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GIGASPORA RAMISPOROPHORA: A NEW SPECIES WITH NOVEL SPOROPHORES FROM BRAZIL

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ABSTRACT

Gigaspora ramisporophora develops sporophores (term suggested for the spore bearing structure in the Endogonaceae) with morphological variation from other described species in the genus. The sporophore may be simple, having a single sporogenous cell (term recommended to replace suspensor-like cell), or branched, forming multiple (2-3) sporogenous cells. A protrusion on a sporogenous cell may give rise to a branch with a spore. The spore is characterized by a hyaline to sub-hyaline wall over two pigmented walls. The middle wall is laminate. Germ tubes emerge from the germinal wall (term introduced to describe a wall distinctive in both texture and function) and directly penetrate the outer walls.

SUMÁRIO

Gigaspora ramisporophora desenvolve esporóforos (termo sugerido para estruturas que sustentam o esporo nas Endogoneceae) com características morfológicas que variam de outras espécies descritas no gênero O esporóforo pode ser simples, tendo uma única célula esporogênica

(termo recomendado para substituir célula de sustentação), ou ramificado, formando células esporogênicas múltiplas (2-3). Uma protuberância na célula esporogênica pode desenvolver uma ramificação com um esporo. O esporo é caracterizado pela presença de uma parede hialina a sub-hialina sobre duas paredes pigmentadas. A parede mediana é laminada. Tubos de germinação emergem da parede germinal (termo introduzido para descrever uma parede distinta em textura e função) e penetram directamente nas paredes externas.

INTRODUCTION

Spores of an undescribed species of Gigaspora were recovered by wet sieving soil and root samples from plots of Pueraria phaseoloides. The golden yellow to yellowish-brown spores varied greatly in size and some were borne on branched sporophores. The novel features of the sporophore are described in this paper. The suggested terms "sporophore", used in the Endogonaceae by Tandy (1975) and Ferrer and Herrera (1980), and "sporogenous cell are discussed. The spore wall description follows the terminology of Walker (1983) with the exception of "germinal wall".

GIGASPORA RAMISPOROPHORA Spain, Sieverding et Schenck sp. nov. Figures 1-4

Spora formatur plerumque in apice cellulae sporogenae. Sporae lutae vel fulvae, globosae, (96-)200-450(-567) µm diam. vel subglobosae, (143-)150-400 X 200-450(501) µm diam. Totus paries sporae 9-31 µm crassus, constans ex stratis tribus: stratum exterior 1.4-4.0(-5.7) µm tenue; medianum lamellatum, 4-28 µm crassum; interior 1.3-2.6 µm tenue cum papillis, adhaesum ad stratum secundum vel separatum in regione quo spora germinat. Sporophori plerumque singulari vel bipartiti vel tripartiti ramosi. Sporophori cum cellula inflata terminant; cellula inflata quae cellula sporogena est, (32-)40-60(-72) µm lata et (50-)60-80(-83) µm longa; unae rare duae cellulae inflatae sub cellula sporogena. Sporophori novi non rare ex cellula sporogena progerminant. Cellulae auxiliares usque ad 20 in fasiculo humi vel in cortice radiciarum vel in stercore herbarum formantur. Cellulae auxiliares primo leves deinde cum projectionibus digitoidis, usque ad 10 µm longae. Spora directe per parietem germinans. Endomycorrhizam cum arbusculis in radicibus.

