

SPECIES OF *GIGASPORA* AND *SCUTELLOSPORA* (ENDOGONACEAE) IN TAIWAN

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[Abstract] Soil samples collected from coastal windbreak plantations, nurseries and other forest plantations (or stands) in Taiwan were examined for the distribution of *Gigaspora* and *Scutellospora* of Endogonaceae. Three species of *Gigaspora* and six species of *Scutellospora* are discovered; namely *Gigaspora alboaurantiaca* sp. nov., * *G. decipiens* Hall & Abbott, *G. gigantea* Gerd. & Trapp, *Scutellospora calospora*, * *S. coralloidea*, * *S. erythropha*, *S. gregaria*, *S. nigra*, *S. pellucida* (Walker & Sanders comb. nov.). Among them three species (with * mark) are previously unreported from Taiwan, and one species is treated as a new species (*G. alboaurantiaca*). These species were examined by light microscope or scanning electron microscopy and were illustrated or redescribed.

Key words: VA mycorrhizae, *Gigaspora*, *Scutellospora*.

台灣内生菌科 *Gigaspora* 屬及 *Scutellospora* 屬 之調查

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【摘要】在海岸防風林，造林地及苗圃之樹種根域調查中，共發現 *G. alboaurantiaca* sp. nov., *G. gigantea* Gerd. & Trappe, * *G. decipiens* Hall & Abbott 等 3 種 *Gigaspora* 屬與 *S. calospora*, * *S. coralloide*, * *S. erythropha*, *S. gregaria*, *S. nigra*, *S. pellucida* (Walker & Sanders comb. nov.) 等 6 種 *Scutellospora* 屬内生菌科孢子，其中有星號(*)者係台灣新記錄種共三種，而 *G. alboaurantiaca* 則為一新種；本報告中將這些内生菌科孢子以光學顯微鏡及掃描式電子顯微鏡進行微細構造觀察之結果以圖文說明。

INTRODUCTION

The genus *Gigaspora* Gerd. & Trappe was erected to contain fungi in the Endogonaceae which form arbuscular mycorrhizae and produce large spore on a bulbous suspensor-like cell^(3,17). Observations by Walker and Slanders⁽¹⁸⁾ suggested that there are two distinctive groups within the genus of *Gigaspora* sensu Gerd. & Trappe. They, hence, further proposed to assign each of the group into a different genus, *Gigaspora* sensu Walker & Slanders and *Scutellospora* gen. nov.. Spores of *Gigaspora* have only a single wall group; they germinate by production of one or more germ tubes produced directly through the spore wall near the attachment of suspensor cell. Spores of *Scutellospora* have at least two wall groups and they germinate by means of one or more germ tubes produced from a germination shield formed upon or within a flexible inner wall.

The investigation of the genera *Gigaspora* and *Scutellospora* in Taiwan started in 1980's and so far only five species, *G. gigantea*, *S. calospora*, *S. gregaria*, *S. nigra*, *S. pellucida* were reported^(6,7,19,20,21). The purpose of this study was to identify the fungal species of *Gigaspora* and *Scutellospora* associated with coastal windbreak plantations of *Casuarina equisetifolia* and some silvicultural tree species in Taiwan.

MATERIALS AND METHODS

Soil samples of coastal windbreak plantations, nurseries and forest plantations were carefully collected from the rhizosphere of each tree to a depth of 30 cm, they were, then, kept under 4 °C in the laboratory for later treatment.

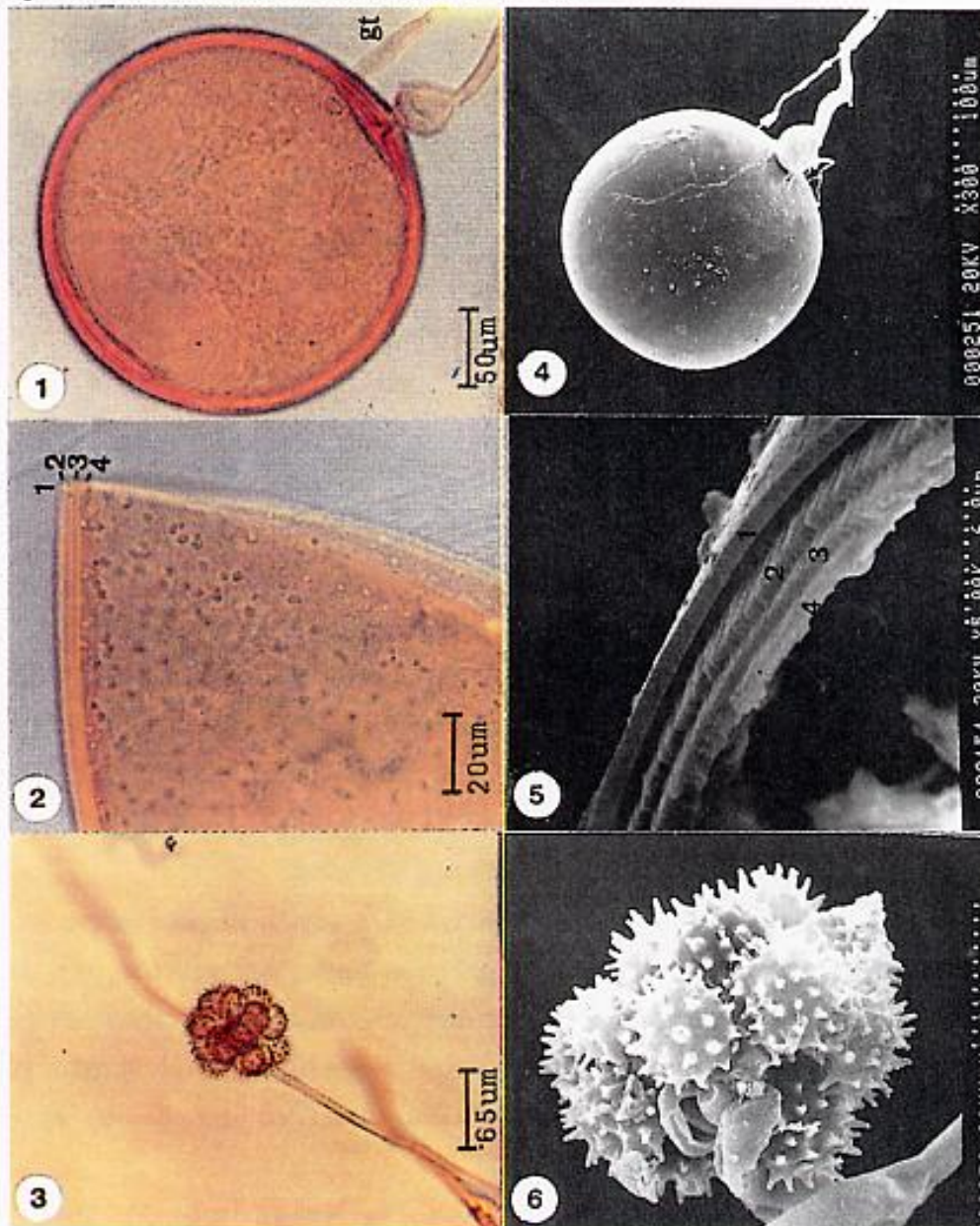
Spores were isolated from soil samples using the wet sieving-decanting technique or sucrose-density gradient centrifugation method^(2,8). Spore specimens were mounted on slides in a PVL^(4,9). They were keyed and identified according to Hall⁽⁴⁾, Trappe⁽¹⁷⁾ and Schenck & Perez⁽¹⁴⁾. Some spores of each species were surface-sterilized by immersing in 2% chlomatin T plus 2 ppm streptomycin for 10 min followed by four washes with sterile distilled water and stored at 4 °C until needed⁽¹⁶⁾.

