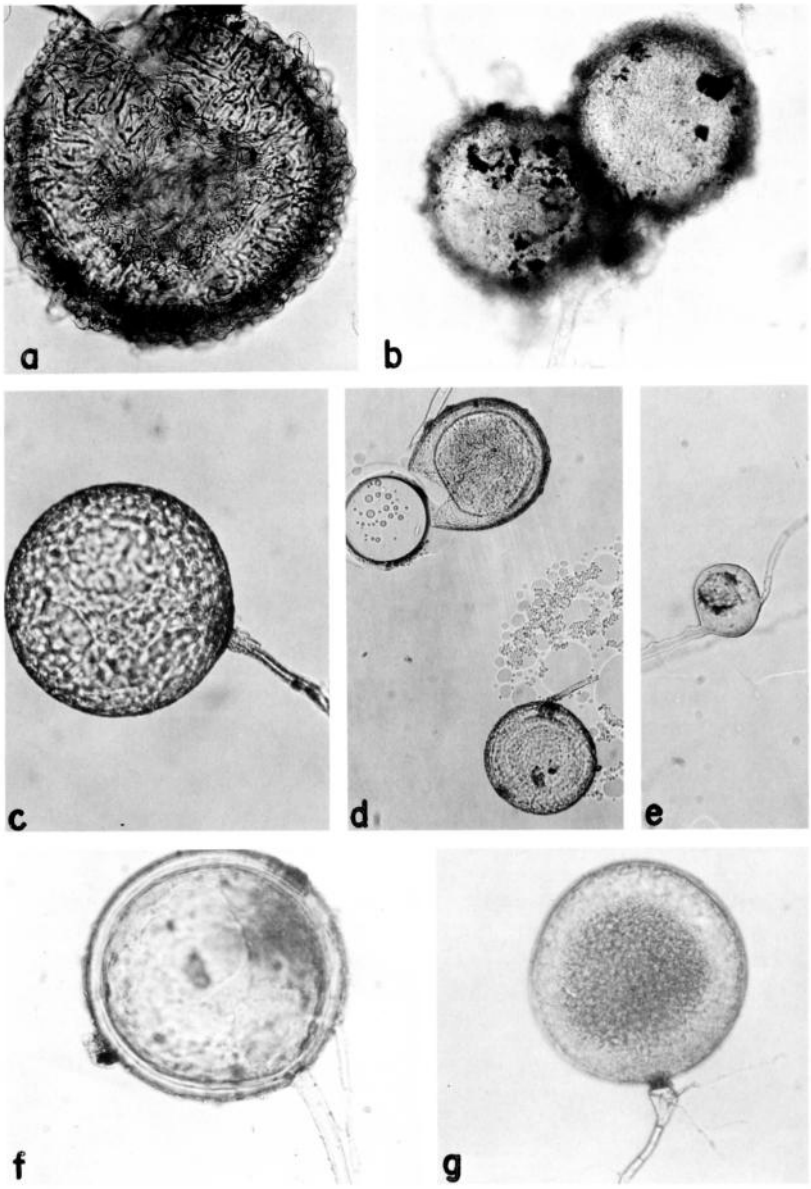

FIG. 2a, b. *Glomus tortuosum*. a. Chlamydospore covered by mantle of convoluted hyphae. b. Two chlamydospores adhering to each other by the mantle. (All figs. × 112.) FIG. c–e. *Glomus leptotichum*. c. A single chlamydospore and hyphal attachment, ×112. d. Two chlamydospores with walls showing the typical faint reticulation associated with them, ×56. e. Intercalary extramatrical vesicle, ×112. FIG. f. *Glomus claroideum*. A single chlamydospore with hyphal attachment, ×200. FIG. g. *Gigaspora albida*. Azygospore with bulbous hyphal attachment, ×28.

