

## ENDOMYCORRHIZAS OF RUBBER GROWING SOILS OF SRI LANKA

By

A. H. R. JAYARATNE

### SUMMARY

A detailed survey of the endomycorrhizal fungi present in rubber growing soils of Sri Lanka was conducted. Eleven species are reported for the first time from local rubber growing soils. Of these seven species are new to Sri Lanka. Spore numbers varied considerably from site to site but there was no definite pattern in the variation of spore numbers with the age group of rubber plantations sampled.

### INTRODUCTION

Vesicular-arbuscular (VA) mycorrhizae occur in a large number of agricultural, orchard and plantation crops. Most of these crops show an increased growth response after inoculation with VA endophytes. Current evidence suggests that these beneficial effects are usually attributed to improved P nutrition. Mycorrhizal associations do enhance the absorption of other mineral nutrients including S (Gray and Gerdemann, 1973; Rhodes and Gerdemann, 1978), Zn (McIlveen *et al*, 1975), K (Powell, 1975), Ca and Cu (Ross, 1971; Abbott and Robson, 1982).

Though it is known that both *Hevea* and *Ficus* form VA mycorrhizae (Wastie, 1965; Waidyanatha *et al*, 1978) it is not known what species of fungi are responsible for their formation. A detailed survey of VA mycorrhizal spore types was carried out and its results are reported in this paper.

### MATERIALS AND METHODS

Soil samples were collected from six different rubber estates in five different districts of the Island viz; Kalutara, Matale, Kurunegala, Kegalle and Galle (Fig. 1). Five samples were collected from different age groups of replanted rubber in each estate, as follows :

- (a) 1 to 3 years old with a good ground cover
- (b) 7 to 8 years old
- (c) 15 to 20 years old
- (d) Very old replanting (> 30 yr) due for uprooting
- (e) A cleared land which was being prepared for replanting

Sampling of soil was done between 15 March 1979 and April 1979. Each sample consisted of two main sub-samples collected from two points. Each point was 1m<sup>2</sup> in size. Sub-samples from each of these points consisted of five bulk samples of about 1kg. Only the

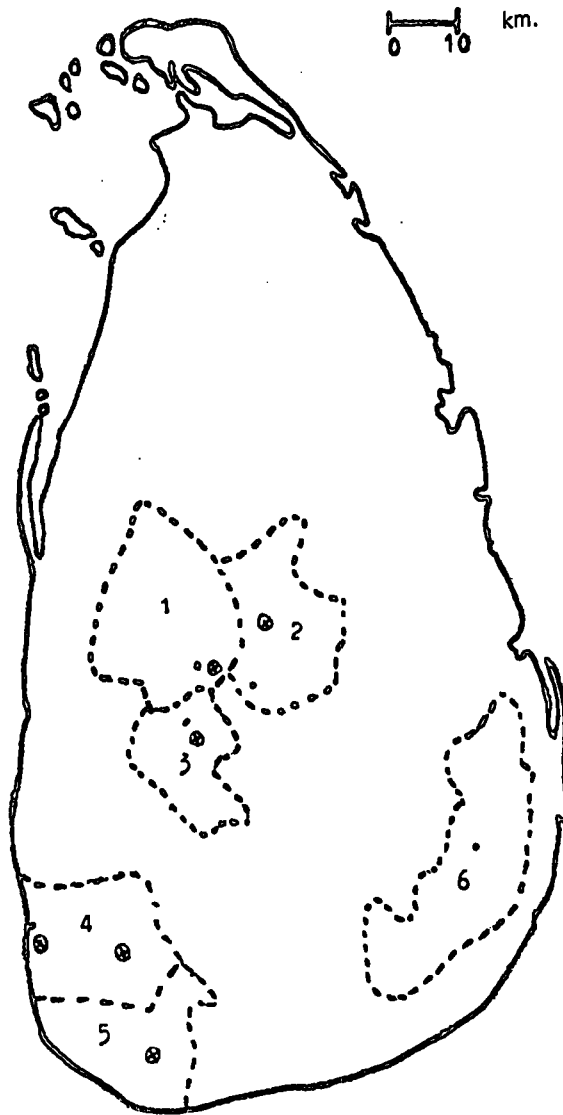


Fig. 1. Major rubber growing districts of Sri Lanka.

1. Kegalle 2. Kurunegala 3. Matale 4. Kalutara 5. Galle 6. Moneragala  
Sampling sites

*Location*

Hedigalla (Kalutara District)

Lowment (Kalutara District)

Parambe (Kegalle District)

Nalanda (Matale District)

Muwankande (Kurunegala District)

Nakiyadeniya (Galle District)

*Soil Type*

Red yellow podzolic soils with well developed laterite and drainage associates  
Red yellow podzolic soils with well developed laterite

Red yellow podzolic soils

Reddish brown, latosolic soils

Red yellow podzolic soils with weakly developed laterite and their drainage associates

Red yellow podzolic soils

top 10 cm of soil was collected. The two main sub-samples from each site were brought to the laboratory, mixed thoroughly by hand and stored at 4°C. Soil pH was determined in a 1 : 5 solution with distilled water. Separate air dried 10 g sub-samples from each site were stored in a refrigerator for subsequent analysis of phosphorus content using Bray's method (Dickman and Bray, 1940). The spores were extracted from the soil, using the method of wet-sieving and decanting (Gerdemann and Nicolson, 1963). Fractions retained on 500  $\mu\text{m}$ , 210  $\mu\text{m}$ , 110  $\mu\text{m}$ , 53  $\mu\text{m}$ , sieves were examined. The fraction that passed through the 53  $\mu\text{m}$  sieve was retained and the flotation-adhesion technique (Sutton and Barron, 1972) was carried out to extract the spores that were smaller than 53  $\mu\text{m}$ . Different mycorrhizal spore types were isolated with a pointed wet-mounting needle on to wet, thin, filter paper strips. These spores were surface sterilized using NaOCl for 2 sec and inoculated on to seedlings of *Pueraria phaseoloides*. The spores formed in these cultures were observed and identified after about 2 months. Percentage infection of the rubber root pieces found in each sample was also determined after staining with trypan blue (Phillips and Hayman, 1970) and observing 25 root pieces, each 1 cm long. The extent of infection in each root piece was recorded as follows :

0 — no infection observed	
1 — 25%	} of the length of the root piece infected
2 — 50%	
3 — 75%	
4 — 100%	

The total score for 25 pieces was given as the percentage infection.

