SEVERAL NEW AND UNREPORTED VESICULAR-ARBUSCULAR MYCORRHIZAL FUNGI (ENDOGONACEAE) FROM COLOMBIA

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ABSTRACT

Six new species of Endogonaceae are described, Acaulospora appendicula, A. longula, A. mellea, A. morrowae, Glomus manihotis, and Entrophospora colombiana. Acaulospora appendicula is an unusual species that forms chlamydospores and thin-walled accessory cells similar to those formed by species in the genus Glomus. In addition, observations on the occurrence of Acaulospora foveata in Colombia and some characteristics of this fungus not included in the original description are presented. A dichotomous key to all described species of Acaulospora is presented.

Key Words: Acaulospora, Entrophospora, Glomus, taxonomy.

Several vesicular-arbuscular mycorrhizal fungi were isolated from a number of different plant species and locations in Colombia and were established in a greenhouse as pot cultures on Pueraria phaseoloides Benth. (tropical kudzu). Several new and unreported species of Endogonaceae were included among these pot cultures. The purpose of this paper is to describe these fungi and note their occurrence in Colombia and elsewhere.

Unless otherwise stated, the species were first recovered from Carimagua, Meta, Colombia. Carimagua is in eastern Colombia in a tropical savanna landscape characterized by grass covered, smooth, interfluvial plains and forests along streams. The predominant grass species are Trachypogon vestitus Anderss. and Paspalum pectinatum Nees in Trin. Most of the soils are well drained oxisols which are deficient in N, P, K, Ca, Mg, and S; a typical surface soil has the following characteristics: 38% clay, 12% sand, 4% organic matter, pH 4.4, 1 ppm P, and the following meq/100 g of soil: Al = 3.8, Ca = 0.2, Mg = 0.2, K = 0.1, Na = 0.1. Most crops grown in these soils without liming suffer aluminum toxicity.

TAXONOMIC ACCOUNT

A pot culture of Acaulospora foveata Janos et Trappe on Paspalum plicatum Michx. was examined. The spores were collected originally near Carimagua in a sward of native grasses in 1981. The spores occurred in soil separately and were usually globose, subglobose, or occasionally irregular. Occasionally, spores were

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Fig. 1. *Acaulospora foveata*. a. Two azygosporas (A) with their attached terminus (1) formed within a root, ×100. b. Hyphal terminus and tapering hypha with two azygosporas attached, ×250.

noted in plant roots with several spores/cm of root (Fig. 1a). These spores were usually cylindrical or ellipsoidal, 250–300 × 185–250 μm diam, and yellow-brown. Spores formed in the soil were dark brown to red-brown, globose to subglobose, (135–)250(–300) μm diam. The spore wall was (6.3–)12.5(–17.5) μm wide and consisted of three layers with the outer red-brown, middle layer butterscotch to brown, and the inner layer hyaline. The swollen hyphal terminus giving rise to the azygosporae was globose, (170–)270(–310) μm diam, with a wall width of (4.5–)6.3–7.5(–10) μm. The length of the hypha from the swollen terminus to the spore was (38–)45–55(–70) μm. Depressions on the spore wall were usually round, 4–10 μm diam, and 1–3 μm deep, but occasionally were elongate and 8–16 × 6–12 μm. Occasionally, two spores formed on the same hypha (Fig. 1b).

The azygosporae diam of the specimen examined in Colombia was somewhat smaller and the spore wall thickness slightly greater than that reported by Janos and Trappe (1982). The occurrence of azygosporae in the roots and the formation of more than one azygosporae per hyphal terminus were not reported in the original description. The above differences were not considered sufficient to erect a new taxon. Specimens of this isolate have been deposited at OSC, FLAS (No. F53670) and FH.

