

SPECIES AND MYCORRHIZAL INFECTIONS OF NEW ZEALAND ENDOGONACEAE

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Species of the New Zealand Endogonaceae are described, including four new species and one new combination in *Glomus* and one new species in *Gigaspora*. The morphology of synthesized vesicular-arbuscular mycorrhizas was affected by the nutritional status of the host, the host species, and the species of fungus. Except in the case of the polymorphic vesicles associated with *Acaulospora* infections and the external vesicles of *Gigaspora* species, the addition of characters of the mycorrhizal infections to the species diagnoses does not seem warranted. Spore numbers tended to be low in bush soils but high in disturbed areas and under seral vegetations, and reasons for this are discussed.

A substantial revision of the taxonomy of the Endogonaceae has recently been completed by Gerdemann & Trappe (1974). According to their classification the genera are: *Endogone*, *Gigaspora*, *Acaulospora*, *Glomus* (including *Rhizophagus*, *Sphaerocreas* and *Stigeosporium*), *Sclerocystis* (including *Xenomyces* and *Ackermannia*), *Glaziella* and *Modicella*.

Gerdemann & Trappe restricted their attentions to the Pacific North-west area of the U.S.A., although they noted extralimital species. The only published account for New Zealand species of the Endogonaceae is that given by Mosse & Bowen (1968*a*). In this paper descriptive names were assigned to spore types. Unfortunately in some cases the descriptions of spore types are incomplete and specific names cannot always be chosen. A survey and revision of the N.Z. species of the Endogonaceae was therefore undertaken.

Vesicular-arbuscular mycorrhizal (VAM) infections can roughly be divided into two groups: those with coarse hyphae – *Rhizophagus populinus* (Dangeard, 1900) – and those with fine hyphae – the fine endophyte or *R. tenuis* (Greenall, 1963). With improved techniques for staining and observing infections in whole roots (Bevege, 1968; Fassi, Fontana & Trappe, 1969; Gerdemann, 1965; Phillips & Hayman, 1970) it has become apparent that different types of coarse infection are produced by *Glomus*, *Gigaspora* and *Acaulospora* (Nicolson & Gerdemann, 1968; Mosse, pers. comm.; Gerdemann & Trappe, 1974). However, the work of Mosse (1973) and a preliminary field survey showed that there is a wider range of infection types than can be accounted for merely

by differences between *Glomus*, *Gigaspora*, *Acaulospora*, and the fine endophyte.

MATERIALS AND METHODS

Soil samples were collected from a variety of areas (Fig. 1). Particular attention was paid to the podocarp, *Weinmannia racemosa* Linn. f. (Cunoniaceae), *Metrosideros umbellata* Cav. (Myrtaceae) communities of the Tautuku and William King Reserves in the Catlins and the reserved bush in the Akatore Forest. Samples were either put in pots and planted with *Coprosma robusta* Raoul. to stimulate the activity of mycorrhizal fungi and hence raise the number of spores, or were wet sieved immediately (Gerdemann & Nicolson, 1963). After sieving, fractions retained on 250, 105 and 53 μm sieves were observed for Endogonaceous spores. Spores and sporocarpic material were mounted in lactophenol and deposited in the herbarium of Plant Diseases Division, Department of Scientific and Industrial Research, Auckland. Hall numbers in the text refer to these collections. Isotypes or paratypes have been deposited in the Herbarium, Oregon State University. The descriptions in this paper are drawn up from N.Z. material. Where there is a good fit with a taxon described by Gerdemann & Trappe they are limited to key characteristics. A record outside a normal size range is bracketed.