Glomus leptotichum Schenck & Smith, sp. nov. FIG. 2c–e

Chlamydosporae singulatae vel laxe gregaria in solo efformatae, globosae 48–262 μm diam; subglobosae, ovatae vel formae irregulares 104–233 × 155–262 μm. Contenta sporae globulae, primo alba deinde vel cremea. Tunica sporarum singula, primo hyalina aetate albolutea vel fusca, 1.5–7.4(–10.5) μm crassa, cum reticulata indistincta alveolata 0.5–1 μm crassa in humo adherente. Hyphae subten-

dentes 9–27 μm diam ad sporam basem. Vesiculae extramatrices, leptodermae 29–48 μm diam, terminaliter vel intercalares in hyphis efformatae. Hyphae extramatrices 7.5–18 μm diam, cum hyphis magnis frequens squarrosis. Formans mycorrhizas sine vesiculi vel arbusculi.

Sporocarps unknown; chlamydospores formed singly or in loose clusters in the soil but frequently enmeshed and bound to roots in profuse hyphae. Chlamydospores globose, extremely variable in size, (48–)175(–262) μm diam; subglobose, ovate or irregular-shaped spores 104–233 × 155–262 μm; chlamydospores with a single wall, hyaline in young spores, becoming light yellow with age, 1.5–7.4(–10.5) μm thick, averaging 4.3 μm; spore wall with an indistinct alveolate reticulum of shallow ridges (0.5–1 μm wide) which is most apparent on young spores devoid of contents; spore wall with adhering debris on the outer surface especially at the hyphal attachment. Spore contents globular, predominantly white to cream but hyaline in young spores and becoming yellow-white on older spores; contents and walls of young spores frequently collapsing in the clearing and staining process. Subtending hyphae 9–27 μm diam at the spore attachment, narrowing gradually with distance from the spore; hyphal wall continuous with the spore wall; spore contents enclosed with a membrane which occasionally bulges into the subtending hyphae; pore size 5–18 μm usually 6–8 μm; pore occluded by the spore wall on old spores. Thin-walled extramatrical vesicles, 29–48 μm diam, formed terminally or in an intercalary manner on hyphae; the distal hyphae on intercalary vesicles frequently aborting, leaving a short vestigial projection on the vesicle apex. Extramatrical hyphae 7.5–18 μm diam, with the outer surface of larger hyphae frequently roughened from portions of sloughed wall fragments and adhering debris. Forming mycorrhizal associations with plant roots, but not forming typical internal vesicles or arbuscles; coiling hyphae formed in outer cortical cells with hyphal walls becoming indistinct and only weakly staining with trypan blue after growth through 2 to 3 cortical cells; hyphal contents frequently enlarging to completely fill cell lumen.

ETYMOLOGY: Latin (*leptotichum* = thin-walled) referring to the thin walls on this large-spored *Glomus* species.

TYPE: From a pot culture of bahia grass derived from spores collected from soil associated with corn roots near Live Oak, Florida. TYPE OSC No. 40,249; ISOTYPES FH; FLAS No. F52576.

DISTRIBUTION: Collected from soil associated with roots of corn near Live Oak, Florida; from around sweet gum (*Liquidambar styraciflua* L.) roots in Aiken, South Carolina, and from pearl millet [*Pennisetum glaucum* (L.) R. Br.] in Athens, Georgia.

Glomus leptotichum typically has large, white to cream-colored spores with hyaline walls bearing a faint reticulum of ridges. Spores and extramatrical vesicles are produced both terminally and in an intercalary manner. Because of its large size and white to cream-colored spores it could possibly be confused with *G. lacteum* Rose & Trappe (**14**), but *G. leptotichum* lacks the merging hyphae on the attachment associated with *G. lacteum*. *Glomus fecundisporum* Schen. & Smith, which *G. leptotichum* resembles somewhat, has generally smaller spores with yellow to brown walls, gray-white contents, and lacks a reticulum.

Glomus tortuosum Schenck & Smith, sp. nov. FIGS. 2a, b

Sporocarpia ignota. Chlamydosporae maturae luteae vel griseae cum hyphis sinuosis appressis, 4–10 μm crassa, formans stratae ad 25 μm crassitudem, saepe cum humo adhaerente. Chlamydosporae globosae, 120–210 μm diam, vel subglobosae 94–180 × 112–230 μm, excludens hyphis sinuosis appressis. Chlamydosporae immaturae, hyalinae, leptodermae, 0.4–1.5 μm, sine sinuosis appressis. Tunica sporarum singula, 0.5–2 μm crassa; hyphae subtendentes 9–20(–26) μm diam ad sporam basem. Formans mycorrhizas sed sine vesiculis vel arbusculis.