Zea mays, *Sorghum vulgare*, *Leucaena leucocephala* or *Taiwania cryptomerioides* were selected as host plants for inoculation test. They were inoculated by transferring single or 30-50 surface-sterilized spores. Pot culture were maintained in greenhouse for 12-16 weeks (*Z. mays* and *S. vulgare*) or more than one year (*L. leucocephala* and *T. cryptomerioides*). Root systems of host plants were examined for sporulation. Spores were further prepared for scanning electron microscopy and light microscopy observations.

RESULTS AND DISCUSSION

During the examination of samples collected from coastal windbreak plantations one species of *Gigaspora* and four species of *Scutellospora* were discovered. Species discovered from nursery and forest plantations were two species of *Gigaspora* and three species of *Scutellospora*. These species are illustrated and described in the following sections:

1. *Gigaspora alboaurantiaca* Chou sp. nov., Figs. 1-6.



Figs. 1-6. The azygospore of *Gigaspora alboaurantiaca*.

Fig. 1. Whole spore and germ tube(gt). Fig. 2. Crushed spore showing wall group structure. Fig. 3. Auxiliary cells with spines surface. Fig. 4. Whole spore (SEM). Fig. 5. Spore wall structure(VAM). Fig. 6. Auxiliary cells with spines surface (SEM).

Azygospores in solo singulatim formatae, albae vel aurantiacae, globosae vel interdum ellipsoideae, 140-270 μm diametro, structureae parietis sporae cum 3-5 inseparabilibus, 7-14 μm crassae, paries externus tenuis laevis cum 1 pariete, 0.8-2.2 μm crassus, paries internus plerumque 2-3, sed interdum cum 4 lamellatis parietibus. Tubis germinationis genitis per parietes sporae prope suspensas hyphas. Cellula instar suspensa bulbosa, 24-43 μm lata, pallida-brunnea. Cellulae auxiliares hyalinae ad luteas, obovatae, 17-36 μm latae, apice echinulatae cum spinis 4-8 μm longis facientes in fasciculis ex 4-16. Formantes arbusculae mycorrhizae.

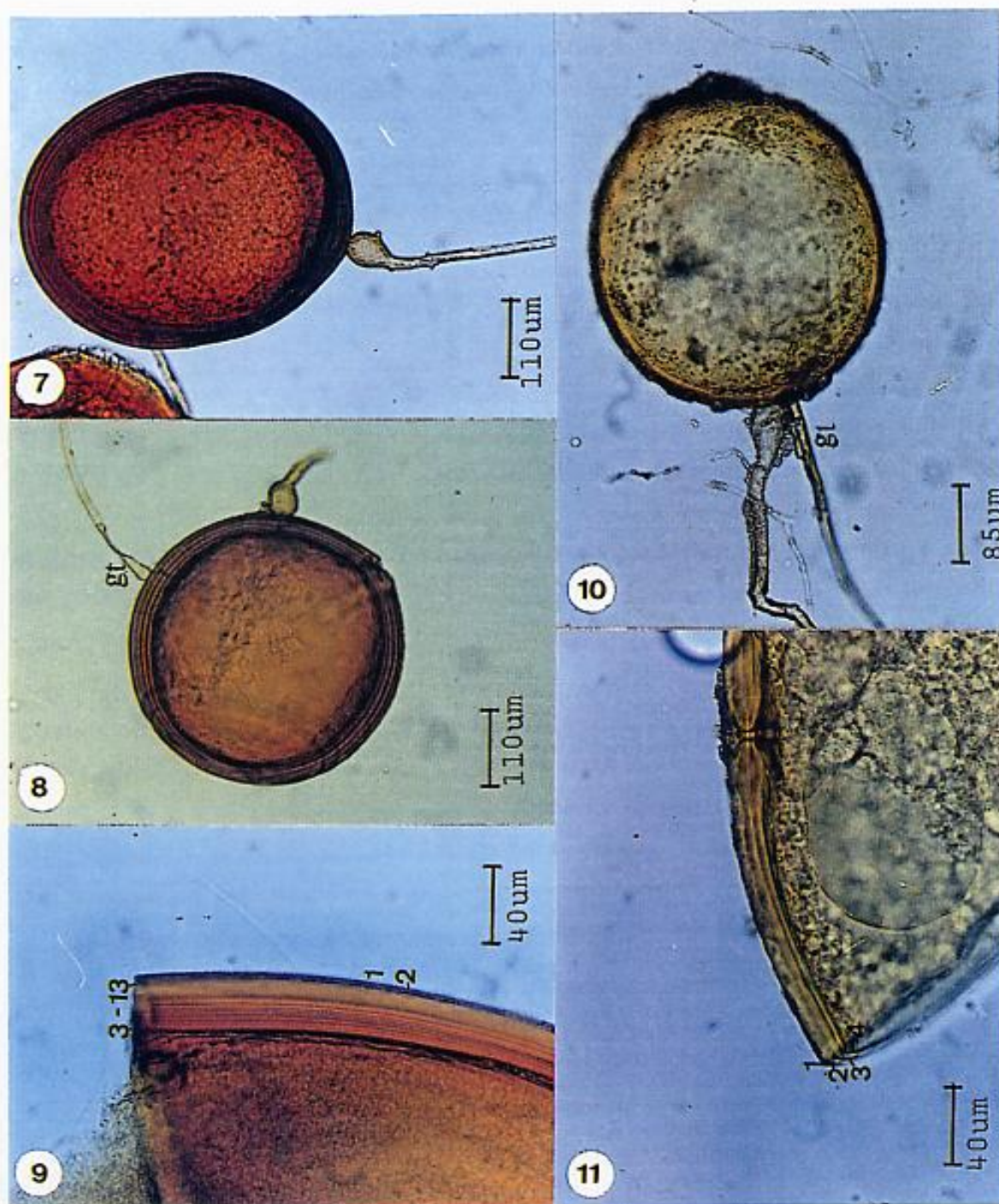
Azygospores formed singly in the soil, white or with a orange color (probably due to ageing), globose occasionally ellipsoidal, 140-270 μm (mean 220 μm) diam. Spore wall structure [see micrograph (Fig. 44)] of 2 to 5 layers inseparable wall (walls 1-5), 7-14 μm thick; outer wall with a thin smooth unit wall (wall 1), 1.8-2.2 μm thick; inner wall usually 2 to 3 but occasionally 4 layers of laminated wall (walls 2-5). Germ tubes produced directly through the spore wall near the suspensor hypha. Suspensor-like cell bulbous, 24-43 μm broad, pale brown. Auxiliary cells hyaline to yellow, obovate, 17-36 μm broad, apex echinulate with spines 4-8 μm long, formed in clusters of 4-16 on coiled hyphae in the soil. Forming arbuscular mycorrhizae.