*Acaulospora appendicularia* Spain, Sieverding et Schenck, n. sp. Figs. 2, 3, 9

Azygosporae singulae in solo efformatae; azygosporae penduculato gestae in attenuata hypha cum terminatone inflata globsa (190–)250(–380) μm. Sporae globosae, (170–)250(–390) μm, cremeae vel aurantio-alutaceaeplerumque cum pendiculato; sporae tunica stratis quatuor: exterior, 8–16 μm crasso, reticulato cum tenuibus rimalibus; secundo adhaerenti, 2–6 μm crasso, reticulo alveolato; terto separabile, 4–8 μm crasso, reticulo alveolato; interiore adhaerente, laeve, 2–8 μm crasso. Hyphae crassitunicatae chlamydospore singulae vel gregatim gestae, 120–240 μm crasso, tunicae 2–8 μm crassae; hyphae leptotichae vesiculae efformatae. Formans vesicular-arbusculares mycorrhizas.

Azygosporae formed singly in the soil adjacent to roots; borne on a short, hyphal pedunculate protuberance, 30–100 μm long, 20–50 μm wide, arising from a tapering hypha terminating in a globose, swollen hyphal terminus, (190–)250 (–380) μm diam, with a wall 1–6 μm thick consisting of an outer wall of overlapping
plate-like structures and a membranous inner wall; hyphal terminus contents white-opaque when newly formed; hyphal terminus becoming gray-white, subhyaline, or transparent when contents empty to form a spore; hyphal terminus usually persisting on young spores, generally not collapsing when detached from the spore at the juncture of the hypha and the pedicel. Azygospores (170–)250 (–390) μm diam, white-opaque when young, becoming dull yellow-cream to orange-tan when mature; hyphal pedunculate protuberance attached to the reticulate inner wall and forming an appendage on the spore; azygospores with two separable
walls each consisting of two walls not readily separating; the outer wall 8–16 (−20) μm thick, somewhat roughened, becoming yellow to brown with age, with an irregular, reticulate pattern of fine cracks that serve as fracture lines when an azygosporic is crushed; second wall hyaline, 2–6 μm thick, with an alveolate reticulum; reticulum 8–12 × 4–8 μm; third wall hyaline, 4–8 μm thick, also with an alveolate reticulum similar to the previous wall; innermost wall hyaline smooth, 2–10 μm thick; outer wall firm and difficult to break on young azygosporic, and turning orange-red with Melzer's reagent, but becoming less rigid and staining less red with Melzer's reagent with age. Thick-walled, rigid, persistent hyphae, 12–20(−25) μm wide, branching sparsely, and giving rise to thin-walled hyphae bearing terminal chlamydospore-like hyphal swellings 120–240(−280) μm diam,
with a thick wall, 2–8(–12) μm, frequently with a mucilaginous outer layer with adhering debris. Chlamydospore-like structures borne singly or occasionally in loose clusters and can function as propagules; also borne on thin-walled hyphae are thin-walled (1–2 μm), globose (40–80 μm), or ellipsoidal (68–120 × 54–112 μm) swollen hyphal tips which readily collapse in lactophenol. Forming vesicular-arbuscular mycorrhizae.

**Type**: Maintained in pot culture on *P. phaseoloides*, culture no. C-13-1 at Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia; originally isolated from native grasses and tropical kudzu at Carimagua. OSC 41495; **Isotypes** FLAS No. F 53673 and FH.

**Etymology**: Latin, *appendicula* (little appendage), referring to the pedicel on the azygospora.

**Distribution**: Occurring naturally in Colombia from Carimagua, Meta, CIAT Quilichao, Agua Blanco, and Popayan, Cauca and also observed from acid soils (pH 5–5.5) near Gainesville, Florida.

*Acaulospora appendicula* can be easily separated from all other species of *Acaulospora* by the pedicel on the azygosporc and presence of more than one type of spore. The azygosporc outwardly resembles *A. gerdemannii* Schenck et Nicolson (Nicolson and Schenck, 1979) but the outer wall on *A. appendicula* is much thicker, more rigid, and lacking the deep folds associated with the outer wall of *A. gerdemannii*. No other species of *Acaulospora* has yet been described with *Glomus*-like chlamydospores and thin-walled "vesicle-like" structures. *Acaulospora appendicula* seems to be a fungus with characteristics that link species of *Acaulospora* and *Glomus*.