Sporocarps unknown. Chlamydospores borne singly in soil but occasionally adhering in pairs. Immature spores subhyaline without a mantle, thin-walled (0.4–1.5 μm diam) and attached to extramatrical hyphae up to 500 μm long. Mature spores yellow to dull gray-brown with a mantle of sinuous hyphae closely appressed to the spore and flattened, 4–10 μm wide, forming layers of hyphae on the spore surface up to 25 μm thick; occasionally, mantle extends down the hyphal attachment. Mantle hyphae hyaline when young, acquiring a brownish pigment with age, and originating from swellings on the hyphal attachment 10–20 μm below the spore or arising from other hyphae adjacent to the spore. Mantle frequently with adhering debris and soil particles. Chlamydospores largely globose, (120–)160(–210) μm diam, some subglobose 94–180 × 112–230 μm excluding the mantle; spores with a single, laminate, thin wall, 0.5–2 μm diam; spore contents globular but usually obscured by the mantle. Width of hyphal attachment at the spore base 9–20(–26) μm. Extramatrical hyphae 2–11 μm diam, hyaline to light yellow. Forming mycorrhizae on plants without typical vesicles or arbuscules; intracellular hyphae lacking distinct walls and frequently enlarging to fill the lumen of cortical cells.

ETYMOLOGY: Latin (*tortuosum* = winding) referring to the winding pattern of hyphae in the spore mantle.

TYPE: From a bahia grass pot culture derived from spores originally obtained from around soybean roots at the Agricultural Research Center, Live Oak, Florida. TYPE OSC No. 40,251; ISOTYPES FH; FLAS No. F52573.

DISTRIBUTION: Known only from soil around soybean roots located at the Agricultural Research Center, Live Oak, Florida.

Glomus tortuosum is distinctive among *Glomus* species in having a mantle of sinuous hyphae covering each spore. Only *G. convolutum* Gerd. & Trappe has been described as having a mantle of intertwined hyphae but this species is only known from sporocarps collected from snow banks. *Sclerocystis sinuosa* Gerd. & Bakshi also has sinuous hyphae surrounding the spores but the sporocarpic nature of this species would readily differentiate it from *G. tortuosum*. The mantle of *G. tortuosum* can be confused with the peridium on chlamydospores of *G. mosseae* (Nicol. & Gerd.) Gerd. & Trappe and *G. monosporum* but can easily be distinguished from these species under the microscope by the sinuous nature of the mantle on *G. tortuosum*.

Glomus claroideum Schenck & Smith, sp. nov. FIG. 2f

Chlamydosporae singulae in solo vel radice efformatae; sporae globosae, 70–180 μm diam, vel subglobosae 59–126 × 72–145 μm; tunica sporarum una vel duabus stratis formata, hyalinae vel alboluteae, glabro-tunicatae, saepe cum humo adherente. Contentae sporarum globulosae, hyalinae vel alboluteae; hyphae subtendentes 7.5–15 μm diam ad sporam basem, ramosae 50–150 μm sub spora. Mycorrhizae vesicular-arbuscular formans.

Sporocarps unknown; chlamydospores formed singly or in loose clusters in the soil and infrequently as single spores in the root. Chlamydospores globose (70–)130(–180) μm diam; occasionally subglobose to irregular; 59–126 × 72–145 μm; spore wall (4.5–)7.6(–10.5) μm consisting of 1 or 2 walls with the outer wall laminate and usually thicker than the inner wall; spore walls hyaline to yellow, becoming yellow-brown with age; outer spore wall smooth but frequently with soil particles or debris adhering. Spore contents globular, hyaline to light yellow, retained by a membrane on young spores and occluded by spore walls on older spores. Spore subtending hyphae 7.5–15 μm diam at the spore attachment; walls of subtending hypha on young spores 3.0–5.5 μm thick and 1.5–3.0 μm thick on older spores at the point of attachment, usually abruptly tapering below the spore;

considerable branching of subtending hyphae usually occurs 50–150 μm below the spore. Extramatrical hyphae 3–14 μm diam with hyaline to yellow walls usually 1.5–3 μm thick. Forming typical vesicular-arbuscular mycorrhizae with plant roots.