Collection examined: Taiwan-Taipei at Chinshan, Taoyuan at Haihu, Tainan at Anpien and Hualien at Hoping from rhizosphere of *Casuarina equisetifolia* Oct.1985 - Feb. 1987. TYPE: From pot culture of *Zea mays* L., July 24, 1987, Chou-2010 (TFRI). PARATYPE: From pot culture of *Sorghum vulgare* Pers., Oct. 14, 1988, Chou- 2011 (TFRI), Dec. 6, 1990, Chou-2013 (TFRI); From pot culture of *Leucaena leucocephala* (Lam.) de Wit, Aug. 8, 1989, Chou-2012 (TFRI). Culture on pot of *Taiwania cryptomerioides* and *Sorghum vulgare*.

Note: *G. alboaurantiaca* most resembles *G. candida* Bhattacharjee et al.⁽¹⁾ or *G. albida* Schenck & Smith⁽¹⁵⁾ by spore size and gloss morphology. However, the colour of azygospore and suspensor-like cell in *G. candida* is always white, the colour of azygospore in *G. albida* is dull white with a light greenish- yellow tint, while in *G. alboaurantiaca* they are white becomes orange with age and suspensor-like cell always pale brown.

2. *Gigaspora decipiens* Hall & Abbott, Trans. Br. Mycol. Soc. 83: 293-208, 1984. Figs. 7-9.

Azygospores formed singly in the soil, yellowish or pale orange yellow, globose or irregular, 320-500 x 290-430 μm diam. Spore wall structure [see micrograph (Fig. 44)] of 4 to 14 layers inseparable wall (walls 1-14) from 24-48



Figs. 7-9. The azygospore of *Gigaspora decipiens*. Figs. 10-11. The azygospore of *Gigaspora gigantea*.

Fig. 7. Whole spore. Fig. 8. Whole spore and germ tube(gt). Fig. 9. Crushed spore showing wall group structure. Fig. 10. Whole spore and germ tube(gt). Fig. 11. Crushed spore showing wall group structure.

μm thick; outer wall with 1-3 layers of smooth unit wall (walls 1-3), 1-2.5 μm thick; inner wall usually with 4-7 but occasionally 8-11 layers of laminated wall (walls 4-14), pale orange. Germ tubes produced directly through the spore wall near the suspensor hypha. Suspensor-like cell bulbous, 43-58 μm broad, orange. auxiliary cells not observed in this collection. Forming arbuscular mycorrhizae (5).

Collection examined: Taiwan-Taipei at Yangminshan from rhizosphere of *Alnus formosana* Dec. 1, 1986 Chou-2040 (TFRI). Sep. 20, 1987 Chou-2041 (TFRI); Inoculated test, no success.

3. *Gigaspora gigantea* (Nicol. & Gerd.) Gerd. & Trappe, Mycologia Memoir No.5:29-30, 1974. Figs. 10-11.

Azygospores formed singly in the soil, greenish-yellow, globose or irregular, 250-410 x 260-650 μm diam. Spore wall structure [see micrograph (Fig. 44)] of 2 to 4 layers inseparable wall (walls 1-4) from 7-12 μm thick; outer wall with a thin smooth unit wall (walls 1), 1-2 μm thick; inner wall with 2-3 layers of pale yellow laminated wall (walls 2-4), 6-11 μm thick. Germ tubes produced directly through the spore wall near the suspensor hypha. Suspensor-like cell bulbous, 30-50 μm broad, yellow. Auxiliary cells not observed in this collection. Forming arbuscular mycorrhizae⁽³⁾

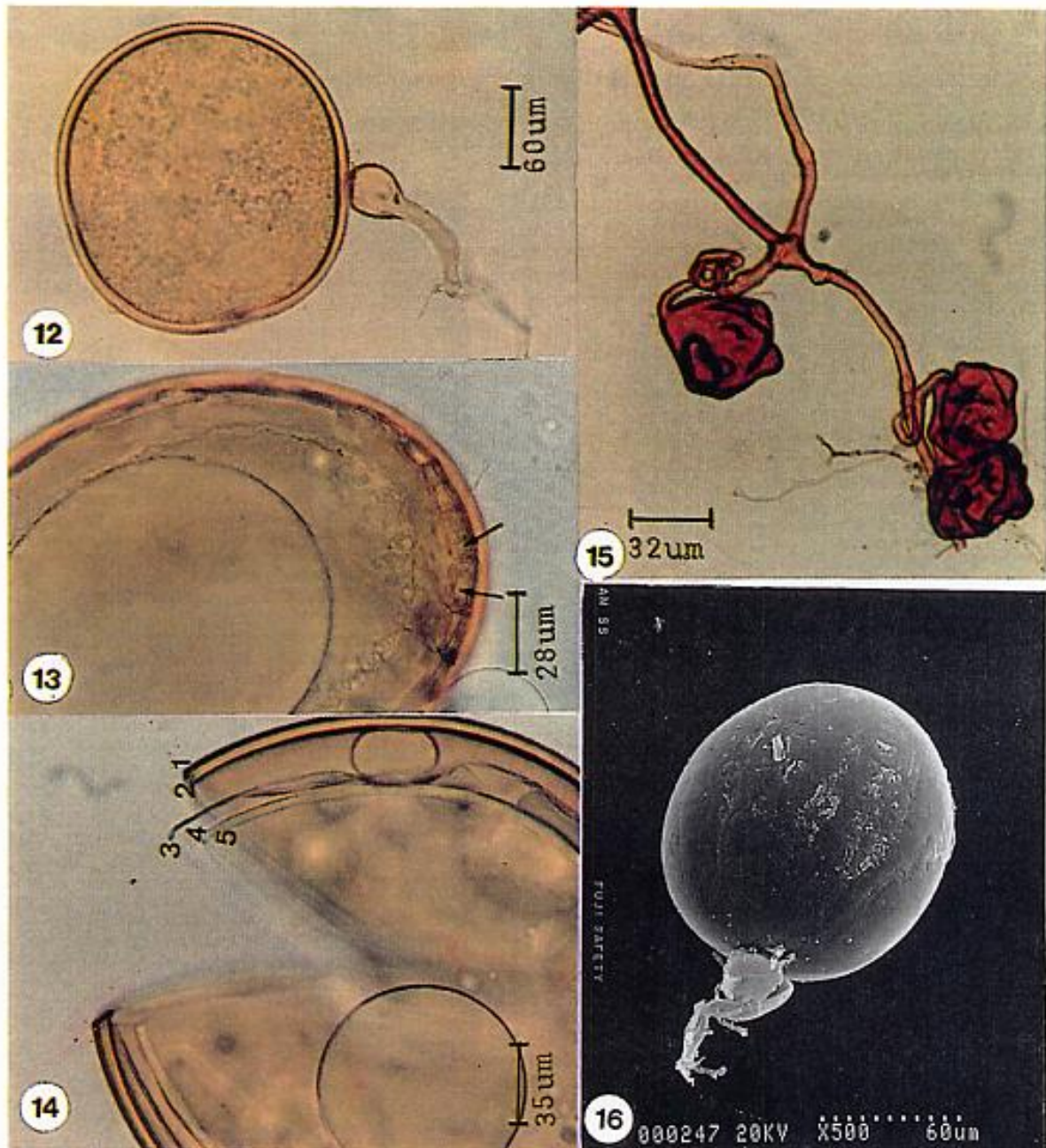
Collection examined: Taiwan - Kaohsiung at Liukuei of Shanpine nursery from rhizosphere of *Cunninghamia lanceolata* Jan. 19, 1987 Chou-2030 (TFRI), Sep. 28, 1987 Chou-2031 (TFRI); Inoculated test, no success.