#### Spore types

Spore types observed were classified according to Gerdemann and Trappe (1974), as far as possible.

#### *Glomus fasciculatus* (Thaxter *sensu* Gerdemann) Gerdemann and Trappe 1974 (Fig. 2)

Found in Hedigalla, Lowmont (Kalutara District), Nalanda (Matale District) and Muwankande (Kurunegala District) Estates. Chlamydospores borne free in soil or in loose aggregations, 1 – 3 mm broad or sometimes in compact clusters. Peridium absent, interwoven hyphae 12  $\mu\text{m}$  in diam., thin walled, Chlamydospores 61-96 x 76-125  $\mu\text{m}$  diam., globose, subglobose or irregular. Spore wall yellow to yellowish brown, thickness varies from 4-11  $\mu\text{m}$  laminated, radial fissures present in mature spore. Subtending hyphae with a diam of 9-12  $\mu\text{m}$ . Walls of attached hyphae often thickened (4.5  $\mu\text{m}$ ) near the spore base.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

#### *Glomus microcarpus* Tul & Tul (Gerdemann and Trappe, 1974) (Fig. 3)

Found in Hedigalla, Lowmont (Kalutara District) and Nakiyadeniya (Galle District) Estates. Sporocarps irregular, up to 2 mm broad, light brown in colour with a very thin peridium. Chlamydospores free in soil 25 - 35  $\mu\text{m}$  diam., globose to subglobose, very frequently occur in pairs with short subtending hyphae (3.5  $\mu\text{m}$  diam). Spore walls hyaline

to bright yellow, laminate thickness 2.5–3  $\mu\text{m}$ , smooth or appearing roughened from adherent debris. Opening into subtending hyphae nearly occluded at maturity by spore wall thickening.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

*Glomus multiculis* (Gerdemann and Bakshi, 1976) (Fig. 4)

Found in Muwankande (Kurunegala District) and Nalanda (Matale District) Estates. Chlamydospores are borne in loose aggregations. Thin peridium like layer present, spores dark reddish brown to olive brown in colour, ellipsoid to oval, 153 x 125  $\mu\text{m}$  diam. Spore wall up to 10  $\mu\text{m}$  thick. Rounded protuberances are evenly dispersed on the wall, 1-2 hyphal attachments generally occurring at opposite ends of spores.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

*Glomus macrocarpus* var. *geosporus* (Nicol & Gerd) Gerdemann and Trappe (1974) (Fig. 5)

Found in Lowmont (Kalutara District), Parambe (Kegalle District) and Nakiyadeniya (Galle District) Estates. Chlamydospores formed singly in soil or sometimes in loose aggregations (0.63 – 1.0 mm). Interwoven hyphae thick walled (2.5  $\mu\text{m}$ ). Under low magnifications the spores appear to have long black stiff stalks. Chlamydospores 138 – 150  $\mu\text{m}$  diam., smooth or roughened from adherent debris, dark brown to black. Spore wall 7  $\mu\text{m}$  thick, dark brown to brownish black, perforated at maturity. Subtending hyphae 30  $\mu\text{m}$  diam. Spore wall thickening extends 100 – 110  $\mu\text{m}$  along the hyphae from the spore.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

*Glomus mosseae* (Nicol & Gerd) Gerdemann and Trappe (1974)

Found in Kalutara and Kurunegala Districts. Sporocarps 150 x 250  $\mu\text{m}$  diam. Peridium of loosely interwoven hyphae (2 – 10  $\mu\text{m}$  diam). Chlamydospores yellowish to reddish brown, globose, subglobose to ellipsoid, 125 x 154 – 169  $\mu\text{m}$ . Spore wall laminated, brownish, thickness 9 – 15  $\mu\text{m}$ , highly perforated, outermost layer easily separable. Comparatively long subtending hyphae, funnel shaped, diameter at the proximal end is 21  $\mu\text{m}$ , and 11 – 14  $\mu\text{m}$  at the distal end. Subtending hyphae are very often branched at the distal end. Hyphal walls highly thickened (4  $\mu\text{m}$ ). Spore wall thickening extends into the hyphae (14 – 16  $\mu\text{m}$ ). Pore (2  $\mu\text{m}$ ) in some spores seems to be covered with a distinct septum.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants

*Glomus monosporus*. Gerdemann and Trappe (1974) (Fig. 6)

Found in Lowmont Estate (Kalutara District). Sporocarps 600 x 900  $\mu\text{m}$ , globose or irregular, containing mostly 1 or occasionally 2 spores. Peridium of branched interwoven, thin walled hyphae, usually incorporating many soil particles. Spores completely enclosed and obscured. Chlamydospores 132 – 138  $\mu\text{m}$  diam., yellowish brown to reddish brown, generally globose to subglobose. Subtending hyphae not observed, possibly it may have got detached from the spore while crushing the sporocarp. Spore wall characters are not clear. Spores containing oil globules or occasionally filled with thin walled hyphae.