**Acaulospora longula** Spain et Schenck n. sp.  

Azygosporae in solo efformatae; sporeae sessiles, lateriter gestae in hypha subbattenuata, cum terminatone inflata globosa vel subglobosa, 70–90 μm diam; hypha interjacens spora et terminalis 100–200 μm long. Sporeae subhylineae ad stramineae, globosae vel subglobosae, 75–90 μm diam; sporeae tunica e stratis quinque: exteriore ephemero, mucilagino, 0.5–3 μm crasso; secundo 2–3 μm crasso, insepabilis e tunica tertiario, 0.5 μm crasso; quattuor et quinque membranaceo, 0.5–1 μm crasso, quinque in iodo subpurpurescens. Mycorrhizae vesicular-arbusculares formans.

Azygosporc formed singly in the soil, borne laterally on hyphae slightly tapering to a swollen, globose to subglobose hyphal terminus, (60–)70–90(–110) μm diam, with walls 0.5 μm thick; hyphae at the point of spore attachment 6–12 μm diam, distance of connecting hypha between spore and terminus 100–200 μm. Hyphal terminus often collapsing after spore formation and usually becoming detached from the mature spore in the soil. Spores dull, subhyline to pale yellow when examined directly from soil but light yellow and shiny from loss of the outer mucilaginous wall when centrifuged in sucrose; spores globose or subglobose, (55–) 75–90(–100) μm diam or occasionally ellipsoidal or irregular, 100–115 × 66–98 μm; composite spore wall 2.5–5 μm thick, of separable portions distinguishable on broken spores; outer wall mucilaginous, ephemeral, 0.5–3 μm thick; wall two, 2–3 μm thick, inseparable from wall three, 0.5 μm thick; wall four hyaline, 0.5–1 μm, usually attached to wall five; wall five membranous, 0.5–1 μm thick, turning light purple in Melzer's reagent; young spores frequently with detritus but generally absent on mature spores. Walls most obvious on broken and stained spores; walls turning light yellow in lactophenol. Spore contents hyaline to subhyaline. Forming vesicular-arbuscular mycorrhizae.

**Type**: Maintained in pot culture of *P. phaseoloides* (culture no. C-12-1) at CIAT, Cali, Colombia; originally observed and collected from a sward of native grasses in Carimagua. OSC 41496; **Isotypes** FLAS No. F 53674 and FH.

**Etymology**: Latin, *longula* (somewhat distant), referring to the somewhat longer than usual distance of the hypha between the azygosporc and the swollen hyphal terminus.

**Distribution**: Known only from Carimagua, Meta, Colombia.
Fig. 4. *Acaulospora longula*. a. Empty hyphal terminus (T) doubled over the tapering hypha, and a newly formed azygospore (A), ×250. b. Mature azygospores, ×100. c, d. Broken azygospores stained with trypan blue (c), ×250, or unstained (d), ×400; note the multiple walls (W).

Azygospores of *A. longula* are similar to *A. trappei* Ames et Linderman (1976) in size and color, but have a distinctly thicker wall (*A. trappei* = 1.2–3 μm, *A. longula* = 2.5–5 μm) with up to 5 walls compared to a single wall for *A. trappei*. The distance between the swollen hyphal terminus ("mother cell") and the spore is somewhat greater than for other described *Acaulospora* species of this size. Although the azygospore size of *A. longula* overlaps somewhat with *A. morrowae* and *A. mellea*, the deep yellow-brown color of *A. mellea* and the bright yellow color of *A. morrowae* can be distinguished from the dull, subhyaline to pale light-yellow color of *A. longula*.

*Acaulospora mellea* Spain et Schenck, n. sp.