Where it was proposed to section spores, fresh fungal material was fixed using either 3% glutaraldehyde for 24 h at 0 °C (Ned Feder & O'Brien, 1968) or 5% acrolein for 24 h at 0 °C (Mosse, 1970), dehydrated in methyl cellulose, and embedded in glycol methacrylate (Ned Feder & O'Brien, 1968). Sections were cut between 0.5 and 5 μm on a Huxley Ultratome, transferred from the

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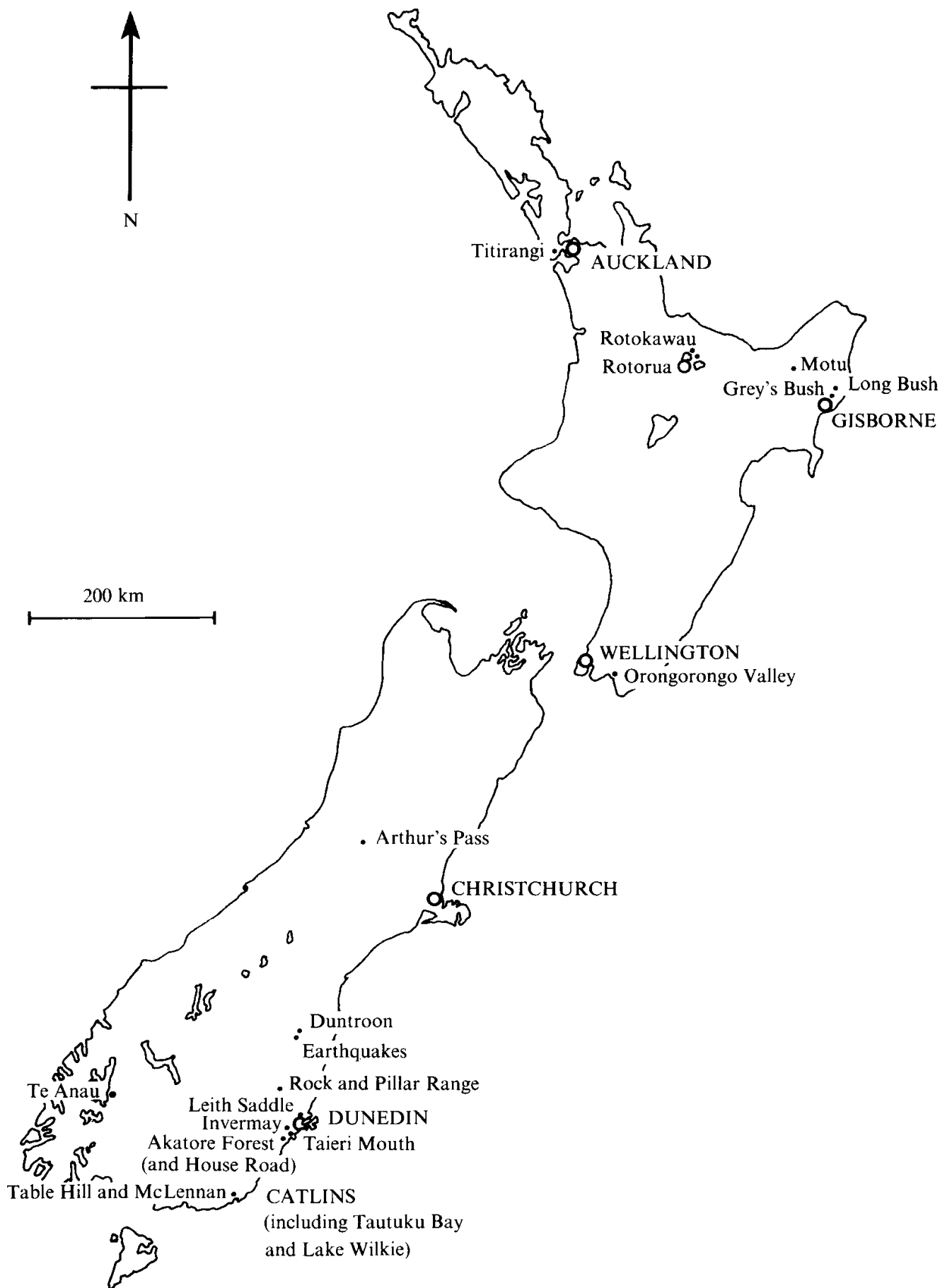


Fig. 1. Soil collection sites in New Zealand. Campbell Island is approximately 800 km south of Dunedin.

knife edge to a drop of water on a slide, air dried at room temperature, and mounted in paraffin oil. Best results were obtained if the glycol methacrylate resin was hardened for 48 h at 60 °C and the blocks stored at room temperature for several months before sectioning.