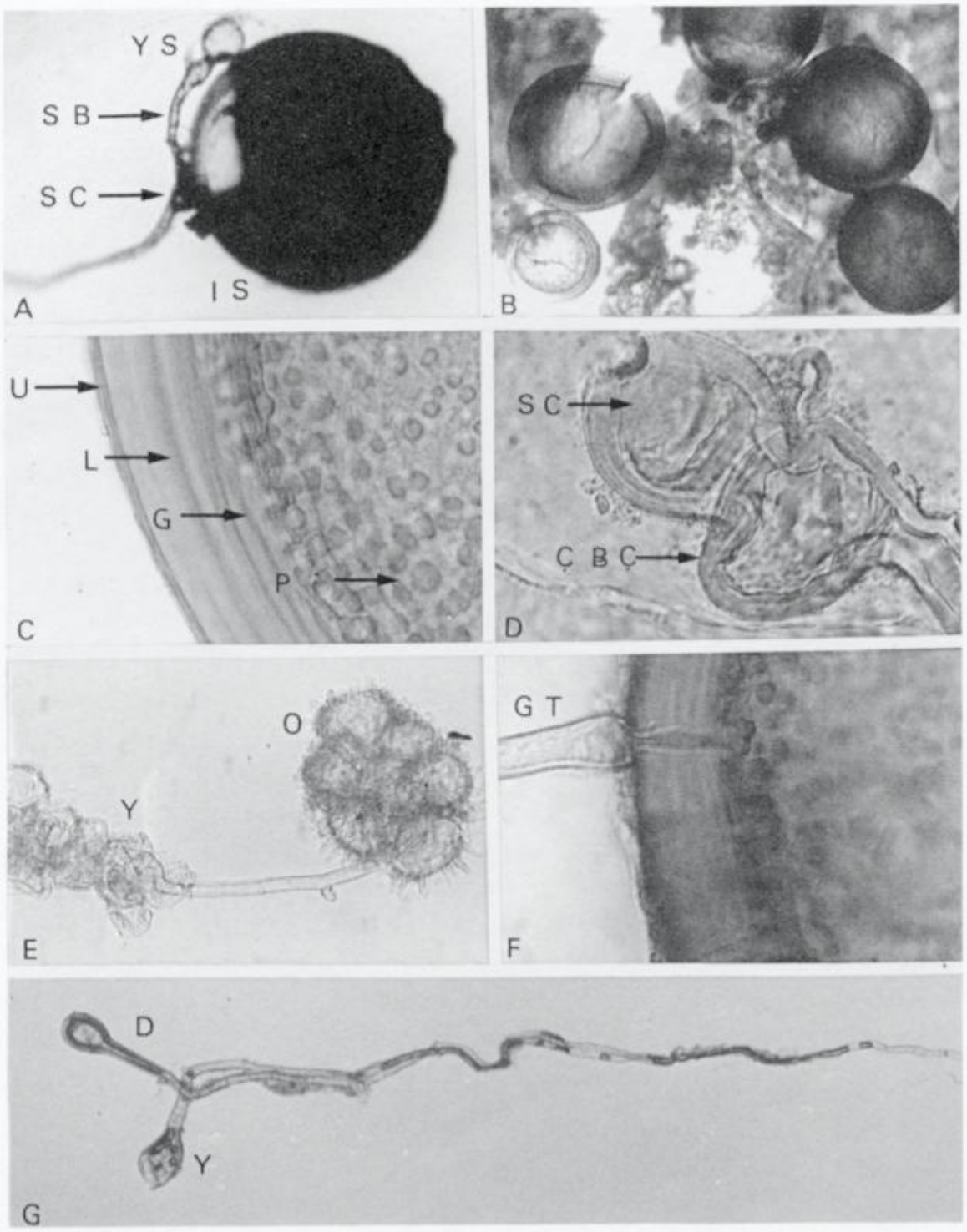

Figure 1. Gigaspora ramisporophora. A. Young spore (YS) on sporophore branch (SB) emanating from sporogenous cell (SC) attached to immature spore (IS) 160X. B. Colonized organic matter 63X C. Spore walls: unit (U); laminated (L); germinal (G) with papillae (P) 400X. D. Sporogenous cell (SC) with contiguous bulbous cell (CBC) 400X. E. Auxiliary cells: ornamented (O); young (Y) 400X. F. Germ tube (GT) 400X. G. Branched sporophore with two sporogenous cells: young (Y); detached from spore (D) 250X.

SPORE, usually formed at apex of bulbous sporogenous cell, smooth, golden yellow to yellowish-brown, globose, (96-)200-450(567) µm to sub-globose, (143-)150-400 X 200-450(-501) µm; total wall thickness 9-31 µm.