Azygosporae singulæ in solo efformatae; sporæ sessiles, in hypha subbattenuata gestae, cum terminatiónе inflata globosa; sporæ fulvae ad melleas, globosae vel subglobosae (72–)95–105–(126) μm, interdum ellipsoidae vel irregulare. Sporæ tunica e stratis quinque: exteriores pluristatoso, fulvo, 2–6 μm crasso; inseparabili secundo, 0.5 μm, crasso; tertio 0.5–1 μm crasso, hyalino ad alboluteum;
Fig. 5. *Acaulospora mellea*. a. Mature azygospore, ×400. b. Broken spore in lactophenol showing three walls, ×250. c. Young azygospore attached to empty hyphal terminus, ×100. d. Broken azygospore showing five walls (W), ×400. e. Broken azygospore in Melzer's reagent with inner membrane having a positive reaction (light purple), ×400.

quarto et interiore membranaceo, inseparabili, 0.5–1 μm crasso; interiore in iodo subpurpurescenti. Mycorrhizae vesicular-arbusculares formans.

Azygospores formed singly in soil; borne laterally on hyphae tapering to a globose to subglobose swollen hyphal terminus 90–100 μm diam. Hyphal terminus contents white, emptying during spore formation, resulting in a transparent to subhyaline receptacle attached to the azygospore; hyphal terminus remains attached to young spores in water and retains its shape but readily collapses in lactophenol; old spores in soil usually devoid of a hyphal terminus. Azygospores honey-colored to yellow-brown, globose to subglobose, (72–)95–105(–126) μm diam, ellipsoidal or irregular, 96–130 × 78–92 μm, spore wall 4–8(–11) μm thick, usually widest at the point of attachment; wall consisting of 3 separable parts distinguishable on broken spores; the outermost wall, wall one, yellow-brown to dark brown, 2–6 μm thick, laminate, inseparable from wall two, 0.5 μm thick; wall three hyaline to light yellow, membranous, 0.5–1 μm thick; wall four and five membranous, rarely separating; wall four shriveling on breaking, resulting in
a “beaded” appearance, 0.5 μm thick; wall five, 0.5 μm thick turning light purple in Melzer’s reagent. Spore contents yellow, globular to reticulate in appearance. Forming vesicular-arbuscular mycorrhizae.

Specimens examined: Acaulospora mellea was observed from 1) a pot culture of P. phaseolioides (kudzu) at CIAT, 2) from numerous soil and root samples of Coffea arabica L., (coffee) in the state of São Paulo, Brazil, 3) from several soil samples from the state of Minas Gerais, Brazil, and 4) from turf grass soil samples near Gainesville, Florida.

Type: Maintained in pot culture of P. phaseolioides (cultures no. C-15-2) at CIAT, originating from native grasses at Carimagua. OSC 41494; isotypes FLAS No. F 53672 and FH.

Etymology: Latin, mellea (honey-colored), referring to the predominant color of the azygospores under reflected light.

Distribution: Acaulospora mellea is widespread in South America, being first observed and established in pot culture in 1979 in Carimagua by Joyce Spain. In 1980, it was collected in northern Brazil near Belém on Piper nigrum L. by Elizabeth Oliveira. In 1981, it was seen in soil samples from all coffee plantations in a survey of coffee in São Paulo, Brazil by Eli Lopes, Instituto Agronômico, Campinas, S. P., Brazil, and from several soil samples from Minas Gerais, Brazil, taken by Laercio Zambolim, Universidade Federal de Viçosa, Viçosa, M. G. It was noted from turf grass soil samples and from several native plant species in central Florida.

Azygospores of A. mellea are superficially very similar to azygospores of A. laevis Gerd. et Trappe (Gerdemann and Trappe, 1974) in color and appearance, but they are consistently of smaller diam, averaging less than and rarely exceeding the lower limits for the spore diam (119 μm) of A. laevis. Acaulospora laevis has one wall, 2–4 μm thick, and two h. aline membranes, while A. mellea has a two-layered outer wall 4–8 μm thick with three membranous walls (Fig. 5b, d).