ETYMOLOGY: Latin (*clarum* = clear, *oideum* = like) referring to its similar appearance to *Glomus clarum*, a hyaline-spored *Glomus* species.

TYPE: From soil around soybean roots collected at the Agricultural Research and Education Center near Sanford, Florida, in July 1976 and maintained in bahia grass pot culture at the University of Florida, Gainesville. TYPE OSC No. 40,252; ISOTYPES FH; FLAS No. F52578.

DISTRIBUTION: This species is only known from two locations. It was originally recovered from soil around soybean (*Glycine max*) roots at the Agricultural Research and Education Center, University of Florida, Sanford, Florida. It was also observed as a contaminant in pot cultures of VA mycorrhizal fungi of H. D. Skipper from Clemson, South Carolina. The original isolate from soybean has been established on bahia grass (*Paspalum notatum*) and been maintained for several years.

Glomus claroideum is most similar to *Glomus clarum* in appearance but can be separated from it by its generally smaller spores, thinner walls and production of abundant extramatrical spores. *Glomus claroideum* forms chlamydospores only rarely within the root, whereas *G. clarum* rarely produces them outside the root. Other *Glomus* species producing white or hyaline spores have either thinner walls [*G. albidum* Walker & Rhodes (**20**)], have more than one hyphal strand on the attachment [*G. lacteum* Rose & Trappe (**14**)], or are of smaller diameter [*G. pallidum* Hall (**9**)].

Gigaspora albida Schenck & Smith, sp. nov. FIG. 2g

Azygosporae singulatae in solo efformatae, albae viridulae suffusae; globosae, 143–330(–350) μm diam, raro ellipsoideae, 232–252 × 234–250 μm; tunica sporarum, 4–12 μm crassae, cum 1–6 tunicae; tunica exteriore tenui, laevis, 1–2 μm crassa cum presso levi rumpens; tunicae interiore, 2–3, raro 4–5 tunicae inseparabiles. Tubis germinationis tunicam prope basim penetrantibus. Azygospore cum suspensore bulbose uno, hyaline vel luteo, 24–50 μm diam. Vesiculae extramatrices hyalinae vel lutei, turbinatae, obovatae, vel clavatae, 17–36 μm diam, in fasciculis 5–14 in hyphis complexis ortae in humo efformatae; vesiculae apicis echinulatae. Formans arbusculares mycorrhizas.

Azygospores formed singly in the soil, dull white with a light greenish-yellow tint; mostly spherical 143–330(–350) μm diam, averaging 265 μm, occasionally ellipsoidal, 232–252 × 234–250 μm; spore walls continuous, except for an occluded pore, from 4–12 μm thick, with 1 (on young spores) to 6 walls; outer wall thin, smooth, 1–2 μm thick, readily cracking under light pressure; usually 2 or 3 but occasionally 4 to 5 inner walls, inseparable, of varying thickness. Germ tubes produced directly through the spore wall near the bulbous suspensor without forming an enclosed compartment separating it from the spore contents. Azygospore attached to a single, hyaline to yellow, bulbous suspensor, (24–)36(–50) μm attached to septate hyphae with fine hyphal branches. Extramatrical vesicles hyaline to yellow, turbinate, obovate, or clavate, (17–)25(–36) μm diam formed in clusters of 5 to 14 on coiled hyphae in the soil; vesicle apex echinulate with spines 2.5–10 μm long; spines frequently septate and occasionally bifurcate. Forming arbuscular mycorrhizae.

ETYMOLOGY: Latin (*albida* = whitish) referring to the color of the azygospores.

TYPE: From a bahia grass pot culture originally obtained from spores asso-

ciated with soybean soil on the Agronomy Farm, University of Florida, Gainesville. TYPE OSC No. 40,253; ISOTYPES FH; FLAS No. F52575.

DISTRIBUTION: Collected from Coastal bermuda grass [*Cynodon dactylon* (L.) Pers. var. *coastal*] by R. E. Garrett and soybean soil on the Agronomy Farm, University of Florida, Gainesville and tomato from the Agricultural Research Center, Immokalee, Florida.