SPORE WALL STRUCTURE (Figs. 1-C, 4) of three walls in a single group. Spores measured in water or fixed in FAA and mounted in lactophenol. Wall 1, unit wall, hyaline to sub-hyaline, brittle, 1.4-4.0(-5.7) µm thick, continuous with outer wall of sporogenous cell and usually adherent to wall 2; wall 2 laminate, yellow to yellowish-brown, 4.0-28 µm thick, adherent to wall 3; outer part of wall 2 continuous with middle wall of sporogenous cell; wall 3, germinal wall, yellow to yellowish-brown, 1.3-2.6 µm thick excluding papillae, 1.4-8.3 µm diam. and up to 5.6 µm high, which develop prior to germination. Walls 2 and 3 are reactive to Melzer's reagent turning reddish-purple. Spore contents finely granular.

BULBOUS SPOROGENOUS CELL (Fig. 2), apical or sub-apical cell of sporophore, (32-)40-60(-72) X (50-)60-83 µm usually with three walls totalling 6-11(-14) µm thick: outer wall hyaline; laminate middle wall and innermost wall brown. Wall thickness variable, usually greater at spore initial site. Sporogenous cells may develop a branch (sporogenous cell with connecting hypha) which gives rise to another spore (Fig. 1-A). The sporogenous cell may have thick-walled, 3-4 µm, hyphal protrusions (pegs), 8-10 µm diam. A thin-walled hypha, 0.7-3 µm, with 6-8 µm diam., may extend from a thick-walled protrusion or develop directly from the sporogenous cell wall.

SPOROPHORE (Figs. 1-G, 3) light brown, simple or branched with 1-3 sporogenous cells, formed of specialized septate hypha, 9.3-13.9 µm diam., wall 1.4-2.8 µm thick (excluding bulbous cell measurements); distance between septae variable but septation more frequent near sporogenous cell. One or rarely two bulbous cells, some with hyphal protrusions, may be contiguous with apical sporogenous cell (Figs. 1-D, 2 I-L).