Two methods were used to establish VAM in the glasshouse:

(i) Non-mycorrhizal seedlings of *C. robusta*, *W. racemosa*, *M. umbellata* and *Lycopersicon esculentum* Mill raised in a steamed soil low in available P, were transplanted to pots of the same soil and their roots inoculated (Hall, 1975) with a single spore, groups of like spores, or a single sporocarp.

(ii) Non-mycorrhizal seedlings of *C. robusta*, *M. umbellata*, and *W. racemosa* were potted in unsteamed soils and transplanted to a steamed soil low in available P after the seedlings had resumed growth and presumably become infected. Up to 18 months later, their roots were washed clean of soil, cleared and stained (Phillips & Hayman, 1970), and teased out in lactophenol on microscope slides before squashing with coverslips. The rhizospheres and soil in the vicinity of the roots were observed for viable spores. Note was made of infections in plants volunteering in the unsteamed soils.

Only those hosts which have formed VAM with a particular fungus at the University of Otago Botany Department are noted in the text.

In field surveys, soils from the rhizospheres of collected roots were sieved and examined for spores and the roots washed and stained. Soils with extremely low or high numbers of spores were noted. Soil names refer to New Zealand D.S.I.R. Soil Bureau Bulletin Number 27 (1968).

Photomicrographs were made using a Miranda Sensomat and either a standard microscope or a Reichert Diapan fitted with Nomarski Interference. Only a selection of them are reproduced here. However, sets of colour slides of the species described in this paper and others described by Gerdemann & Trappe (1974), Gerdemann & Bakshi (1976) and Becker & Hall (1976) have been deposited in the following herbaria: Oregon State University (Corvallis, Oregon), Farlow Herbarium (Harvard University, Cambridge, Massachusetts), Kew Herbarium (Richmond, Surrey, England), Plant Diseases Division Herbarium (D.S.I.R., Auckland, New Zealand) and Invermay Agricultural Research Centre (Private Bag, Mosgiel, New Zealand). Slide numbers in the text refer to these slide collections and Figure numbers to text Figures.

DESCRIPTIONS OF THE SPECIES

GLOMUS Tul. & Tul.

Glomus pallidus Hall, sp.nov. (Fig. 2-4, Slides 4.22.1-16)

Etymology: *pallidus* – pale, refers to the colourless sporocarps.