Acaulospora morrowae Spain et Schenck, n. sp.

Figs. 6, 9

Azygospores singulare in solo efformatae; sporae lateraliter gestae in hypha 10–14 μm diam, cum terminacione inflata globosa (58–94 μm diam); hypha interjacens spora et terminationis 100–160 μm long. Azygospores alboluteae, globulis contentis, globosae vel subglobosae, 63–92(–120) μm diam, interdum lacrimoidea ad irregularis. Sporae tunica (2–4 μm crassa) e stratis quinque: exteriore hyalino, 0.5–1 μm crasso; secundo alboluteo, 1.5–3 μm crasso, inseparabili et tertio, 0.5 μm crasso; quarto et quinque membranaceo, 0.5–1 μm crasso; quinque ido atropurpurescens. Mycorrhizae vesicular-arbusculares formans.

Azygospores formed singly in the soil, borne laterally on hyphae ending in a globose hyphal terminus (58–79(–94) μm diam with walls 0.5–1 μm thick; hyphae at the point of spore attachment 10–12 μm wide and at the hyphal terminus 10–14 μm wide; hyphal terminus contents subhyaline to white; distance between the hyphal terminus and the developing azygospore 100–160 μm; terminus contents emptying to form the spore, leaving a hyaline, thin-walled, empty terminus that readily collapses and detaches from the spore; spores rarely found with an attached terminus. Young azygospores with light yellow walls and white contents, becoming light yellow with globular, transparent contents in reflected light. Spores predominantly globose or subglobose, (63–79–92(–120) μm diam, but also lacrimoid to irregular, 86–100 × 64–96 μm diam; spore wall 2–4(–6) μm thick consisting of several wall layers, readily apparent on broken spores; outer wall 0.5–1 μm thick, hyaline in water, adhering to wall two but swelling in lactophenol, separating and sometimes with adhering debris; wall two light yellow to yellow, 1.5–3 μm thick; wall three brittle, hyaline, 0.5 μm thick; wall four membranous, 0.5 μm thick, usually adhering to wall five; wall five membranous, 0.5 μm thick, staining dark maroon in Melzer’s reagent. Forming vesicular-arbuscular mycorrhizae.

Type: Maintained in pot culture on P. phaseolioides (culture no. C-14) at CIAT, but originally collected from a sward of native grasses at Carimagua. OSC 41493; isotypes FLAS No. F 53671 and FH.
Fig. 6. *Acaulospora morrowae*. a. Newly formed azygospore attached to hypha and collapsed hyphal terminus, ×100. b. Mature azygospore with adhering detritus, ×250. c. Broken azygospore in Melzer's reagent showing multiple spore walls and the strong positive reaction of the inner membranous wall (dark purple), ×400. d. Broken azygospore in lactophenol showing multiple spore walls (W), ×250.

**Etymology:** Named in honor of Dr. Marie B. Morrow, for many years mycologist at the University of Texas, Austin, Texas and former professor of Joyce L. Spain.

**Distribution:** Known only from Carimagua.

*Acaulospora morrowae* is a small-spored species that overlaps the spore diam of *A. mellea*, *A. longula*, and *A. trappei*, but can be separated from these species by its bright yellow color and multiple walls. Azygospores of *A. mellea* have a deeper yellow color, yellow-brown walls, and usually a slightly greater diam than *A. morrowae*. *Acaulospora longula* has dull, subhyaline to pale yellow spores and usually with considerable distance separating the hyphal terminus and the azygospore. Azygospores of *A. morrowae* are bright yellow and appear to “sparkle” in reflected light and rarely have an attached hyphal terminus. Spores of *A. trappei* have a single hyaline wall and the azygospore is in close proximity to the terminus.