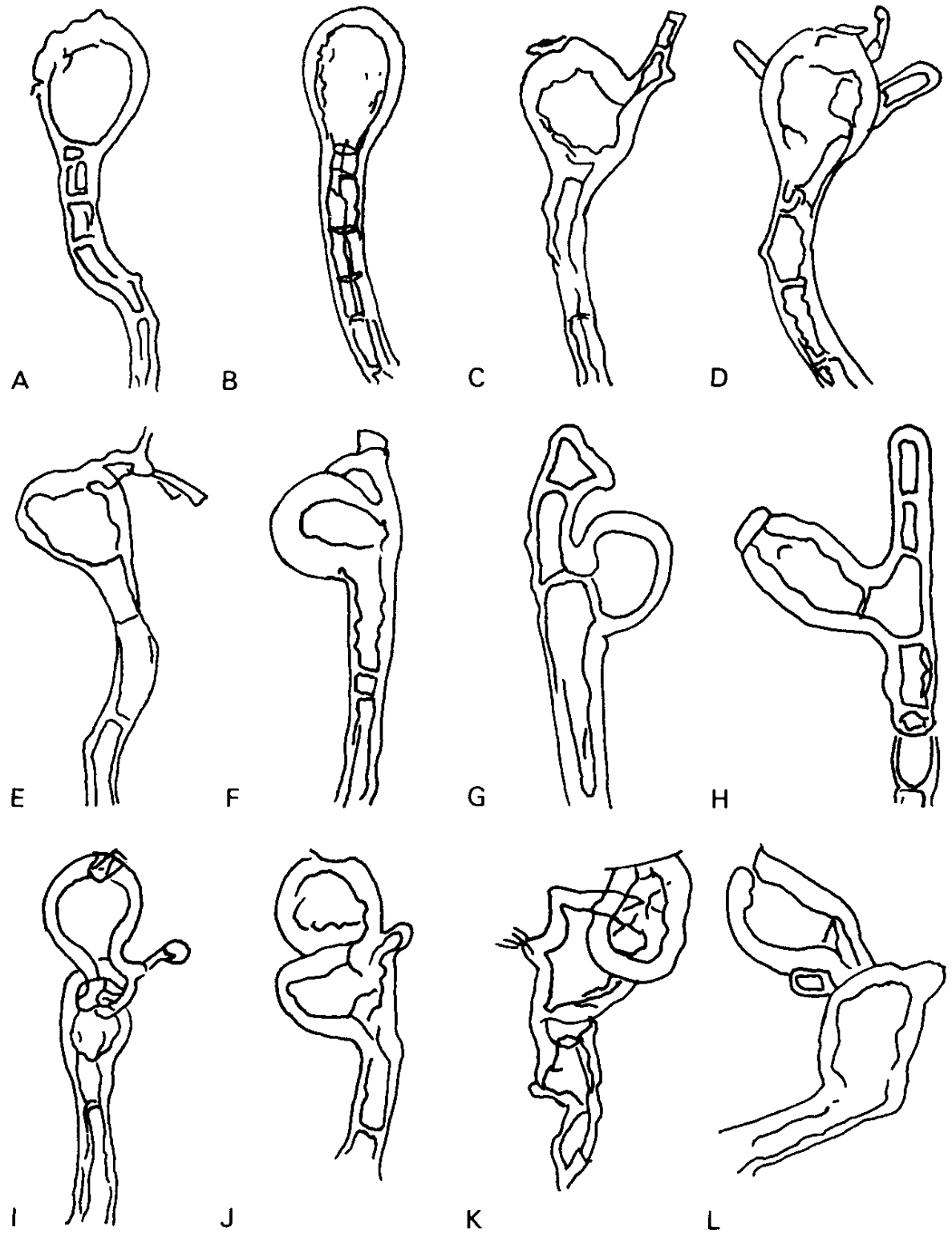

Figure 2. Sporogenous cells of Gigasporophora ramisporophora: A-F) apical sporogenous cells; C-F) sporogenous cells with thick hyphal protrusions (pegs) or slender hyphae; G-H) sub-apical sporogenous cells; I-L) sporogenous cells with contiguous bulbous cells. Camera lucida drawings.