Gigaspora albida can be separated from *G. gigantea* (Nicol. & Gerd.) Gerd. & Trappe by its generally smaller spores and very light tint of green. The outer thin wall of *G. albida* readily separates or cracks under pressure, a characteristic typical of *G. gigantea*, but the inner wall is thicker than *G. gigantea*, and frequently is composed of several inseparable walls, a characteristic more like *G. margarita*. The consistency of this species in pot culture over several years and its occurrence on several different plant species at different locations in Florida justifies this description of a new species, in the authors' opinions.

SYNOPTIC KEY TO FLORIDA ENDOGONACEAE

The following key contains all 34 species recorded from Florida and, in addition, four *Gigaspora* species not known to occur in Florida, *G. aurigloba* Hall, *G. gilmorei* Trappe & Gerd., *G. calospora* (Nicol. & Gerd.) Gerd. & Trappe, and *G. coralloidea* Trappe, Gerd. & Ho. To use the key effectively, several mature spores of each specimen to be determined should be available and, most preferably, spores and root material from an actively growing pot culture. Several species are difficult to separate, e.g., *Gigaspora gigantea* from *G. albida*; also *Glomus etunicatum*, *G. macrocarpum*, *G. fecundisporum*, and *G. claroideum* from each other. For separation of these species, the original or other descriptions should be consulted. For unfamiliar terms in the body of the key, consult Snell and Dick (**16**) or some other glossary of mycological terminology.

To use the key, first determine the genus using the diagrams in FIG. 3. Each genus is depicted by drawings of representative spore types with several stages in the development of spores for *Acaulospora* and *Entrophospora* shown. Some of the variability in appearances of spores and other structures are shown for each genus except *Complexipes* which is monotypic and relatively uniform.

The following comments regarding the genera of Endogonaceae included in FIG. 3 are made to clarify differences among the genera. The azygosporic genera all produce spores singly in the soil. *Gigaspora* species have a suspensor cell (swollen hyphal tip) that is attached to the spore vertically or horizontally. Infrequently, the suspensor cell is broken away from the azygospore and these spores may resemble mature azygospores of *Acaulospora* which usually are found without any attachment. On a few *Gigaspora* species the suspensor cell may be narrow or hyaline and for this reason mistaken for a simple hyphal attachment such as found on chlamydospores in the genus *Glomus*. Thin-walled vesicles (extramatrical vesicles) are produced singly or in loose clusters on coiled hyphae in the soil by *Gigaspora* species but these are of little diagnostic value except in pure pot cultures of a single species.

Species in the genus *Acaulospora* produce spores on tapering, swollen hyphae terminating in a vesicle. Remnants of the hyphae or vesicle may be associated with azygospores of *Acaulospora* species but most frequently mature spores lack any attachment. Many times the laterally attached hyphae will persist and such spores can be mistaken for *Glomus* spores with a recurved hyphal attachment.

Spores in the genus *Entrophospora* are formed on swollen hyphae terminating in a vesicle, but the spore is formed within the hypha not laterally as in the genus *Acaulospora*. Because of their similarity, azygospores of these two genera must