**Entrophospora colombiana** Spain et Schenck, n. sp.

Azygosporae singulac in solo vel raro radicibus efformatae; sporae intra hypham subattenuatum gestae, cum terminatone inflata globosa, 50–125 μm diam; tunica terminationis, 1.5–3 μm crassa, immunda adherens. Azygosporae primo subhyalinae deinde cum luteolo ad auream, globosae 100–115 μm diam; hypha interjacens spora et terminationis 50–125 μm long. Sporae tunica e stratis quinque: exteriore hyalino, caduco, 0.5–2 μm crasso, inseparabilia et tunicae secundae; secundo fulvo ad au-
Fig. 7. *Entrophospora colombiana*. a. Dumbbell configuration of a newly-formed azygospore and hyphal terminus, ×100. b. Azygospore and attached empty hyphal terminus, ×100. c. Collapsed hyphal terminus remaining attached to mature azygospore, ×100. d. Broken azygospore showing multiple walls (W), ×250.

reobrunec, 2–3 μm crasso, laminato; tertio hyalino 1 μm crasso; quatuor membranaceo, 0.5 μm crasso, globulino; interiore membranaceo, hyalino, 1 μm crasso, iodo atro purpureascens. Mycorrhizae vesicular-arbusculares formans.

Azygospores produced singly in soil and occasionally in roots; spores developing within a slightly tapering hypha, 20–30 μm diam, terminating in a globose to subglobose swollen tip, (50–)70(–125) μm diam; wall of swollen hyphal terminus 1.5–3 μm thick and with detritus frequently attached; hyphal terminus white to subhyaline, becoming transparent as contents empty to form a spore. Azygospores at first subhyaline to white becoming pale yellow to light golden brown at maturity, (75–)100–115(–135) μm diam; interconnecting hypha between the azygospore and the swollen hyphal terminus 50–125 μm long in water, shrinking considerably in lactophenol; azygospore, interconnecting hypha, and swollen hyphal terminus having a dumbbell-shaped configuration. Azygospore composite wall 3–7 μm thick consisting of 2–3 separable walls; the outer spore wall confluent with the wall of the hyphal stalk, hyaline, ephemeral, 0.5–2 μm thick, firmly adhered to wall two and found only on newly-formed spores; wall two yellow-brown to golden-brown in color, 2–3 μm thick, with laminae; wall three hyaline, 1 μm thick, separating from other walls on broken spores; wall four membranous, having a “beaded” appearance, 0.5 μm thick, hyaline, tightly wrinkled when broken; wall five membranous, 1 μm thick, hyaline, turning dark purple in Melzer’s reagent. Contents of the azygospore yellow, granular or reticulate. Azygospores often becoming detached from the empty hyphal terminus in soil; site of the connecting hyphal attachment from the hyphal terminus occasionally visible on the mature azygospores, ca. 25 μm diam. Forming typical vesicular-arbuscular mycorrhizae.

Type: Maintained in pot culture of *P. phaseoloides* (culture no. C-10) at CIAT. Originally observed and collected from cassava roots and native grasses in Carimagua. OSC 41497; *ISOTYPES* FLAS No. F 58675 and FH.
ETYMOLOGY: colombiana, referring to the country in which this species was first observed in 1978.

DISTRIBUTION: In addition to the collections of E. colombiana from Colombia, this species has also been observed by the senior author from central Florida and by J. B. Morton in five locations in West Virginia, frequently associated with broomedge (Andropogon sp.). Spores of a West Virginia isolate were 104–122 μm diam, light yellow, with the composite wall 5–8 μm thick.

Entrophosphora colombiana is easily separated from the only other species in this genus, E. infrequens Ames et Schneider (1979), by its somewhat smaller spore diam, its multiple layered wall, and its lack of a wall having vacuolated spines. However, azygospores of E. colombiana could be confused with similar-sized azygospores of Acaulospora species if the hyphal terminus were detached. This would be especially true of A. morrowae and A. mellea which have yellow azygospores with multiple walls.

Glomus manihotis Howeler, Sieverding et Schenck, n. sp. 