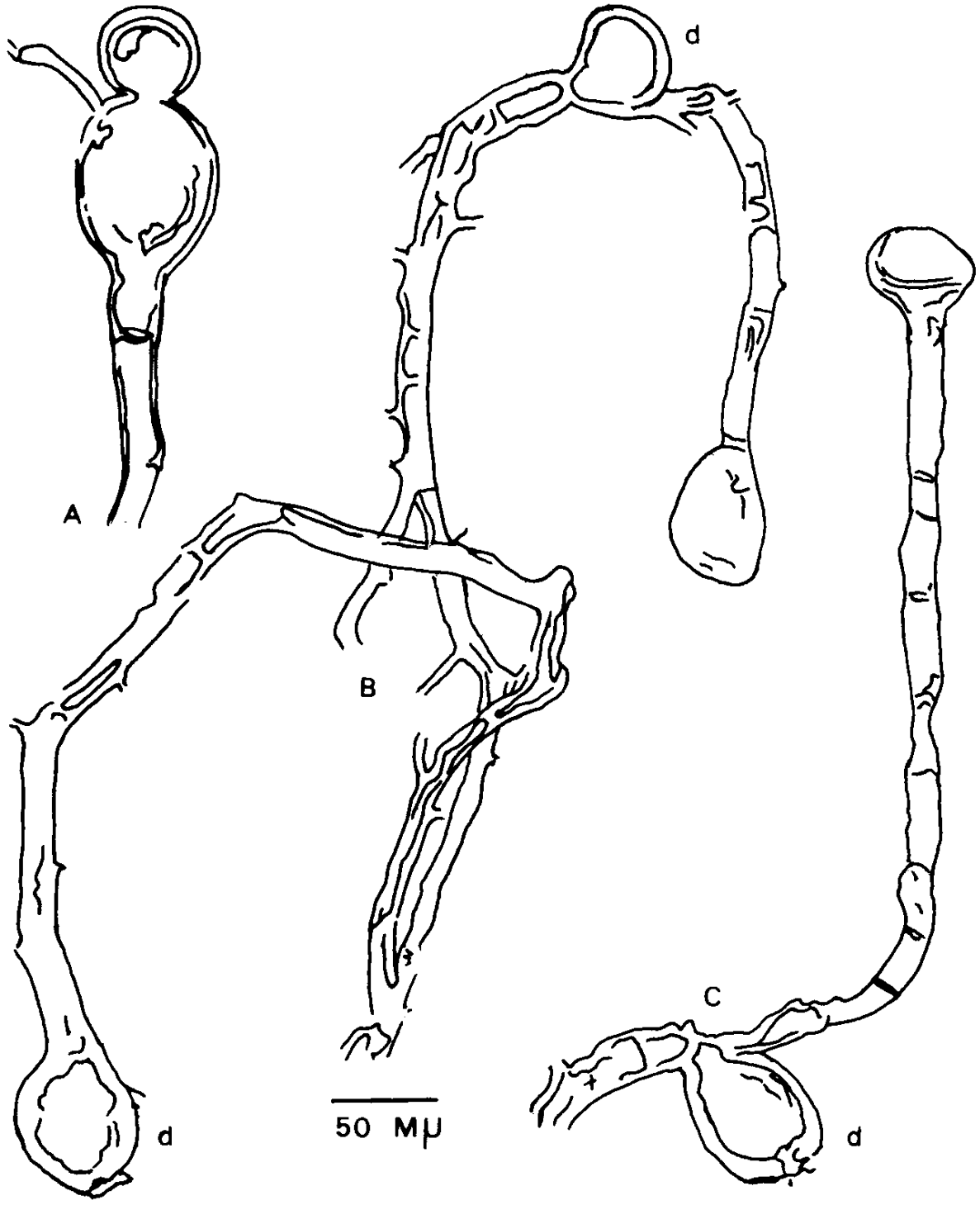

Figure 3. Sporophores of Gigaspora ramisporophora: A) young spore forming from sporogenous cell on simple sporophore; B) branched sporophore with three sporogenous cells, two with spores detached (d); C) branched sporophore with two sporogenous cells, one with spore detached (d). Camera lucida drawings.

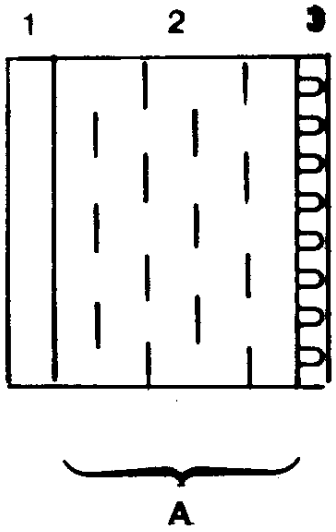

Figure 4. Murograph: Gigaspora ramisporophora. One group, A; three walls: unit, laminated & germinal.

AUXILIARY CELLS (Fig. 1-E) tan, round to clavate, 24-41 µm diam.; smooth initially becoming ornamented with digitate projections (rarely bifurcate) up to 10 µm high; borne in clusters of less than 20 on coiled hyphae, 6-8 µm diam., with thin walls, 0.5-1.3 µm; coils develop on short hyphal stalks or along the coenocytic hyphae. Auxiliary cells found in the mineral soil, decomposing organic matter and in the cortex of roots.

DIRECT GERMINATION (Fig.1-F): one to several germ tubes (1-8; $\bar{x}$ 4) emerge from the germinal wall where the papillae are largest. The germ tube within the spore wall is 5.6-9.7 µm diam. and at egress 14-17(-22) µm diam.

ENDOMYCORRHIZAE formed with arbuscules.

TYPE obtained from a pot culture with Sorghum halipense, previously seeded with P. phaseoloides Benth, culture CP 75, at the Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brasil. Holotype FLAS; Isotypes OSC, GOET and IBt.

ETYMOLOGY: Latin, rami (branch), referring to the sporophore configuration.

DISTRIBUTION, HABITAT AND MYCORRHIZAL ASSOCIATIONS: Gigaspora ramisporophora is known from a single site in southern Bahia. Spores associated with P. phaseoloides were collected

from a CEPEC forage seed production field 2 km east of Itapebi. Decomposing plant residues were frequently colonized and abundant spore production occurred. Chemical analysis of surface soil: pH 6.3; P 4 mg/kg soil; exch. Al 0.0; Ca 5.7, Mg 1.3, K 0.26 meq/100g soil. Pot cultures were established in CEPEC, Itabuna, Bahia; the fungus formed a symbiosis with P. phaseoloides and S. halipense producing arbuscules and auxiliary cells in roots and auxiliary cells and spores in decomposing organic matter and mineral soil.