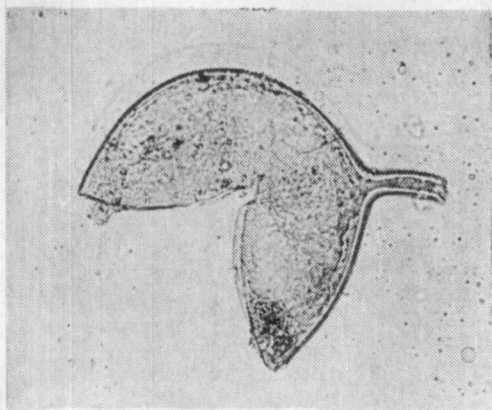


Fig. 2 *Glomus fasciculatus*  
Crushed spore to show  
spore wall characters  
(x 13200)

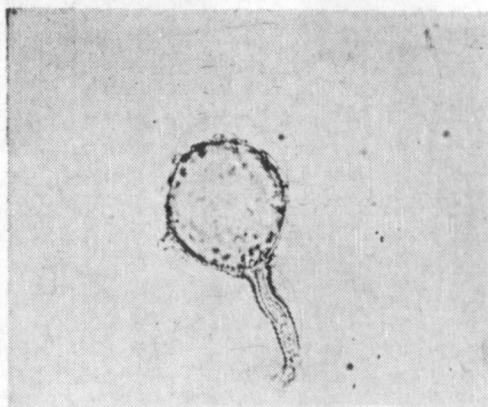


Fig. 3 *Glomus microcarpus*  
Single spore  
(x 2100)

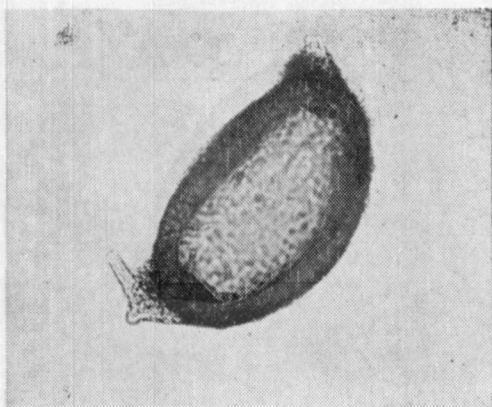


Fig. 4 *Glomus multicutis*  
Single spore. Note the  
two hyphal attachments  
at the opposite ends  
(x 800)

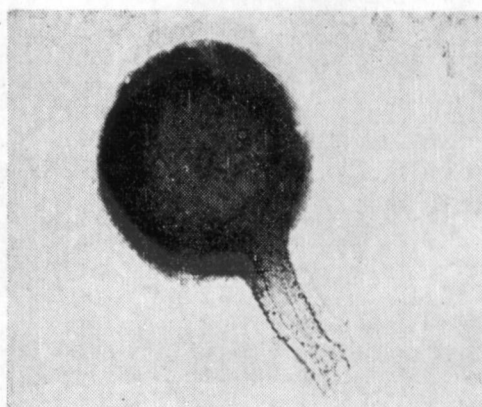


Fig. 5 *Glomus macrocarpus*  
Var. *geosporus*  
Single spore. Note the  
thick stout subtending  
hyphae (x 1500)

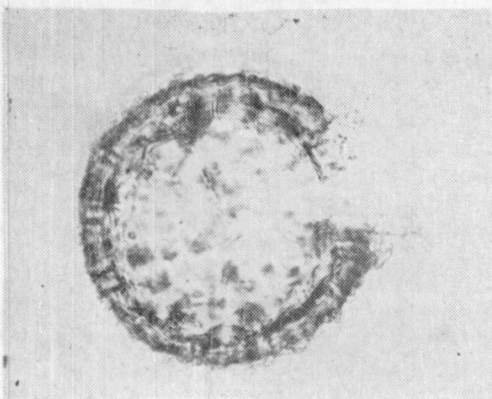


Fig. 6. *Glomus monosporus*  
crushed spore  
(x 800)

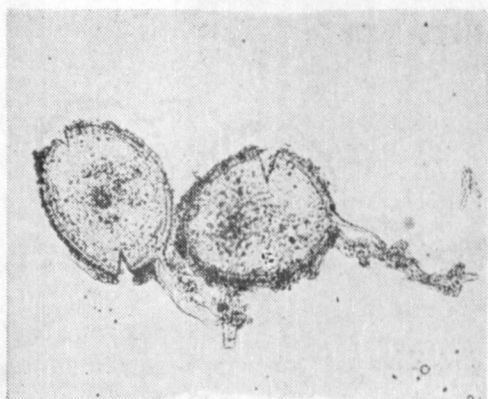


Fig. 7 *Glomus* species  
Two crushed spores  
(x 660)

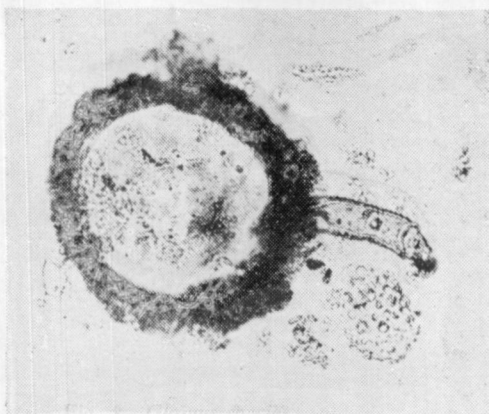


Fig. 8 *Glomus species*  
Entire spore. Note  
the large quantities  
of adherent debris  
(x 1500)

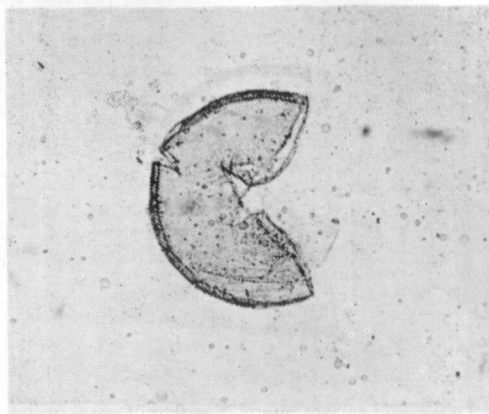


Fig. 9 *Glomus species*  
Crushed spore  
(x 660)