Chlamydospores singulæ vel gregatim in solo et abundanter intra radices efformatae. Sperae globose vel subglobosae, 145–235(–450) μm diam; tunicæ spororum 7–16(–40) μm crassa; tunicæ exterior rigida, hyalina ad alboluteam 10–15 μm crassa; tunicæ interior fulva ad auream, 0.5–2 μm crassa; contentae spororum primo albae deinde lutescens. Hyphae subtendentes 18–30 μm diam, tunicæ 7–16 μm crassa. Mycorrhizae vesicular-arbusculares formans.

Chlamydomspores formed singly or in loose clusters in soil and abundantly in plant roots; spores globose, subglobose, (145–)170–235(–450) μm diam, ellipsoid, obovate, or occasionally irregular, 125–236 μm. Composite spore wall (7–)10–16(–40) μm, consisting of an outer thick, rigid, sometimes laminate wall, hyaline, subhyaline to light yellow, 10–16 μm, and an inner pliable wall, yellow to yellow-brown, 0.5–2 μm, consisting of two or more inseparable layers of approximately equal thickness being thickest (up to 8 μm) near the hyphal attachment; a subhyaline, mucilaginous, outer layer is associated with some spores being 2–5 μm thick. Spore contents white, becoming yellow to dark yellow with age, outer and inner walls separating occasionally in broken spores, spore contents separated from the hyphal contents by a narrow pore and septum which occasionally protrudes into the pore; on older spores the pore may be occluded by the spore walls. Hyphal attachment hyaline to subhyaline, 18–30 μm wide, with thick walls, 7–16 μm, near the point of attachment; walls of the hyphal attachment abruptly tapering to 2–3 μm thick a short distance from the spore; hyphal attachment frequently detached from the spores in the soil. Forming vesicular-arbuscular mycorrhizae.

TYPE: Maintained in pot culture on P. phaseoloides (culture no. C-1-1) at CIAT. Originally obtained from cassava roots from Santander de Quilichao, Cauca, Colombia in 1979. OSC 41498; ISOTYPES FLAS No. F 535676 and FH; PARATYPE: collected by Diane Doud Miller and deposited at OSC.

ETYMOLOGY: Latin, manihotis, referring to the host, Manihot esculenta Crantz, from which this species was first obtained and with which it is frequently associated in the field.

DISTRIBUTION: Known from several locations in Colombia, from Quilichao, Cauca, associated with Manihot esculenta; from Carimagua on native grasses; from Media Luna, Magdalena, on native pasture grasses and from Puerto Gaitan, Meta on Andropogon gayanus Kunth. Forming mycorrhizae on greenhouse pot cultures of P. phaseoloides, M. esculenta, and Paspalum notatum.

A spore sample from a pot culture of apple (Malus pumila Mill.) from Diane Doud Miller, Iowa State University, Ames, Iowa, was examined and determined to be G. manihotis. This isolate was originally collected from M. pumila growing in Tilsit soil at the University of Kentucky Horticultural Research Farm in Princeton, Kentucky, in August, 1980, by Diane Doud Miller. The isolate formed VA mycorrhizal associations in pot culture with M. pumila, Sorghum vulgare Pers.,
and *Coleus × hybridus*. Spore characteristics of this isolate did not differ significantly from the Colombian isolates.

*Glomus manihotis* is similar to *G. clarum* Nicolson et Schenck (1979) and to *G. halonatum* Rose et Trappe (1980) in having a wide, hyaline outer wall providing
Fig. 9. Murographs of six new species of Endogonaceae. Arabic numerals indicate each wall in order from outer to inner wall; alphabetical letters indicate wall groups that are usually separable on broken spores; * = walls very difficult to discern; O = wall surface ornamented. More than one murograph for a single species indicates that more than one type of wall composition can be observed; wall observations made on broken spores in lactophenol.
a "halo" appearance around the spore. Like *G. clarum*, *G. manihotis* is formed in the roots, but unlike *G. clarum* the inner wall and the spore contents are distinctly yellow, the outer wall is somewhat narrower, and the hyphal attachment is readily detached in soil. *Glomus manihotis* differs from *G. halonatum* in forming its spores readily in the roots of plants, in having a smaller spore diam, and an inner wall that is thin (inner wall of *G. manihotis* = 0.5–2 µm thick, *G. halonatum* = 10–15 µm thick). Other *Glomus* species forming spores readily in roots, *G. fasciculatum* (Thaxter sensu Gerdemann) Gerd. et Trappe (1974) and *G. intraradices* Schenck et Smith (1982), lack a thick outer wall and have a smaller spore diam than *G. manihotis*.