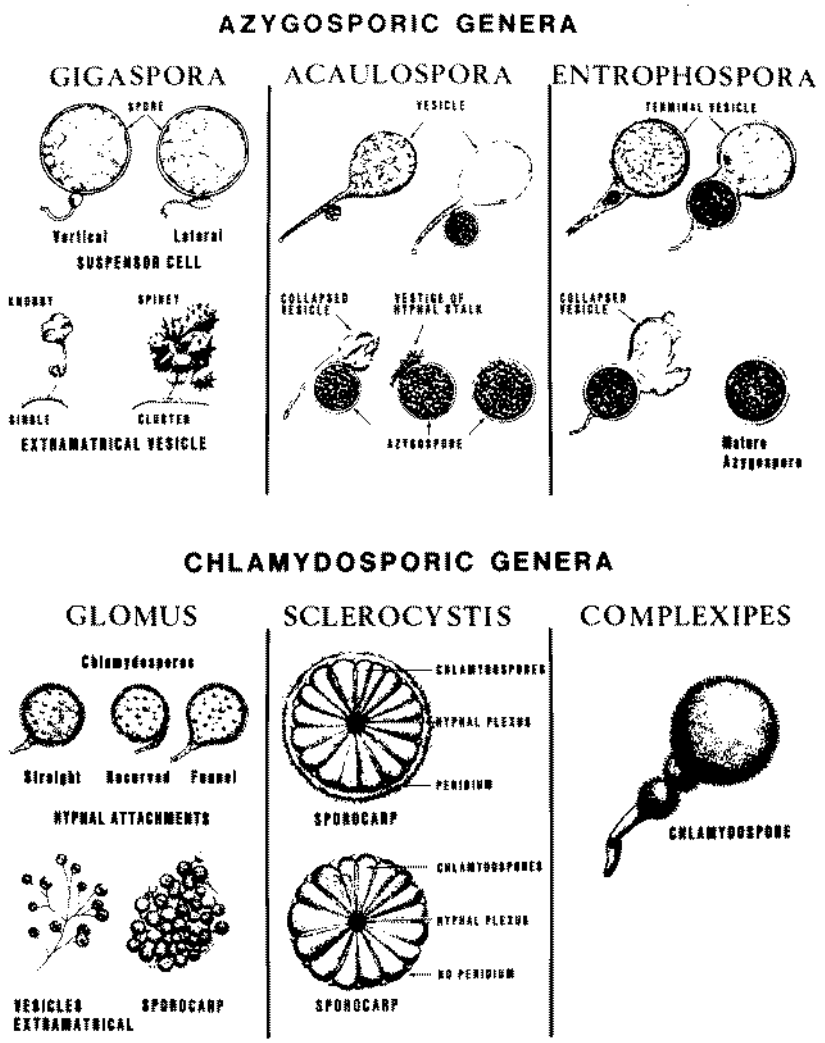

FIG. 3. Diagrammatic drawings of typical spores of six genera in the Endogonaceae. Drawings are to be used to determine genus of unknown spores before proceeding to body of the synoptic key for species determination. Spore sizes are not to scale.

be examined carefully to distinguish them. The mature azygospore of *Entrophospora* often resembles a *Glomus* species when the hyphal attachment remains and the vesicle is lost.

Chlamydospores in the genus *Glomus* can occur singly or in tight clusters (sporocarps) which may or may not be covered with a hyphal peridium. The hyphal attachment is either confluent with or firmly attached to the spore wall with only a small pore opening to the spore contents. Some species form extramatrical, smooth-walled vesicles.

Species in the genus *Sclerocystis* always form sporocarps in which the chlamydospores are radially arranged around a central hyphal plexus. They may or may not have a hyphal peridium covering the spores. A cross section through the sporocarp readily reveals the radial arrangement of chlamydospores and distin-

guishes them from *Glomus* sporocarps which usually have spores arranged randomly.

Chlamydospores of the genus *Complexipes* are produced singly on swollen monilioid cells.

After determining the genus for the specimen to be identified, proceed to the appropriate key to determine the species. Select a character in the key that is associated with the species to be identified. Write down the species numbers listed in the key for that characteristic. Then select another characteristic in the key associated with the species to be identified and also record the species numbers having that characteristic. Cross out the species numbers not listed for both characters. Then proceed to another characteristic and also cross out all numbers not in common with the second characteristic. Proceed in this fashion until all the characters displayed by the specimen species have been exhausted in the key. Only one or a few species numbers should then remain. Citations to detailed descriptions are listed after each species in the key and may have to be consulted to differentiate morphologically similar species. Other keys to the Endogonaceae which may be helpful in identifying unknown species are listed in citations **4**, **7**, **10**, **12**.

SYNOPTIC KEY

List of genera and species.—Species numbers are those used in the key to indicate species and species description numbers refer to references in the Literature Cited.