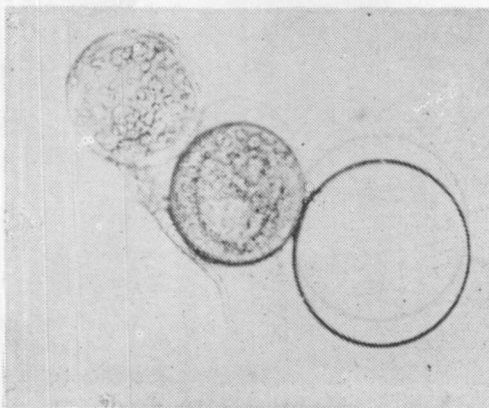


Fig. 10 *Acaulospora elegans*  
Young spore attached  
to mother vesicle.  
Note the large oil  
globule released from  
the spore (x 500)

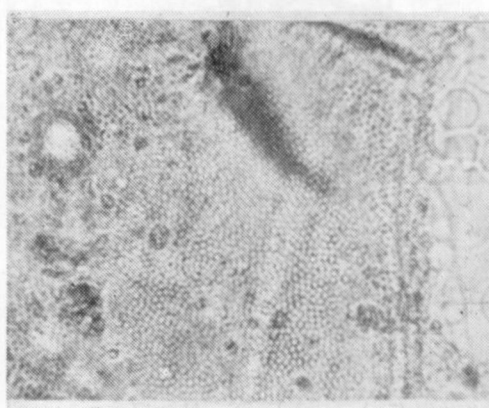


Fig. 11 *Acaulospora elegans*  
spore wall (x 1500)

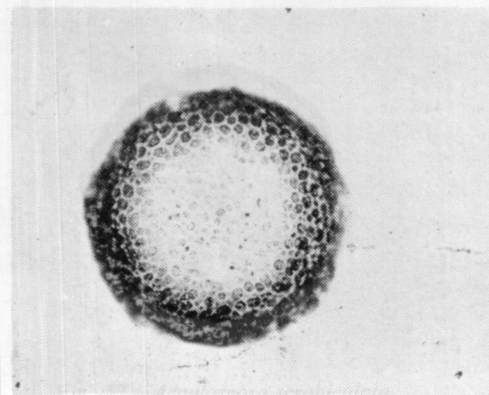


Fig. 12 *Acaulospora scrobiculata*  
Entire spore showing pitted  
spore wall surface (x 500)

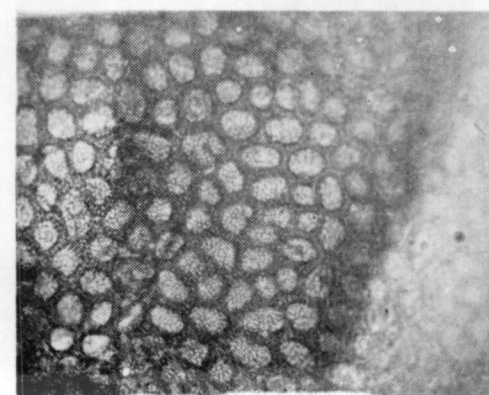


Fig. 13 *Gigaspora nigra*  
Spore wall details  
(x 1800)

Mycorrhizal association – not observed.

*Glomus* species (Fig. 7)

Found in Matale District. Chlamydospores are borne in loose aggregations or free in soil. Interwoven hyphae thick walled (2 – 3  $\mu\text{m}$ ). Chlamydospores 155 x 184  $\mu\text{m}$  diam., globose to subglobose, reddish brown in colour. Spore wall dark brown, laminated, perforations present, thickness 10 – 12  $\mu\text{m}$ . Subtending hyphae of simple type, fairly long. It has a twisted or wavy appearance. Entire spore surface is roughened with adherent debris. This is more prominent near the spore base, spore wall thickening extends into the subtending hyphae, pore not occluded.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants

*Glomus* species (Fig. 8)

Found in Matale soils. Sporocarps not observed, chlamydospores found singly in soil. Globose to subglobose, oval or pale yellow 75 x 100  $\mu\text{m}$  diam. Spore walls are roughened due to adherent debris. Comparatively stout subtending hyphae (10 – 15  $\mu\text{m}$  diam). Spore walls highly thickened near the spore base but spore is not occluded. Spore wall thickening extends up to about 14  $\mu\text{m}$  into the hyphae. In some spores a curved septum seen in the subtending hyphae at about 32 – 36  $\mu\text{m}$  away from the point of attachment

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants

*Glomus* species (Fig. 9)

Found in Kegalle and Galle Districts. Sporocarps were not observed. Chlamydospores borne free in soil, 92 x 123 – 123 x 153  $\mu\text{m}$  diam, pale yellow to brownish yellow or golden yellow, regularly oval or rarely spherical. Spore surface very smooth, sometimes spore contents appear to be reticulate. Spore wall laminated 3 – 4  $\mu\text{m}$  thick, outermost layer very fragile and easily separable, radial fissures rarely seen. Spores appear to be sessile with no trace of subtending hyphae seen.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

Subtending hyphae may have got detached from the spores during the wet - sieving process. Since no hyphal attachment was observed, this species may not come under the Genus *Glomus*. However, it is placed under this Genus because all the other characters of the spores are very similar to the spores of the Genus *Glomus*.