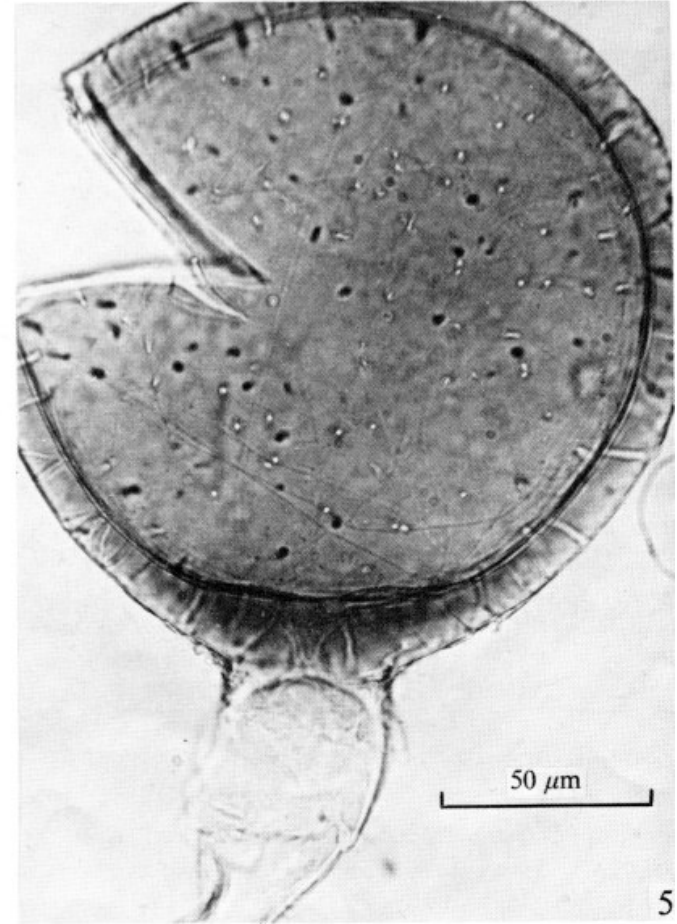
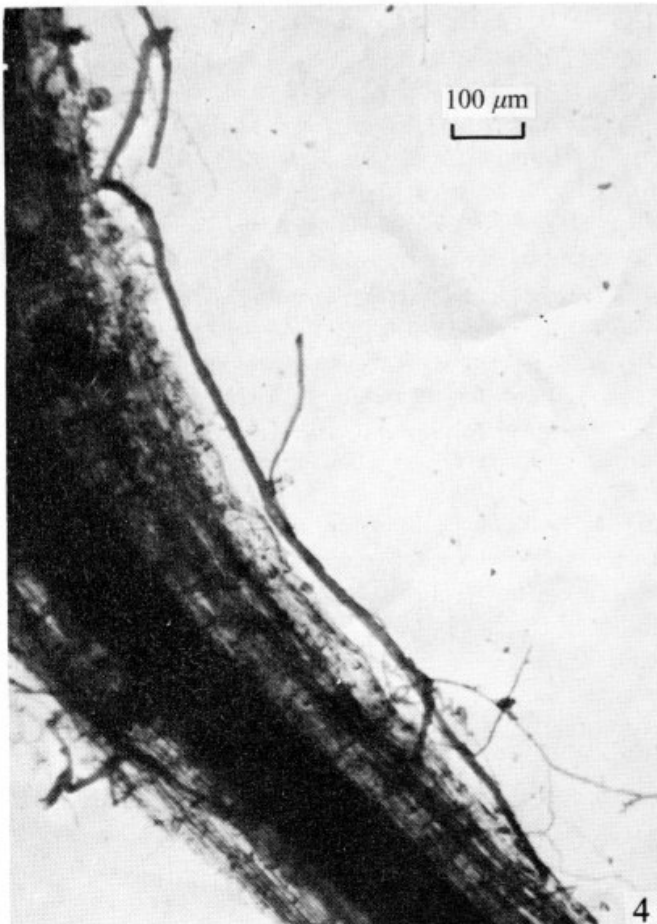
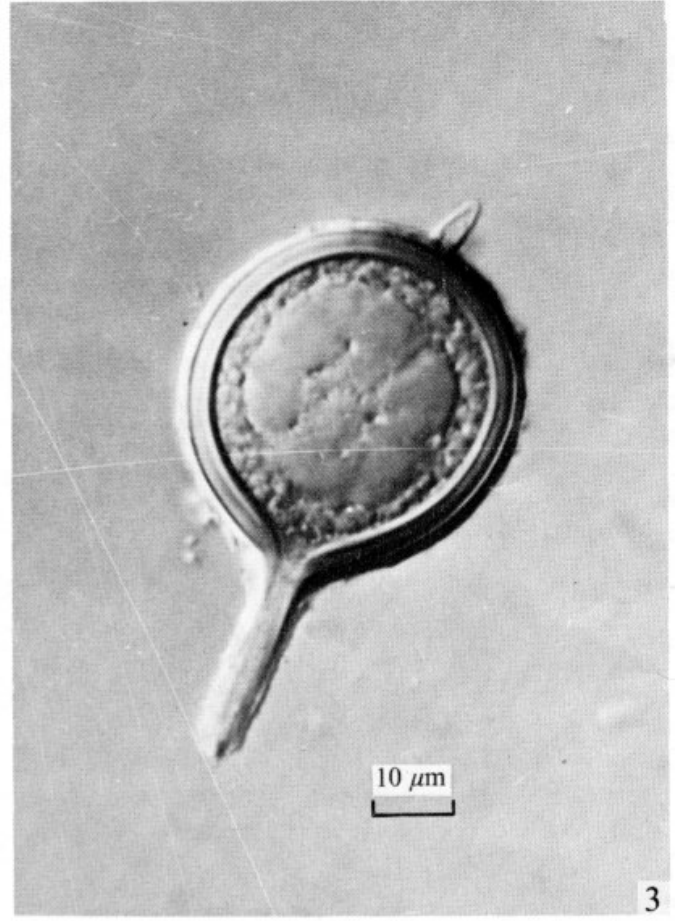
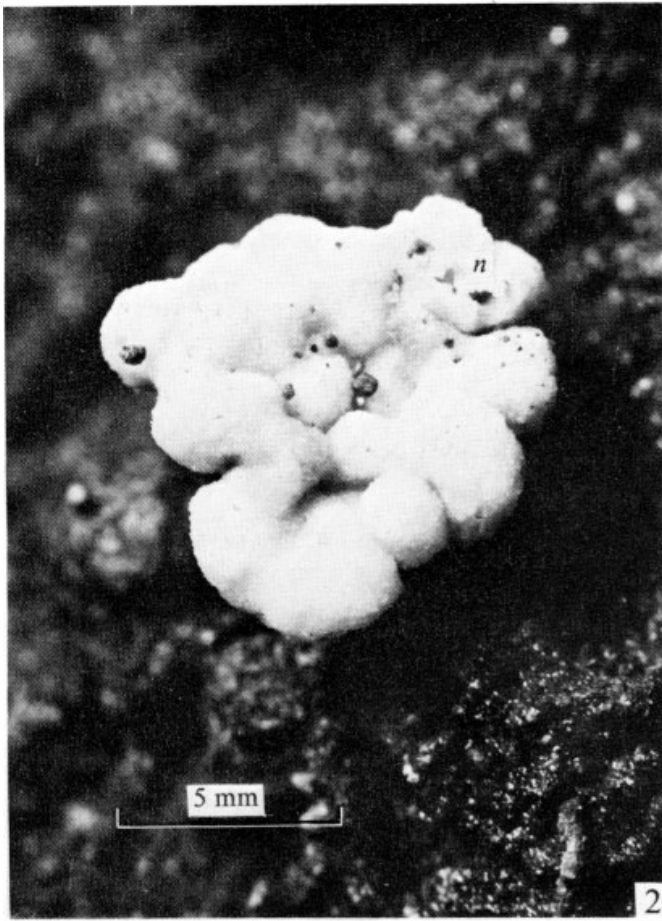
Sporae singulae vel laevis globis in solo vel sporocarpis lobatis vel irregularibus epigaeis, 1-25 mm diametro, solum aliquantum retinentibus formatae. *Sporocarpia* nova alba, senescentia pallide fulva, peridium incohatum aliquando. *Sporae* globosae vel subglobosae 32-78 × 28-68 μm diametro. *Tunica* 1-8 μm crassa senescens laminata. *Hyphae subtendentes* 5-15(-20) μm diametro, porus partim oclusus tunicis hyphae subtendentis, oclusus septo in aliquibus sporis maturis. Sporae novae sporocarpiorum in lateralibus ramis hypharum subtendentium sporarum senesciorum saepe formatae. Sporae intercalares propter germinationem in parte distali aliquando visae. Hyphae glebosae maturae et tunicae sporae et hyphae subtendentes laminatae.