Species numbers:	Species description
GIGASPORA SPECIES	
1. *G. albida* Schenck & Smith	
2. *G. aurigloba* Hall	**9**
3. *G. calospora* (Nicol. & Gerd.) Gerd. & Trappe	**7**, **11**
4. *G. coralloidea* Trappe, Gerd. & Ho	**7**, **12**
5. *G. gigantea* (Nicol. & Gerd.) Gerd. & Trappe	**7**, **11**
6. *G. gilmorei* Trappe & Gerd.	**7**
7. *G. gregaria* Schenck & Nicol.	**12**
8. *G. heterogama* (Nicol. & Gerd.) Gerd. & Trappe	**11**, **12**
9. *G. margarita* Becker & Hall	**4**, **12**
10. *G. nigra* Redhead	**12**, **13**
11. *G. pellucida* Nicol. & Schenck	**12**
12. *G. rosea* Nicol. & Schenck	**12**
ACAULOSPORA SPECIES	
13. *A. bireticulata* Rothwell & Trappe	**15**
14. *A. gerdemanni* Schenck & Nicol.	**12**
15. *A. laevis* Gerd. & Trappe	**7**, **12**
16. *A. scrobiculata* Trappe	**18**
17. *A. spinosa* Walker & Trappe	**21**
18. *A. trappei* Ames & Linderman	**1**
GLOMUS SPECIES	
19. *G. aggregatum* Schenck & Smith	**12**
20. *G. claroideum* Schenck & Smith	
21. *G. clarum* Nicol. & Schenck	**12**
22. *G. etunicatum* Becker & Gerd.	**3**
23. *G. fasciculatum* (Thax. sensu Gerd.) Gerd. & Trappe	**5**, **7**, **17**
24. *G. fecundisporum* Schenck & Smith	
25. *G. fulvum* (B. & B.) Trappe & Gerd.	**7**, **12**, **17**
26. *G. geosporum* (Nicol. & Gerd.) Walker	**7**, **11**
27. *G. intraradices* Schenck & Smith	
28. *G. leptotichum* Schenck & Smith	
29. *G. macrocarpum* Tul. & Tul.	**7**, **17**

30. *G. microcarpum* Tul. & Tul. **7, 17**
31. *G. mosseae* (Nicol. & Gerd.) Gerd. & Trappe **7, 11**
32. *G. tenuis* (Greenall) Hall **8, 9**
33. *G. tortuosum* Schenck & Smith

SCLEROCYSTIS SPECIES

34. *S. coremioides* B. & B. **7, 17**
35. *S. rubiformis* Gerd. & Trappe **7**
36. *S. sinuosa* Gerd. & Bakshi **6, 12**

OTHER GENERA

37. *Entrophospora infrequens* (Hall) Ames & Schneid. **2, 9**
38. *Complexipes moniliformis* Walker **19**

GIGASPORA

SPORE COLOR

Hyaline: 3, 6, 11
Subhyaline to light yellow: 1, 3, 5, 6, 9, 11, 12
Yellow to light brown: 2, 5
Brown: 4, 7, 8
Black: 10
Greenish tint: 1, 5
Pink tint: 12

SPORE SURFACE

Smooth: 1, 2, 3, 5, 6, 9, 11, 12
Pitted: 10
Projections: 4, 7, 8

SPORE SIZE (DIAM)

50–200 μm: 1, 2, 3, 5, 8, 11, 12
200–250 μm: 1, 2, 3, 5, 6, 8, 11, 12
250–400 μm: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12
400–600 μm: 2, 3, 4, 5, 7, 9, 10
>600 μm: 5, 10

SPORE WALLS

Separable outer wall: 1, 5, 6, 11
Walls 2, inseparable: 7, 8, 10
Wall 1, may be laminated: 2, 3, 4, 9, 12
Wall thickness
<6 μm: 1, 3, 5, 8, 9, 12
6–12 μm: 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12
12–18 μm: 2, 4, 6, 7, 9, 10
18–24 μm: 9, 10

SUSPENSOR CELL (DIAM)

10–25 μm: 1, 3, 8, 9, 11
25–40 μm: 1, 3, 6, 7, 8, 9, 11, 12
40–55 μm: 1, 2, 3, 5, 7, 8, 9, 10
55–70 μm: 2, 4, 7, 9, 10
70–85 μm: 7, 10
>85 μm: 10

Attached to spore laterally: 8, 10
Attached to spore vertically: ALL SPECIES

EXTRAMATRICAL ACCESSORY VESICLES

Clustered: 1, 2, 5, 6, 7, 8, 9, 10, 11, 12
Single: 3, 4, 5, 9, 11
Coralloid: 4
Blunt projections (knobby): 2, 3, 6, 7, 8, 10, 11
Elongate projections (spiny): 1, 2, 4, 5, 9, 12