*Acaulospora elegans* Trappe & Gerd (Gerdemann and Trappe, 1974) (Figs. 10,11)

Found in Nakiyadeniya Estate (Galle District). Sporocarps not observed. Spores forming singly in soil, borne laterally on a hypha 30 – 35  $\mu\text{m}$  diam., terminating nearby in an ellipsoid to globose vesicle. Vesicles 150 – 200  $\mu\text{m}$  diam with pale brown walls which collapse at spore maturity. Mature spores, become detached while wet-sieving; therefore, these spores very frequently appear to be sessile. Spores 217 x 246  $\mu\text{m}$  in diam, globose to subglobose or ellipsoid, dark brown to red brown; surface ornamented with crowded, light brown spines, soon developing an alveolate reticulum of hyaline ridges superimposed on the spines, reticulum rarely complete. Spore wall continuous except for the occluded opening, thickness 10 – 12  $\mu\text{m}$ . Hyphae below the spore attachment long tapered to abruptly attenuated.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

*Acaulospora scrobiculata* (Trappe 1977) (Fig. 12)

Found in Kalutara and Matale Districts. Sporocarps unknown, Azygospores forming singly in soil, borne laterally on a wide, thin walled hypha that terminate near-by in a thin walled vesicle. Vesicle globose 150  $\mu\text{m}$  diam, becoming empty and collapsing at spore maturity. Spores globose to subglobose 220 x 250  $\mu\text{m}$  olive brown at maturity. Inner surface of the spore wall is more yellowish. Spore surface evenly pitted with depressions (1 – 2  $\mu\text{m}$ ), separated by ridges 3  $\mu\text{m}$  thick, the mouth of the depressions circular, elliptical or frequently polygonal. Spore wall is continuous except for the occluded opening.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

*Gigaspora nigra* (Nicolson and Schenck, 1979) (Fig. 13)

Found in Muwankande Estate (Kurunegala District). Sporocarps not observed. Azygospores black to dark brown, diameter 537 – 530  $\mu\text{m}$ . Spore wall consists of two layers, the outer wall black, pitted with large pores overlaying the smaller pores of the inner wall. Diameter of a large pore is about 7 to 7.5  $\mu\text{m}$ . Pores of the outer wall are very characteristic in that they are very regularly arranged and polygonal in shape. Azygospores borne laterally on a bulbous suspensor-like cell (35  $\mu\text{m}$ ), with a narrow hypha extending from it. Spore walls are continuous except for a small occluded pore.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

*Gigaspora gigantea* (Nicolson and Gerdemann) Gerdemann and Trappe (1974) (Fig. 14)

Found in Lowmont and Hedigalla Estates (Kalutara District) Azygospores formed singly in soil, 400 x 415 – 500 x 508  $\mu\text{m}$  diam, globose to subglobose or ellipsoid, greenish yellow when fresh becomes brownish when mounted in lactophenol. Azygospores borne terminally on a bulbous suspensor-like cell (46 – 48  $\mu\text{m}$  diam), giving rise to a slender hypha that projects to the spore. Subtending hyphae are septate below the apex. Spore wall consists of two layers, outer layer is fragile and easily separable. Inner wall 10 – 12  $\mu\text{m}$  thick. Spore wall is continuous except for an occluded pore at the spore attachment.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

*Gigaspora* sp

Found in Lowmont and Hedigalla Estates (Kalutara District) Azygospores formed singly in soil, 215 – 250  $\mu\text{m}$  diam, hyaline, globose to subglobose. Spores contain large numbers of tiny oil globules. Spore wall readily separable into an inner and outer wall. Outer wall brittle, thickness upto 4.7  $\mu\text{m}$ , inner wall laminated 7.2  $\mu\text{m}$  thick. Spores borne laterally on a suspensor-like cell, 30 – 36  $\mu\text{m}$  broad, clavate, the walls slightly thickened. Subtending hyphae septate below the swollen apex, vesicles in soil, borne on coiled hyphae in clusters, 20  $\mu\text{m}$  diam, thin walled, hyaline.

ENDOMYCORRHIZAS OF SOILS OF SRI LANKA  
ENDOMYCORRHIZAS OF SOILS OF SRI LANKA

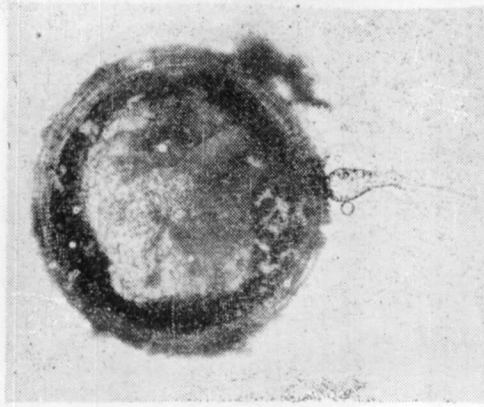


Fig. 14 *Gigaspora gigantea*  
(x 500)

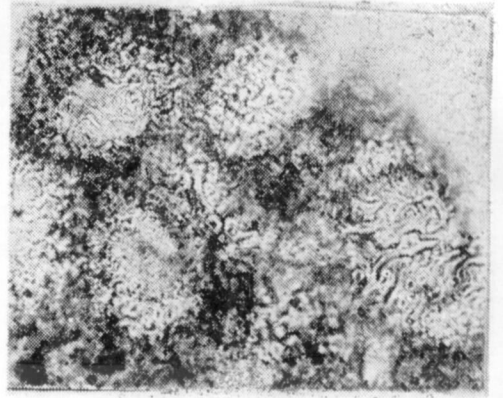


Fig. 15 *Sclerocystis sinosa*  
Surface view of the sporocarp  
(x 1600)