**MUROGRAPHS**

A detailed enumeration of the spore walls for each species described herein is presented diagramatically in Fig. 9. The concept for presenting wall structures in this fashion was recently proposed by Walker (1983), and the term murograph was applied to this form of wall presentation. The wall units (arabic numerals) are in approximate scale size to each other. It is rarely possible to differentiate all the walls shown in a murograph, particularly those that are more complex, by examining only a few intact and broken spores. In most cases, many spores must be examined and then a composite wall can be conceptually deduced from these observations. The murograph potentially aids in distinguishing species of VA mycorrhizal fungi, for which there are few distinguishing characteristics in many instances.

**KEY TO ACAULOSPORA SPECIES**

1. Spore wall surface smooth (or only minutely roughened) ........................................... 2
1. Spore wall surface roughened with spines, tubercles, ridges, folds, pits or cracks ........ 6
   2. Spore diameter usually over 125 µm; walls yellow-brown to red-brown .......... *A. laevis* 3
   2. Spore diameter usually less than 125 µm .............................................................. 3
3. Spore hyaline to subhyaline when mature; wall single, less than 2.5 µm thick .......... *A. trappet*
3. Spore subhyaline to some shade of yellow when mature; wall of several layers .......... 4
   4. Mature spore wall yellow-brown to brown; outer wall 2–6 µm thick (average 4 µm) .... *A. mellea* 5
   4. Mature spore wall subhyaline to yellow; outer wall 0.5–3 µm thick ......................... 5
5. Spore bright yellow in reflected light; inner membranous wall dark red-purple in Melzer's reagent ....................................................... *A. morrowae* 6
5. Spore subhyaline to dull yellow in reflected light; inner membranous wall light purple in Melzer's reagent ................................................................. *A. longula* 7
   6. Spore wall surface with fine spines or tubercles .................................................. 7
   6. Spore wall surface with ridges, folds, pits or cracks ........................................... 9
7. Spore surface with tubercles, 0.7–1.5 µm tall; mature spores yellow-brown to honey-brown, 255–340 µm diam ................................................................. *A. tuberculata* 8
7. Spore surface with spines ......................................................... 8
   8. Spines overlaid with a reticulate pattern; spores olive-brown to red-brown, 140–285 × 145–330 µm ................................................................. *A. elegans* 10
   8. Spines in swirled patterns; spores yellow-brown to red-brown, 100–355 µm diam *A. spinosa* 10
9. Spore surface with ridges or folds ........................................................................... 10
9. Spore surface with depressions (pits) or cracks ..................................................... 11
   10. Spore surface with ridges in a reticulate pattern; 150–155 µm diam ........ *A. bireticulata* 11
10. Spore surface when mature with folds; inner wall with an alveolate reticulum, spores 200–250 µm diam ................................................................. *A. gerdemanneri* 11
11. Spore surface with cracks, usually with a pedicle attached; spores 170–390 µm diam ................................................................. *A. appendicula* 12
11. Spore surface with pits or depressions ................................................................. 12
12. Pits narrow, 1–3 µm diam; spore diam 100–240 µm ........................................ *A. scrobiculata* 12
12. Pits wide, 4–16 µm diam; spore diam 185–350(–480) µm .................................... *A. foveata* 12
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LITERATURE CITED


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