Diam single vesicle

10–25 μm: 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12
25–40 μm: 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12
40–60 μm: 2, 7
>60 μm: 2

Vesicle color
Hyaline to pale yellow: 1, 2, 3, 5, 6, 9, 12
Yellow brown: 3, 4, 6, 9, 11
Brown: 4, 7, 8, 10, 11
Dark brown: 10

ACAULOSPORA

SPORE COLOR
Hyaline to light yellow: 17, 18
Shades of brown: 13, 14, 15, 16, 17

SPORE SURFACE
With spines or projections: 17
Cerebriform or wrinkled: 14
Reticulate: 13
Minutely pitted: 16
Smooth: 15, 18

SPORE SIZE (DIAM)
<100 μm: 18
100–200 μm: 13, 15, 16, 17
200–300 μm: 14, 15, 16, 17
>300 μm: 15, 17

SPORE WALL CHARACTERISTICS
Separable outer wall: 14
Single wall: 18
Multiple wall: 13, 14, 15, 16, 17
Wall thickness
<3 μm: 13, 14, 15, 18
3–7 μm: 15, 16, 17
>7 μm: 17

GLOMUS

SPORE FORMATION
Spores in sporocarps: 19, 23, 25, 29, 30, 31
Spores occurring singly in soil: ALL SPECIES EXCEPT 25
Spores predominantly in roots: 21, 23, 27

SPORE COLOR (MATURE)
Hyaline: 19, 20, 21, 23, 24, 28, 30, 32
Subhyaline to white: 24, 28
Yellow: 19, 20, 21, 22, 23, 24, 25, 27, 29, 30, 31, 33
Brown: 22, 23, 25, 27, 29, 31, 33
Dark brown to black: 26

SPORE SURFACE
Covered with a mantle of sinuous hyphae: 33
Outer surface with fine reticulation: 28
Outer spore wall with mucilage and with debris attached: 20, 22, 24, 28, 29

SPORE SIZE (DIAM)
<15 μm: 32
25–50 μm: 23, 25, 27, 28, 30
50–100 μm: 19, 20, 21, 22, 23, 24, 25, 27, 28, 29, 30, 33
100–200 μm: 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 33
200–250 μm: 21, 24, 26, 28, 29, 31, 33
>250 μm: 21, 26, 28, 31

SPORE WALL
Outer wall brittle, cracking under pressure: 19, 27, 28
Outer wall ephemeral: 22
Wall distinctly multiple layered: 27
With 2 walls: 19, 20, 21, 22, 28, 29, 31
With 1 wall: 20, 23, 24, 25, 26, 29, 30, 32, 33

Wall thickness
<3 μm: 19, 24, 25, 28, 30, 31, 32, 33
3–7 μm: 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31
7–12 μm: 20, 21, 22, 23, 24, 26, 27, 28, 29
12–20 μm: 21, 22, 23, 24, 26, 27, 29
>20 μm: 21

HYPHAL ATTACHMENT
Tubaeform at spore wall (×400): 27
Attachment frequently not present: 22
Attachment funnel-shaped below spore: 29, 31
With hyphal walls tapering and becoming thinner with distance from the spore: 26

HYPHAE CHARACTERISTICS
Hyphae on root fine (<3 μm) with swellings up to 10 μm: 33
Hyphae with thin-walled external vesicles present: 28, 31

SCLEROCYSTIS

SPOROCARP CHARACTERISTICS
Peridium lacking: 35
Peridium present: 34, 36
Peridium hyphae sinuous: 36
Peridium <20 μm: 36
Peridium >20 μm: 34
Sporocarp (diam)
150–250 μm: 35, 36
250–500 μm: 34, 35, 36
500–600 μm: 34, 35
>600 μm: 35

SPORE CHARACTERISTICS
Spore length
25–50 μm: 35, 36
50–100 μm: 34, 35, 36
>100 μm: 35, 36
Wall thickness
1.5–2.5 μm: 34, 36
2.5–4.0 μm: 34, 35, 36
4.0–5.5 μm: 35, 36
5.5–7.0 μm: 35

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[*Note on* Glomus *species, added in proof.*—Although the genus *Glomus* has an apparent masculine ending (*us*), it is neuter, hence all species epithets should be given neuter endings (personal communication, J. M. Trappe)].