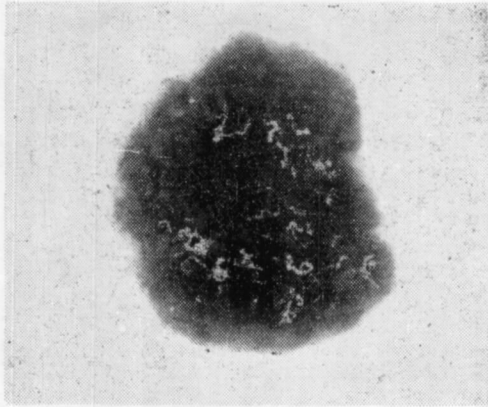


Fig. 16 *Sclerocystis coremioides*  
Sporocarp cut opened to  
show spore arrangement  
(x 500)

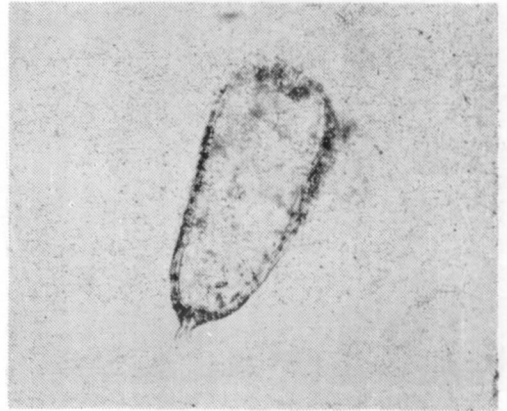


Fig. 17 *Sclerocystis coremioides*  
Isolated spore  
(x 660)

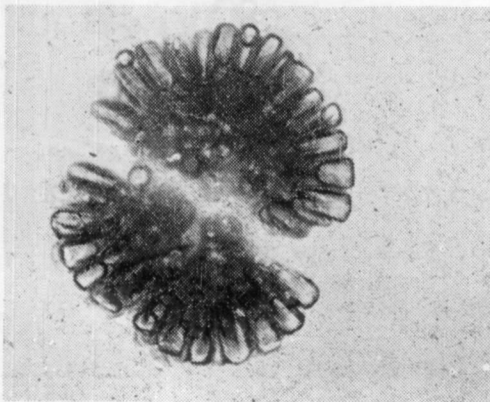


Fig. 18 *Sclerocystis clavispora*  
Sporocarp cut open to show  
spore arrangement (x 800)



Fig. 19 *Sclerocystis clavispora*  
Isolated spore  
(x 1500)

A. H. R. JAYARATNE  
A. H. R. JAYARATNE

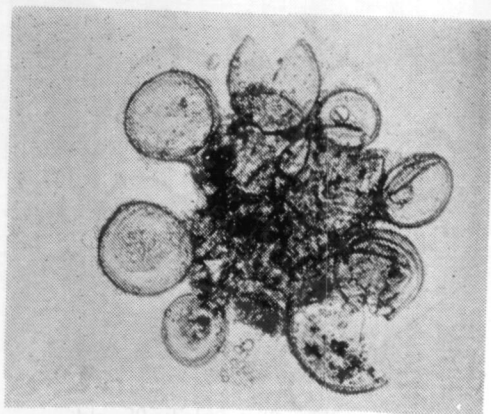


Fig. 20 *Sclerocystis rubiformis*  
Entire sporocarp  
(x 800)

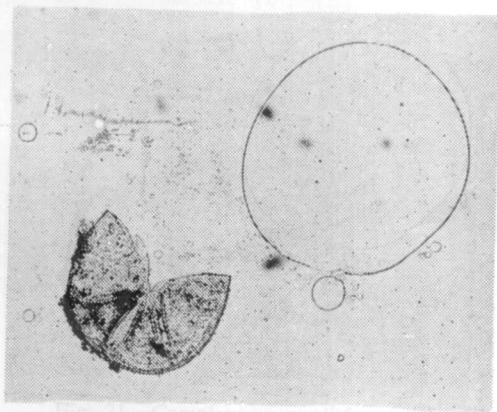


Fig. 21 *Complexipes moniliformis*  
Note the release of a  
large oil globule  
(x 500)

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

This spore type is very similar to *Gigaspora gilmorei* described by Trappe and Gerdemann (1974), but the suspensor-like cell is never light brown and it does not appear as in the case of *Gigaspora gilmorei*. Therefore most possibly this could be a different variety or a strain of *Gigaspora gilmorei* or could be a new species.

*Sclerocystis sinosa* (Gerdemann and Bakshi, 1976) (Fig. 15)

Found in Matale and Galle Districts. Sporocarps globose to subglobose, 385 x 480  $\mu\text{m}$ , brown to black in colour. Peridium composed of thick walled sinuous hyphae. Peridium thickness up to 12  $\mu\text{m}$ . Chlamydospores yellow 48 x 60 – 83 x 72  $\mu\text{m}$ , obovate, fusiform or clavate, radiating out in a single layer from a central plexus of hyphae. Spore wall thickness 3 – 4  $\mu\text{m}$ , very short subtending hyphae with a diam up to 7 – 12  $\mu\text{m}$ . Spore wall thickening extends into the subtending hyphae.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

*Sclerocystis coremioides* (Berk & Broome 1975) (Figs. 16,17)

Found in Matale and Kurunegala soils. Sporocarps globose with a short stalk, 600 – 615  $\mu\text{m}$ , black in colour. Spores arranged in a single orderly layer around the spore free central plexus of hyphae. Thick peridium present. Very often outer surface is roughened with adherent debris. Chlamydospores yellow in colour, 107 x 110  $\mu\text{m}$  sub-globose to pulvinate, short subtending hyphae, 9  $\mu\text{m}$ , diam. Spore wall thickening does not extend into the subtending hyphae.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

*Sclerocystis clavispora* (Trappe, 1977) (Figs. 18,19)