Distribution and habitat in Taiwan: Found in the rhizosphere of *Chamaecyparis formosensis*^(6,20), *Liquidambar formosana*⁽¹⁹⁾ and *Phyllostachys pubescens*⁽²¹⁾.

4. *Scutellospora calospora* (Nicol. & Gerd.) Walker & Sanders, Mycotaxon 27:219-235, 1986. Figs. 12-16.

Azygospores formed singly in soil, hyaline or pale greenish-yellow, globose or ellipsoidal, 140-280 μm diam. Spore wall structure [see micrograph (Fig. 44)] of 4 or 5 walls (walls 1-5) in two groups (A & B). Group A wall from 6-9 μm thick; outer wall with a smooth hyaline unit wall (wall 1), 0.8-1.6 μm thick; inner wall with a pale yellow very finely laminated wall (wall 2), 5-9 μm thick, Group B wall of two hyaline membranous walls, occasionally consisting of three membranous walls (walls 3-5). Germination shield oval. Suspensor-like cell bulbous, 40-60 μm broad, pale yellow. Auxiliary cells hyaline to pale red-brown, 40-50 μm diam, irregular to knobby, borne singly on coiled hyphae in the soil. Forming arbuscular mycorrhizae^(5,12).

Collection examined: Taiwan-Hualien at Peipu from rhizosphere of *Casuarina*



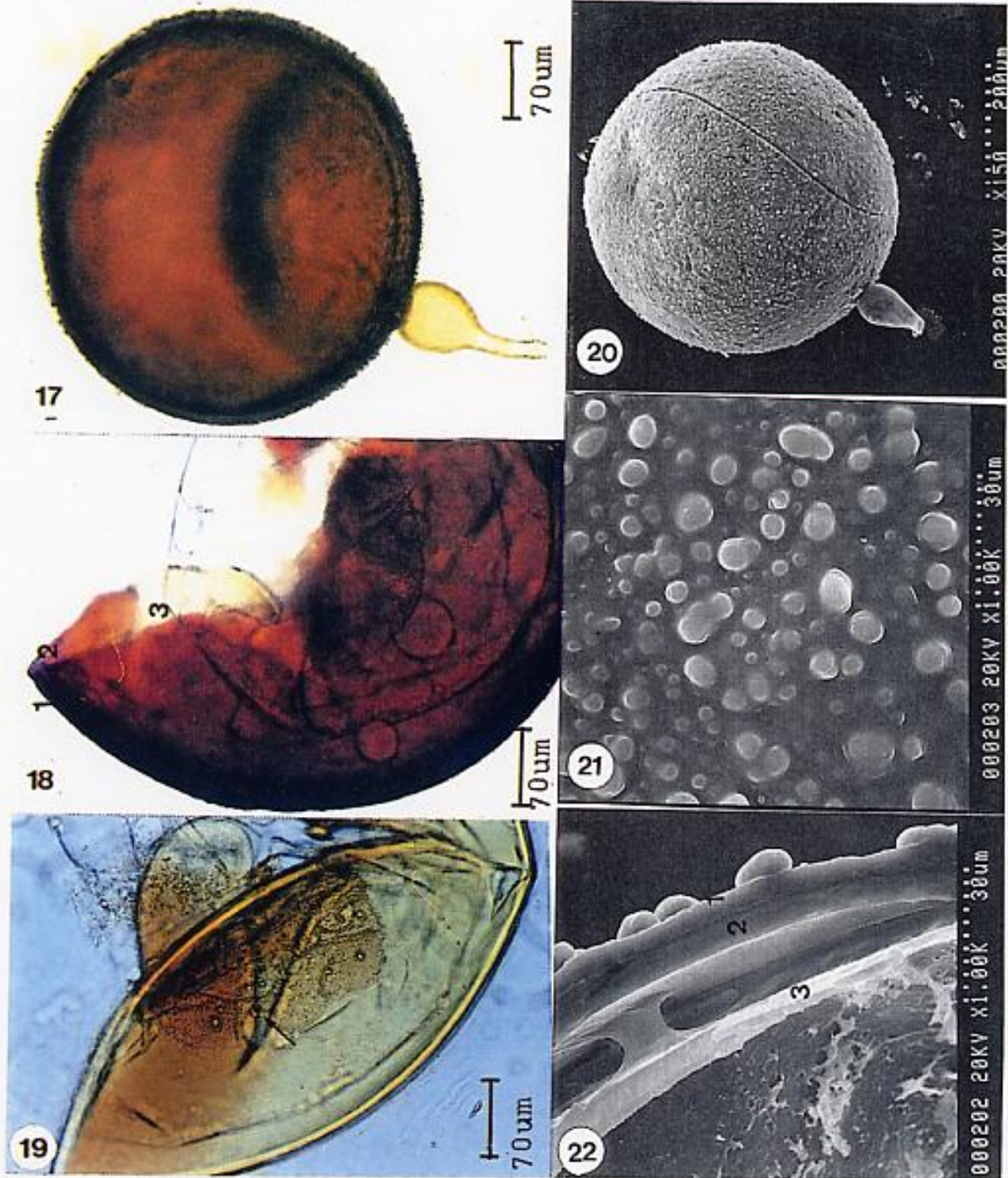
Figs. 12-16. The azygospore of *Scutellospora calospora*.

Fig. 12. Whole spore. Fig. 13 Germination shield(Arrow). Fig. 14. Crushed spore showing wall group structure. Fig. 15. Auxiliary cells with knobby surface. Fig. 16. Whole spore(SEM).

equisetifolia Jan. 21, 1987 Chou-6030 (TFRI), Sep. 24, 1987 Chou-6031 (TFRI), Penghu at Lungmen from rhizosphere of *Casuarina equisetifolia* and Dec. 1, 1988 Chou-6033 (TFRI) and Ilan at Chilanshan from rhizosphere of *Taiwania cryptomerioides* May 6, 1987 Chou-6032 (TFRI); From pot culture of *Leucaena leucocephala* (Lam.) de Wit, July 20, 1989 Chou-6034 (TFRI). inoculation test success and pot culture of *Taiwania cryptomerioides*.