DISCUSSION

Gigaspora ramisporophora spores closely resemble yellow spores of G. decipiens, however, spores of the latter species can also be colorless, pale greenish-yellow or light brown at germination. Total wall thickness parameters overlap but the wall configurations are distinct. G. ramisporophora spores have an outer unit wall, a laminated middle wall and an inner germinal wall; Hall & Abbott (1984) describe a spore wall which changes as the spores age; older spores of G. decipiens have two laminated walls (the outer wall being replaced by 2-3 laminations) over the germinal wall. The refringency of the germinal wall differs from the adhering laminated wall in both species. Large papillae are more numerous and more widely distributed on the germinal wall of G. ramisporophora; germ tubes develop in the area where the papillae are largest, near the sporogenous cell or elsewhere. Germ tubes of G. decipiens emerge near the sporogenous cell usually from clusters of large papillae. Although small papillae may be generalized in both spores they are more often widespread on the germinal wall of G. ramisporophora and confined to the area around the sporogenous cell of G. decipiens. The germinal wall of both species adheres tightly to the middle laminated wall, however, the papillose area can wrinkle when spores are mounted in lactophenol. The sporophore of G. ramisporophora may be simple with a single sporogenous cell or branched having

2-3 sporogenous cells. Branched sporophores have not been reported for other species in the genus.

Dr. R.E. Koske (pers. comm.) interprets wall 3 as the innermost layer of laminated wall 2. We think the germinal wall is a separate wall. This wall was first described by Sward (1981a, b, c) studying the spore wall structure of G. margarita Becker & Hall. The germinal wall (Fig. 4) is represented by a depiction of papillae which form on the inside prior to germination.

One or rarely two bulbous cells contiguous with an apical sporogenous cell are sometimes present on sporophores of G. ramisporophora (Figs.1-D, 2 I-L). Similar structures have been observed on sporophores of Scutellospora pellucida (Nicol. & Schenck) Walker & Sanders, S. heterogama (Nicol. & Gerd.) Walker & Sanders and an undescribed Scutellospora species. Nicolson and Gerdemann (1968) may have reported the same anomaly when they noted that Endogone heterogama (S. heterogama) had "usually one, occasionally two, bulbous suspensors 21-26 µm diam. with a slender hypha extending from the suspensor to the base of the spore...".

Our findings suggest that thick hyphal protrusions, and perhaps the slender hyphae, extending from the sporogenous cells of Gigaspora and Scutellospora species, once thought to be antheridium-like (Gerdemann, 1955) or small suspensors (Nicolson and Gerdemann, 1968) may be vestigal sporophore branches. A branch (sporogenous cell and connecting hypha) emanating from an apical, bulbous sporogenous cell has been a frequent finding in G. ramisporophora; three observations have been made by the senior author of immature spores forming on these branches (Fig. 1-A).

The colonization of decomposing plant residues by G. ramisporophora (Fig. 1-B) results in abundant spore production. This phenomenon has also been observed with some other Gigaspora and Scutellospora species. Ferrer and Herrera (1980) reported finding S. heterogama spores inside seed

coats and Arvantes and Taber (1985) reported abundant Gigaspora spores in weed seeds.

TERMINOLOGY

Becker and Hall (1976) use the term "subtending hypha" for the connecting hypha and the structure variously referred to as a bulbous swelling (Gerdemann, 1955), a suspensor (Nicolson and Gerdemann, 1968), an attachment of a bulbous nature interpreted as a suspensor (Old et al., 1973), a suspensor-like cell (Gerdemann and Trappe, 1974) and bulbous and hyphal suspensor-like cells (Brown and King, 1982). Prior to spore formation "subtending hypha" would be a misnomer; another term is needed. Ferrer and Herrera (1980), describing spores in the genus Gigaspora, apparently limit the term "sporophore" to the "sporogenous cell", however, it can be interpreted broadly (Snell and Dick, 1971; Hawksworth et al., 1983) and is the term suggested for the spore bearing hypha(e) in the Endogonaceae. Tandy (1975) used the term for a Glomus species. The term "sporogenous cell" (spore-producing cell(s) of the sporophore) recognizes the specialized function of the cell.

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