Found in Muwankande Estate (Kurunegala District). Sporocarps globose to subglobose 320 – 250  $\mu\text{m}$ , brownish black to black, minutely verrucose from exposed tips of spores formed radially in a single, tightly packed layer around a central plexus of hyphae; base indented; peridium lacking. Chlamydospores brown 43 x 45 – 10 x 24  $\mu\text{m}$ , clavate to subcylindric, tapering to a hyphal attachment 5 – 6  $\mu\text{m}$  diam. Spore walls 1.5 – 2.0  $\mu\text{m}$  thick on the sides, at the spore apex thicken to 12 – 15  $\mu\text{m}$ . Central plexus 100 – 110  $\mu\text{m}$  diam., of tightly interwoven, pale brown thin walled hyphae.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

*Sclerocystis rubiformis* – Gerdemann and Trappe 1974 (Fig. 20)

Found in Kalutara, Matale, Kegalle and Galle Districts. Sporocarps brown, subglobose 185 x 230  $\mu\text{m}$ ; consisting of a single layer of chlamydospores surrounding a central plexus of hyphae, resembling a miniature blackberry. Peridium completely absent. Chlamydospores brownish yellow to brown, ellipsoid or subglobose 54 x 66  $\mu\text{m}$ . Spore wall laminate 2 – 3  $\mu\text{m}$  thick, more brownish. Subtending hyphae with thick walls (7.5  $\mu\text{m}$ ) with a small spore opening into the spore.

Mycorrhizal association – forms VA mycorrhizae with *Pueraria* plants.

*Complexipes moniliformis* Walker, Mycotaxon (Mosse and Bowen, 1968) (Fig. 21)

Found in Matale soils. Sporocarps not observed. Spores borne singly in soil, pale yellow,  $125 \times 154 \mu\text{m}$  diam. Spore walls roughened with adherent debris. Characteristic pattern of regularly distributed depressions are seen on the spore wall. These depressions are polygonal in shape. Spore contains large amount of oil globules. Spore wall thickness  $4 - 7 \mu\text{m}$ , laminated, occasionally radial fissures seen. Subtending hyphae not observed.

Mycorrhizal association – not observed.

VA mycorrhizal spores occurred in all the soil samples examined. Spore numbers vary considerably from site to site. There was no definite pattern observed in the variation of the spore numbers and the age group of the rubber plantation. These vary from 190 to 4280 per 50 g of dry soil. *Glomus* species are apparently the most common of the VA endophytes found. *Acaulospora* species are also frequent in all six locations. *Gigaspora* and *Sclerocystis* species are the least abundant (Table 1). There is a positive correlation between number of mycorrhizal spores and percentage moisture content within locations (Table 2). Spore numbers are also negatively correlated to the available phosphorus content in soil (Table 3). No correlation was observed between spore numbers and soil pH or percentage root infection of the roots collected from the soil samples.

Table 1. Mean number of different endomycorrhizal spores per 50 g of oven dried soil

Genera location	<i>Glomus</i> sp	<i>Acaulospora</i> sp	<i>Gigaspora</i> sp	Number of <i>Sclerocystis</i> sporocarps
Hedigalla	1683	131	8	3
Lowmont	1229	95	8	Nil
Nalanda	859	15	4	2
Parambe	498	11	2	Nil
Muwankande	431	16	3	4
Nakiyadeniya	1896	12	5	2

Table 2. Percentage of moisture in surveyed soil samples

Location/site	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>
Hedigalla	5.0	22.0	19.0	10.0	13.0
Lowmont	6.3	11.0	6.5	9.9	5.1
Nalanda	3.3	2.1	4.5	8.0	—
Parambe	12.0	21.0	14.0	5.0	—
Muwankande	2.4	7.5	7.0	6.0	5.0
Nakiyadeniya	15.0	18.0	10.0	19.0	17.0

Correlation coefficient between percentage soil moisture and spore number — 0.45226

Table 3. Available phosphorus content of soils  
(NaHCO<sub>3</sub> extractable P : mg/kg)

Location/site	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>
Hedigalla	38.2	28.0	34.6	55.5	18.4
Lowmont	20.6	64.9	56.4	32.0	24.5
Nalanda	38.1	120.3	118.3	46.7	—
Parambe	74.6	58.7	62.2	82.2	—
Muwankanda	46.3	60.8	88.2	95.6	44.1
Nakiyadeniya	48.4	52.1	55.7	36.0	10.8

Correlation coefficient between available phosphorus content and spore numbers – 0.45821

This survey illustrates the variability of the VA mycorrhizal population in rubber growing soils of Sri Lanka, which are largely unrelated, to geographical features. All four genera of the family *Endogonaceae* that forms VA mycorrhizae were found. Of these *Glomus* species were the most abundant in all sites. This is similar to many early reports for several crops, associated with VA mycorrhizae (Hayman, 1970; Abbott and Robson, 1977; Kruckelmann, 1975; Mason, 1964). Since all the spore types isolated were multiplied in sand cultures (Leonard jars) grown with *Pueraria* plants and produced VA infection on roots, it is definite that all these spore types are VA mycorrhizal.

Of the species observed, *Glomus multiculis*, *Glomus macrocarpus*, *Glomus monosporus*, *Acaulospora elegans*, *Acaulospora scrobiculata*, *Gigaspora nigra*, *Gigaspora gigantea*, *Gigaspora gilmorei*, *Sclerocystis sinosa*, *S. coremooides*, *S. clavispora* and *Complexipes moniliformis* have not previously been reported in rubber growing soils of Sri Lanka. Of these, *Glomus monosporus*, *Acaulospora elegans*, *Acaulospora scrobiculata*, *Gigaspora nigra*, *Gigaspora gigantea*, *Gigaspora gilmorei*, *Sclerocystis coremooides* and *Complexipes moniliformis* have not been found before in Sri Lanka.