Distribution and habitat in Taiwan: Found in the rhizosphere of *Cunninghamia lanceolata* and *Taiwania cryptomerioides*⁽⁷⁾.

5. *Scutellospora coralloidea* (Trappe, Gerd. & Ho) Walker & Sanders, Mycologia 77: 702-720, 1985. Figs. 17-22.



Figs. 17-22. The azygospore of *Scutellospora coralloidea*.

Fig. 17. Whole spore. Fig. 18. Crushed spore showing wall group structure. Fig. 19. Germination shield(Arrow). Fig. 20. Whole spore(SEM). Fig. 21. Surface view of spore(SEM). Fig. 22. Spore wall structure(SEM).

Azygospores formed singly in the soil, dark brown, globose or ellipsoid, 270-

490 μm (mean 420 μm) diam. Spore wall structure [see micrograph (Fig. 44)] of three walls (walls 1-3), in two groups. Group A wall from 12-18 μm thick excluding a widely ornamented unit wall (wall 1), dark brown, 3-7 μm thick excluding widely spaced patch-like warts, warts hyaline to pale yellow, 2-5 μm height, 3-12 μm broad, subregular; inner wall of a yellow-brown laminated wall (wall 2), 9-14 μm thick. Group B consisting of a hyaline membranous wall (wall 3), < 0.5 μm thick. Germination shield oval, 150-240 μm broad. Suspensor-like cell bulbous 50-65 μm broad, pale brown. Auxiliary cells not observed in this collection. Forming arbuscular mycorrhizae^(3,11).

Collection examined: Taiwan-Taipei at Pinghsi of coal mine spoil from rhizosphere of *Houttuynia cordata* Dec. 1, 1986 Chou-6070, (TFRI) and Sep. 20, 1987 Chou-6071 (TFRI). Inoculation test success and pot culture of *Taiwania cryptomerioides*.

6. *Scutellospora erythropha* (Roske & Walker) Walker & Sanders, *Mycologia* 76:250-255, 1984. Figs. 41-43.

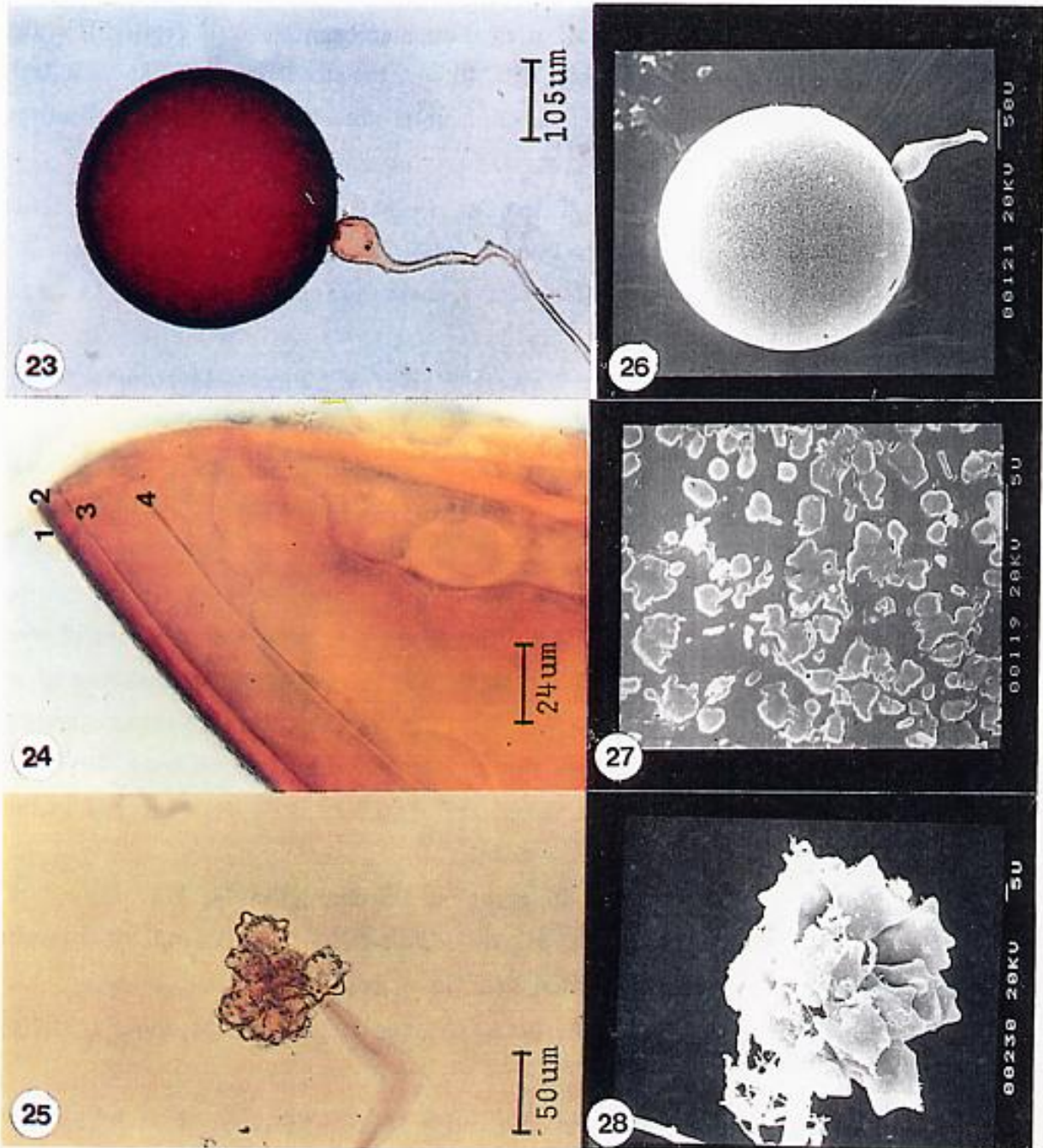
Azygospores formed in the soil, red-brown, globose or ellipsoid, 180-260 μm diam. Spore wall structure [see micrograph (Fig. 44)] of 5 or 6 walls (walls 1-6) in two groups (A & B). Group A wall from 5-8 μm thick; outer wall with a smooth unit wall (wall 1), red-brown, 2-2.5 μm thick; inner wall with a brittle, hyaline unit wall (wall 2), 2-5 μm thick and slight separable 1 or 2 layers of hyaline unit wall (wall 3 or 4) each less than 0.5 μm thick. Group B consisting of an outer laminated wall (wall 5), pale yellow, 2.5-4 μm thick; and an inner membranous wall (wall 6), hyaline, <0.5 μm thick. Suspensor-like cell bulbous, 40-75 μm broad, yellow brown. Germination shield and auxiliary cells not observed in this collection. Forming arbuscular mycorrhizae⁽¹⁰⁾.