The number of endomycorrhizal fungal spores and the amount of available phosphate in soil was negatively correlated. This supports the findings of Hayman (1975) who showed that phosphate additions decreased VA mycorrhizal spore numbers, and that maximum spore numbers were obtained at intermediate levels of phosphate around 20 mg, NaHCO<sub>3</sub> – extractable P/kg of soil. Mosse and Jones (1968) observed a similar inverse correlation between spore numbers and nitrogen fertilizers.

Soil pH and root percentage infection did not show a direct correlation to spore numbers; but some studies have reported that spore numbers increased as soil pH increased (Kruckelmann, 1975; Read *et al*, 1976). There can be some influence of soil pH on VA mycorrhizal spore numbers in rubber growing soils but these influences may be masked by other variable soil parameters such as texture, soil nutrients and soil organic matter. Others have reported similar results where no relationship between soil pH and VA mycorrhizal spore numbers were observed (Abbott and Robson, 1977; Nicolson, 1960). The absence of a correlation between spore numbers and percentage root infection could be attributed to the differences in populations of non-sporing endophytes in the soil and differences in amount of non-spore inoculum such as hyphae and mycorrhizal root fragments.

It will be interesting to investigate whether these VA mycorrhizal fungi which have been established in cultures infect the rubber roots too, and if so the growth responses of these plants due to infection.

#### ACKNOWLEDGEMENT

This research was aided by the National Science Council of Sri Lanka and the International Foundation for Science. The author is grateful to Dr O. S. Peries, the Director of Rubber Research Institute of Sri Lanka for providing necessary facilities to carry out this project and help with the preparation of the manuscript. The author is also thankful to Dr U. P. de S. Waidyanatha for supervising this work.

#### REFERENCES

- ABBOTT, L. K. and ROBSON, A. D. (1977). The distribution and abundance of VA endophytes in some Western Australian soils. *Aust. J. Bot.* **25**, 515 – 522.
- ABBOTT, L. K. and ROBSON, A. D. (1982). The role of vesicular-arbuscular mycorrhizal fungi in agriculture and the selection of fungi for inoculation. *Aust. J. Agric. Res.* **33**, 389 – 408.
- BAYLIS, G. T. S. (1967). Experiments on the ecological significance of Phycomycetous mycorrhizas. *New Phytol.* **66**, 231 – 243.
- DICKMAN, S. R. and BRAY, R. H. (1940). Colorimetric determination of phosphate. *Ind. Eng. Chem. Anal. Ed.* **12**, 665 – 668.
- GERDEMANN, J. W. (1955). Relation of a soil-borne spore to Phycomycetous mycorrhizal infections. *Mycologia* **47**, 619 – 632.
- GERDEMANN, J. W. (1961). A species of Endogone from corn causing vesicular-arbuscular mycorrhiza. *Mycologia* **53**, 254 – 261.
- GERDEMANN, J. W. and NICOLSON, T. H. (1963). Spores of mycorrhizal Endogone species, extracted from soil by wet-seiving and decanting. *Trans. Brit. Mycol. Soc.* **46**, 235 – 244.
- GERDEMANN, J. W. and TRAPPE, J. M. (1974). The *Endogonaceae* in the Pacific Northwest. *Mycologia Mem.* **5**.
- GRAY, L. F. and GERDEMANN, J. W. (1973). Uptake of sulphur-35 by vesicular-arbuscular mycorrhizae. *Plant and Soil* **39**, 687.
- MCLLVEEN, W. D. and SPOTTS, R. A. and DAVIS, O. D. (1975). The influence of soil zinc on nodulation, mycorrhizae and ozone sensitivity of Pinto Bean, *Phytopathology* **65**, 645.
- MOSSE, B. (1973). Advances in the study of vesicular-arbuscular mycorrhiza. *Ann. Rev. Phytopathology* **11**, 171 – 196.

- MOSSE, B. (1977). Plant growth responses to vesicular-arbuscular mycorrhiza X. Responses of stylosanthes and maize to inoculation in unsterile soils. *New Phytol.* **78**, 277 - 288.
- MOSSE, B. and BOWEN, G. D. (1968). The distribution of *Endogone* spores in some Australian and New Zealand soils and an experimental field soil at Rothamsted. *Trans. Brit. mycol. Soc.* **51**, 485 - 492.
- Pannabokke (1967). Soil Science. The soils of Ceylon and use of fertilizers. CAAS, Colombo.
- PHILLIPS, J. and HAYMAN, D. S. (1970). Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection. *Trans. Brit. mycol. Soc.* **55**, 158 - 161.
- POWELL, E. L. (1975). Potassium uptake by mycorrhizas. In F. E. Sanders, B. Mosse and P. B. Tinker (eds.) *Endomycorrhizas*. Academic Press Inc. London.
- RHODES, L. H. and GERDEMANN, J. W. (1975). Phosphate uptake zones of mycorrhizal and non-mycorrhizal onions. *New Phytol.* **75**, 555 - 561.
- ROSS, J. P. (1971). Effect of phosphate fertilization on yield of mycorrhizal and non-mycorrhizal soyabeans. *Phytopathology* **61**, 1400 - 1403.
- WAIDYANATHA, U. P. de S. (1978). Mycorrhizae of *Hevea* and Leguminous ground covers in rubber plantations. *Provisional Report 1, Tropical Mycorrhiza, Kumasi, Ghana*.
- WAIDYANATHA, U. P. de S., YOGARATNAM, N. and Ariyaratne, W. A. (1979). Mycorrhiza infection on growth and nitrogen fixation of *Pueraria* and *Stylosanthes* and uptake of phosphorus from two rock phosphates. *New Phytol.* **82**, 147 - 152.
- WASTIE, R. L. (1965). The occurrence of an *Endogone* type of endotrophic mycorrhiza in *Hevea brasiliensis*. *Trans. Brit. mycol. Soc.* **48**, 167 - 178.