Collections examined: Taiwan-Pingtung at Chechun, Oct. 4, 1987 Chou-6051 (TFRI) and Hualien at Peipu, Jan. 21, 1987 Chou-6050 (TFRI) from rhizosphere of *Casuarina equisetifolia*. Inoculated test, no success.

7. *Scutellospora gregaria* (Schenck & Nicol.) Walker & Sanders, *Mycologia* 77:702-720, 1985. Figs. 23-28.

Azygospores formed singly in the soil, dark red-brown, globose to subglobose, 270-450 μm (mean 320 μm) diam. Spore wall structure [see micrograph (Fig. 44)] of four walls (walls 1-4) in two groups (A & B). Group A wall from 7-12 μm thick; outer wall with an ornamented unit wall (wall 1), dark brown, 2.5-3.5 μm thick excluding packed warts, warts hyaline to pale brown, 0.5-1.2 μm height, 4.5-8.5 μm broad, irregular; inner wall brown to orange-brown with two layers of laminated wall (wall 2 & 3), 4.5-9 μm thick. Group B wall of hyaline membra-

nous wall (wall 4), $< 0.5 \mu\text{m}$ thick. Germination shield not observed in this collection. Suspensor-like cell bulbous, $50-75 \mu\text{m}$ broad, orange brown. Auxiliary cells hyaline to yellow, irregular to knobby, $20-30 \mu\text{m}$ broad, formed in clusters of 6-15 on coiled hyphae in the soil. Forming arbuscular mycorrhizae^(11,13)



Figs. 23-28. The azygospore of *Scutellospora gregaria*.

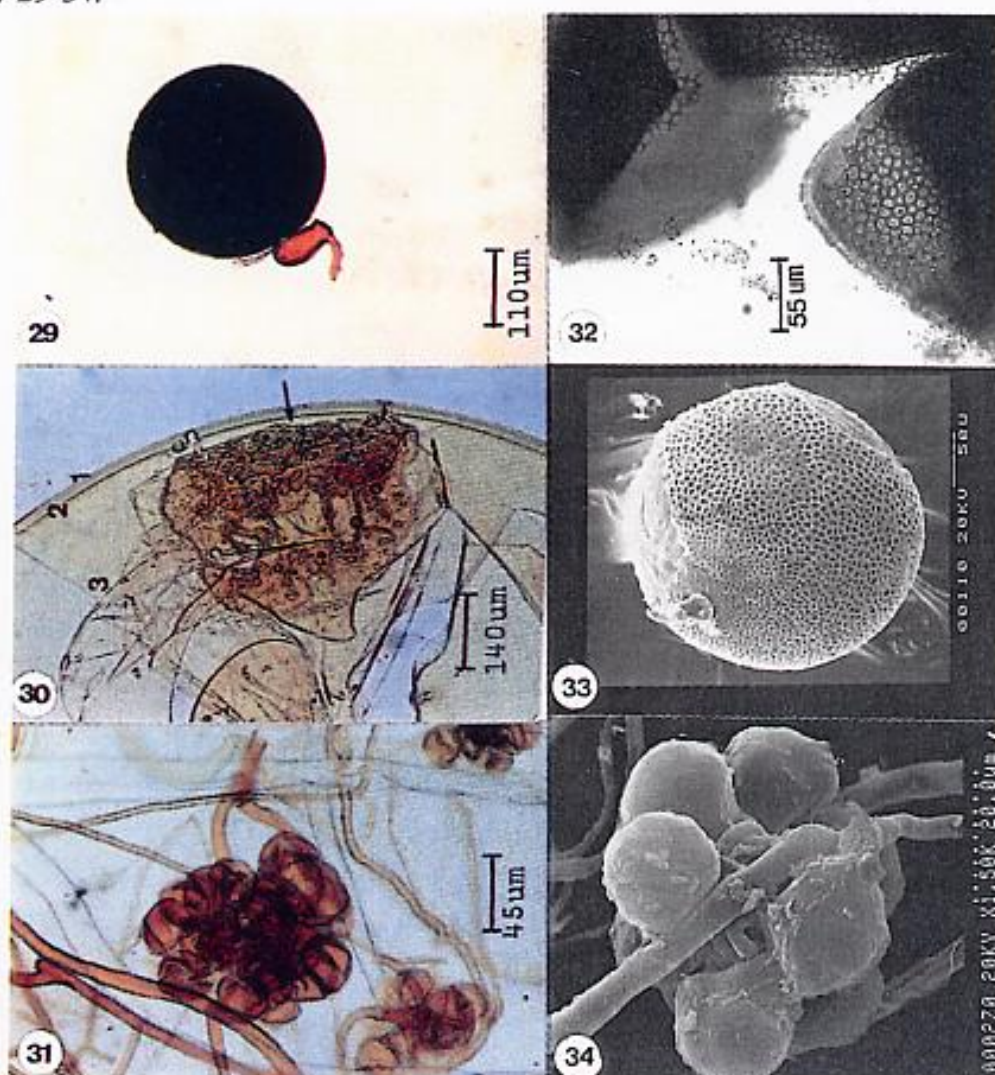
Fig. 23. Whole spore. Fig. 24. Crushed spore showing wall group structure. Fig. 25 & 28. Auxiliary cells with knobby surface. Fig. 26. Whole spore(SEM). Fig. 27. Surface view of spore(SEM). Fig. 28. Auxiliary cells with knobby surface(SEM).

Collections examined: Taiwan-Taoyuan at Haihu Jan. 15, 1986 Chou-6020

(TFRI), Aug. 24, 1987 Chou-6021 (TFRI) and Ilan at Wuchieh Apr. 1, 1988 Chou-6023 (TFRI) from rhizosphere of *Casuarina equisetifolia*; from pot culture of *Zea mays* Oct. 15, 1986 Chou-6024 (TFRI) or *Sorghum vulgare* Jan. 1, 1987 Chou-6025 (TFRI) or *Taiwania cryptomerioides* July 24, 1989 Chou-6026 (TFRI). Inoculation test success and pot culture of *Taiwania cryptomerioides* and *Sorghum vulgare*.

Distribution and habitat in Taiwan: Found in the rhizosphere of *Liquidambar formosana*⁽¹⁹⁾.

8. *Scutellospora nigra* (Redhead) Walker & Sanders, Mycologia 71:178-198, 1979. Figs. 29-34.



Figs. 29-34. The azygospore of *Scutellospora nigra*.

Fig. 29. Whole spore. Fig. 30. Crushed spore showing wall group structure and germination shield(Arrow). Fig. 31. Auxiliary cells with smooth surface. Fig. 32. Crushed spore showing surface reticulation. Fig. 33. Whole spore(SEM). Fig. 34. Auxiliary cells with smooth surface(SEM).

Azygospores formed singly in the soil, black-brown, globose, 340-460 μm

(mean 390 μm) diam. Spore wall structure [see micrograph (Fig. 44)] of three wall (walls 1-3) in two groups (A & B). Group A wall from 9-12 μm thick; outer wall with an ornamented with unit wall (wall 1), dark brown, 2-4 μm thick, excluding reticulate-like pitted with pores, pores ellipsoid, 3-9 μm broad; inner wall with a brown laminated wall (wall 2), 7-10 μm thick. Group B wall of a hyaline membranous wall (wall 3), < 0.5 μm thick. Germination shield oval, 190-260 μm broad. Suspensor-like cell bulbous, 60-100 μm broad, brown. Auxiliary cells brown, globose, 25-30 μm broad, smooth, formed in clusters of 4-16. Forming arbuscular mycorrhizae⁽¹²⁾

Collections examined: Taiwan - Kaohsiung at Liukuei of Shanpine nursery from rhizosphere of *Cunninghamia lanceolata* Jan. 9, 1987 Chou-6040 (TFRI), Sep. 28, 1987 Chou-6041 (TFRI) and from pot culture of *Sorghum vulgare* Sep. 26, 1986 Chou-6042 (TFRI). Inoculation test success and pot culture of *Taiwania cryptomerioides* and *Sorghum vulgare*.

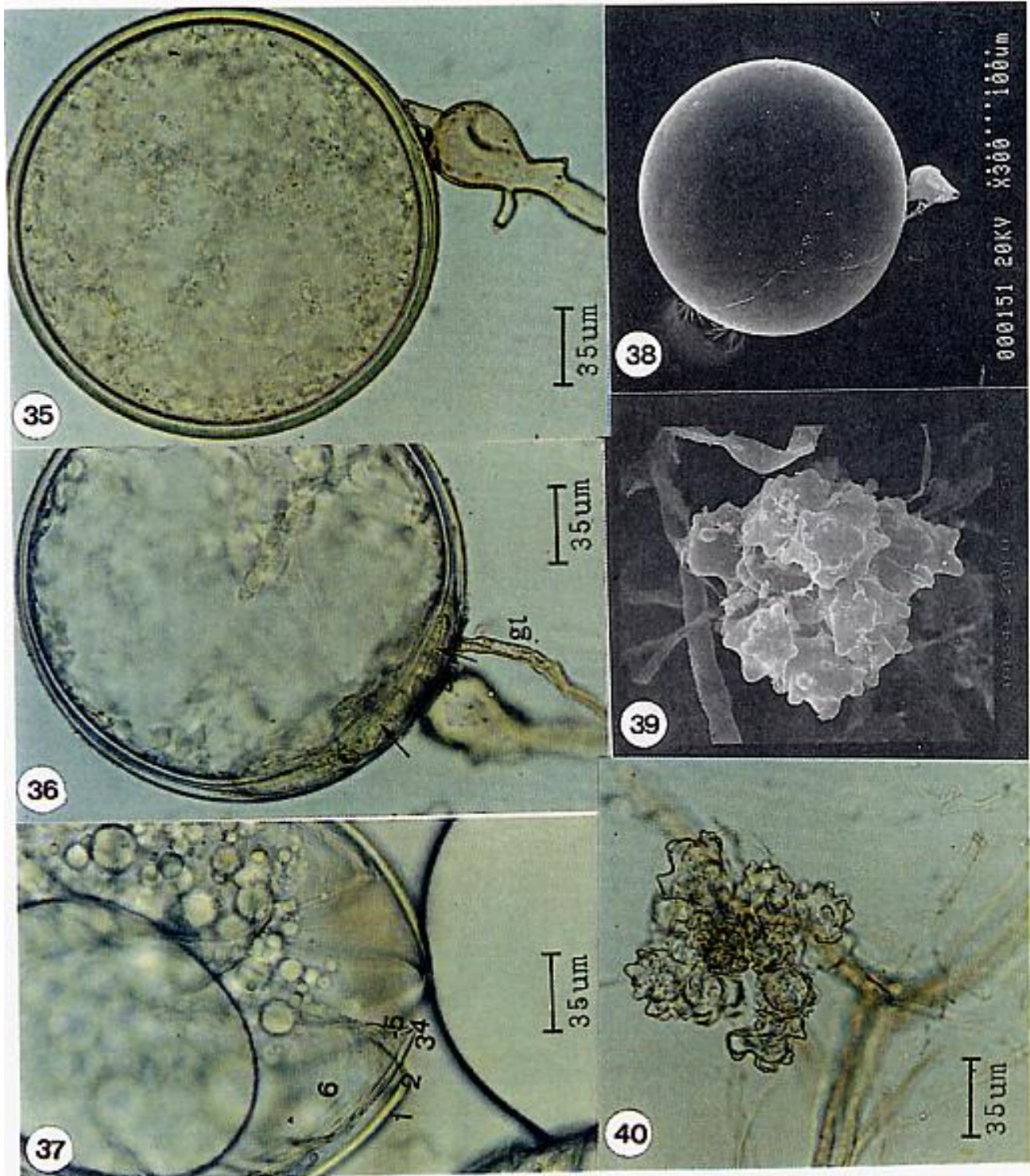
Distribution and habitat in Taiwan: Found in the rhizosphere of *Liquidambar formosana*⁽¹⁹⁾ and *Cunninghamia lanceolata* and *Taiwania cryptomerioides*⁽⁷⁾.

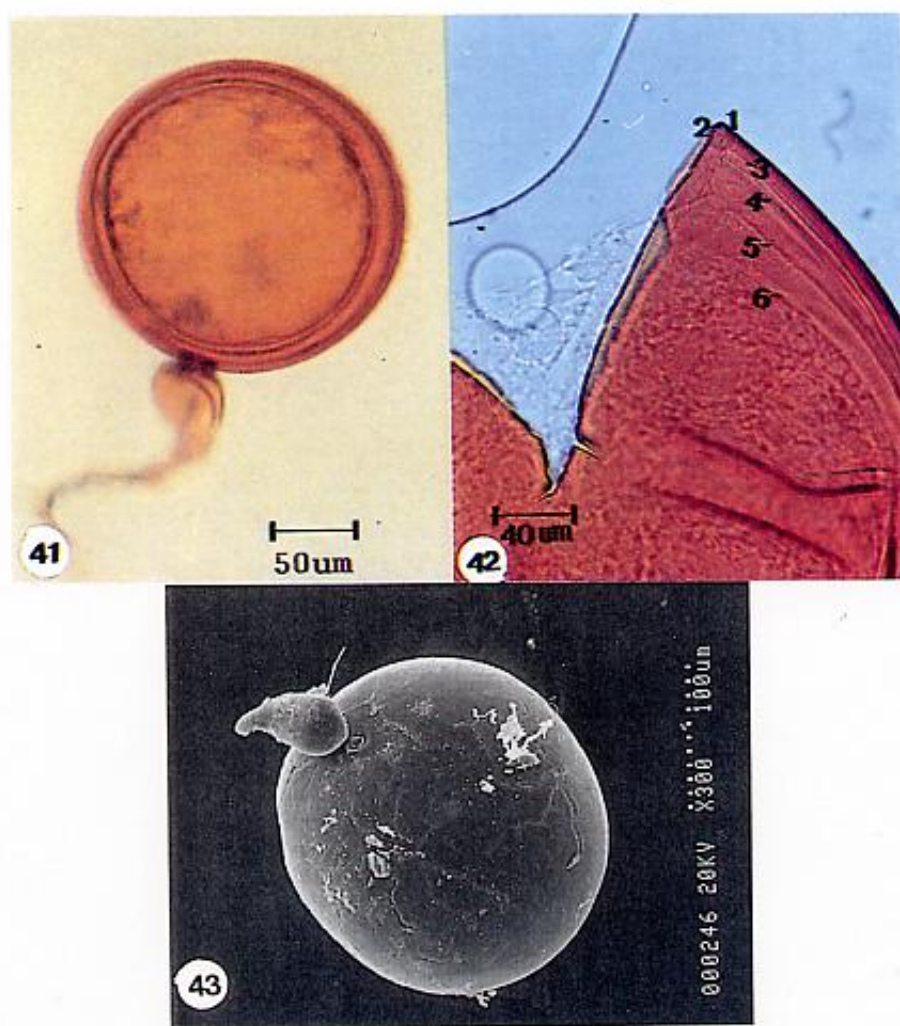
9. *Scutellospora pellucida* (Nicol. & Schenck) Walker & Sanders, Mycotaxon 27:219-235, 1986. Figs. 35-40.

Azygospores formed singly in the soil, white to pale grey-yellow glistening with oil droplets, globose, 140-320 μm (mean 220 μm) diam. Spore wall structure [see micrograph (Fig. 44)] of six walls (walls 1-6) in three groups (A, B & C). Group A wall from 2.5-7 μm thick; outer wall with a smooth hyaline unit wall (wall 1); inner wall with a hyaline to yellow laminated wall (wall 2), 1.8-6.4 μm thick. Group B wall from 3.6-4.8 μm thick consisting of a hyaline membranous wall (wall 3) closely adherent to two hyaline unit wall (wall 4 & 5), unit wall from 2.4-3.6 μm thick. Group C wall of a hyaline amorphous wall (wall 6), <0.5 μm thick. Germination shield oblong. Suspensor-like cell bulbous, 30-45 μm broad, hyaline. Auxiliary cells hyaline, 15-30 μm broad, irregular to knobby, formed in clusters of 5-14. Forming arbuscular mycorrhizae^(12,13).

Collections examined : Taiwan- Penghu at Hsiaomen rhizosphere of *Casuarina equisetifolia* Sep. 11, 1988 Chou-6010 (TFRI) and from pot culture of *Taiwania cryptomerioides* Sep. 24, 1987 Chou-6011 (TFRI), July 20, 1989 Chou-6012 (TFRI). Inoculation test success and pot culture of *Taiwania cryptomerioides* or *Sorghum vulgare*.

Distribution and habitat in Taiwan: Found in the rhizosphere of *Cunninghamia lanceolata* and *Taiwania cryptomerioides*⁽⁷⁾.





Figs. 41-43. The azygospore of *Scutellospora erythropha*.

Fig. 41. Whole spore. Fig. 42. Crushed spore showing wall group structure.

Fig. 43. Whole spore (SEM).

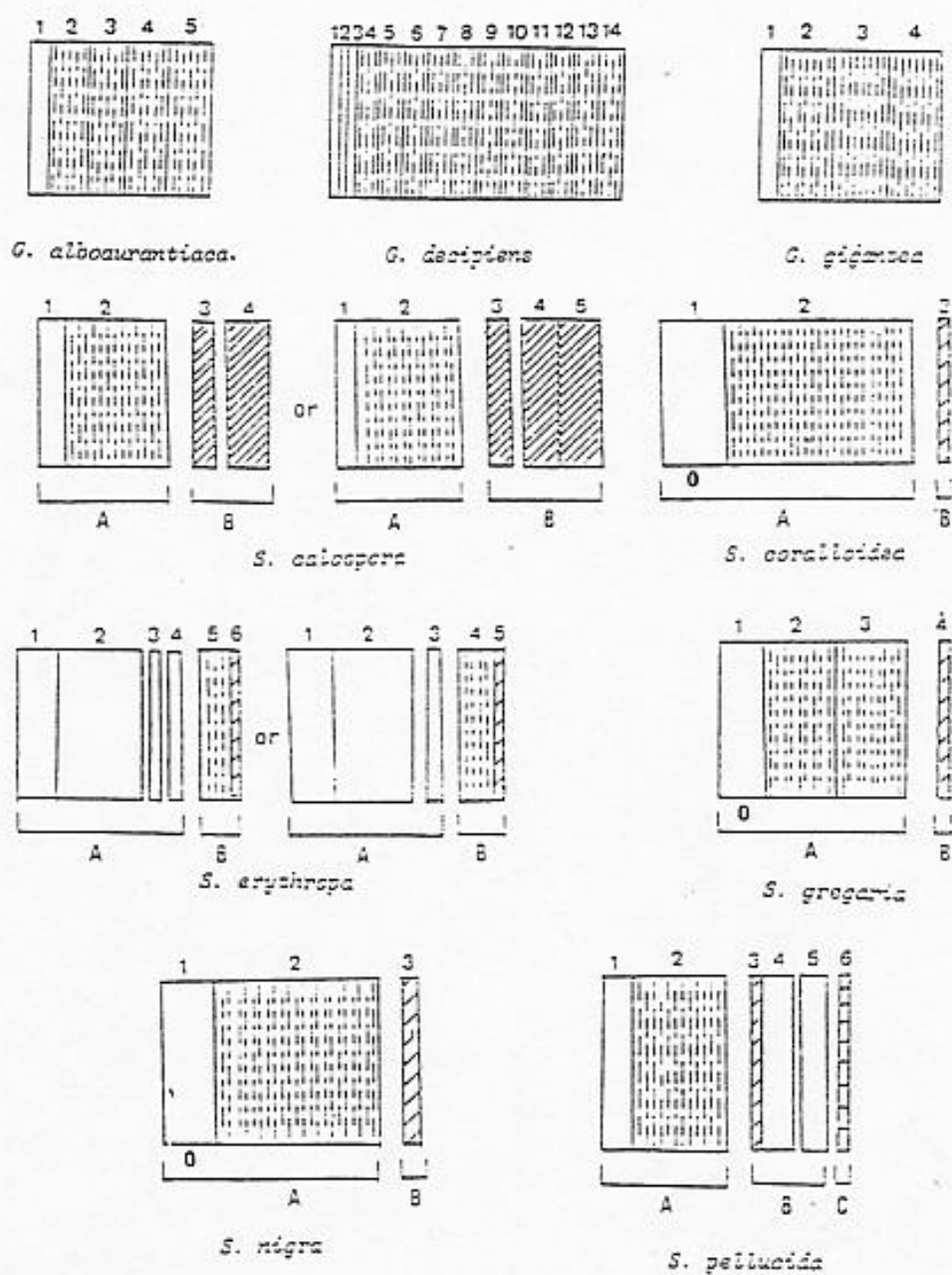


Fig 44. Murographs of *Gigaspora* spp. and *Scutellospora* spp. with spore wall structure.

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