Spores formed singly or in loose clusters in soil, or in lobed or irregular epigeous sporocarps, 1-25 mm diam, incorporating varying amounts of soil. *Sporocarps* white when young turning pale yellow with age, poorly developed peridium may be present. *Spores* globose to subglobose, 32-78 × 28-68 μm diam. *Wall* 1-8 μm thick becoming laminated with age. *Subtending hyphae* 5-15(-20) μm diameter with pore partially occluded by the walls of the subtending hypha, pore closed by septum in some mature spores. In sporocarps new spores often formed on lateral branches of subtending hyphae of older spores. Spores sometimes appear to be intercalary due to germination in distal region. Mature glebal hyphae, spore walls, and subtending hyphae laminated.

Specimens examined. Tautuku Beach, New Zealand, Hall 321 holotype, Hall 322, 257, 316, 320, 318, 333; Earthquakes, New Zealand, Hall 90.

This species repeatedly formed VAM with *Coprosma robusta*, *Metrosideros umbellata*, *Weinmannia racemosa* and *Leptospermum scoparium* J. R. et G. Forst. It differs from *Glomus microcarpus* Tul. & Tul. in having rather inconsistent dome-shaped septa in the subtending hyphae, a greater range in spore size overlapping with the lower limits of *G. fasciculatus* (Thaxter sensu Gerdemann) Gerdemann & Trappe and larger sporocarps. Sporocarps of this species have been seen on the surface roots of *Coprosma robusta*, *Weinmannia racemosa* and *Metrosideros umbellata*.

Infections formed by this species on *Coprosma robusta* are illustrated in Slides 4.22.7-16. Rhizomorphs (Fig. 4, Slide 4.22.14) are not characteristic of the phycomycetes but in this



species they are a regular feature often formed on the surface of roots.

Sporocarps sometimes turn a deep green due to the presence of *Hormidium* sp., *Chlorella* sp., *Stichococcus bacillaris* Naeg. and a small blue green alga. While these are common soil organisms they were often deeply embedded in the sporocarps and for this reason the possibility of an Endogoneaceous lichen cannot be ruled out.

In the field and in pot cultures, sporocarps may be contaminated with spores and sporocarps of *Sclerocystis rubiformis* Gerdemann & Trappe (Hall 318, 333). A small nematode often parasitizes sporocarps which leaves them hollow or perforated (Hall 320). When uninfected sporocarps were placed on plain, malt, or dextrose agars a slow growing mycelium was produced but this formed no reproductive structures.

Glomus magnicaulis Hall, sp.nov. (Fig. 5, Slides 4.12.1-3)

Etymology: *magnicaulis* – thick stemmed, referring to the wide subtending hyphae on the spores.

Sporae singulae in solo efformatae; brunneae materia aliena aliquanta adhaerenti; globosae vel subglobosae 125–175 μm diametro. *Tunica* duplex sporae, externa brunnea laminataque tenuiter nova, 9–20 μm crassa; interna ad 4 μm crassa, incolor vel pallide brunnea. *Hyphae subtendentes* 35–58 μm crassae, prope radicem saepe coartatae tenuiter. *Porus* 4–9 μm crassus. Obturamentum materiae tunicae in tunica interna hyphae subtendentis ad porum maturum omino oclusum. Prominentia lateralis ad 15 μm crassa extremo tumido hyphis subtendentibus aliquantarum sporarum.

Spores formed singly in soil; brown with varying amounts of adhering debris; globose to subglobose 125–175 μm diam. *Spore wall* double, outer brown and finely laminated in young spores, 9–20 μm thick; inner up to 4 μm thick colourless to light brown. *Subtending hyphae* 35–58 μm wide often slightly pinched in at the point of attachment. *Pore* 4–9 μm wide. *Plug* of wall-like material gradually built up on inner wall of subtending hypha till pore occluded completely at maturity. Subtending hyphae of some spores with a lateral projection up to 15 μm wide often with a swollen end.

Specimens examined. Leith Saddle, New Zealand, Hall 474 holotype, 38, 304; Akatore Forest, New Zealand, Hall 135; Lake Wilkie, New Zealand, Hall 148.

Spores failed to form VAM in three separate inoculation trials onto *Coprosma robusta*.

Mosse & Bowen (1968a) also described a wide-necked spore. However, they state that it was the same as *E. australis* Berk., which Thaxter combined with *E. macrocarpa*. The species described above differs from *Glomus macrocarpus* in having very wide subtending hyphae with pores occluded both by lateral wall thickening and a plug, and by having a thin inner wall. The lateral projections on the subtending hyphae are possibly early stages in the formation of another spore as is the case with *G. pallidus*.

Glomus invermaius Hall, sp.nov. (Fig. 6, Slides 4.11.1-2)

Etymology: *invermaius* – of Invermay, refers to the type locality.

Sporae hypogaeae 50–75 μm diametro, sporocarpis laxis ad 1 mm crassis formatae. *Peridium nullum*. *Tunica sporae* duplex, externa incolor, 1–1.5 μm crassa, interna pallide brunnea ad 3–6 μm crassa. *Tunica externa* perducta secus hypham subtendentem ad 100 μm . *Tunicae* individuae. *Hyphae subtendentes* 6–13 μm diametro incolores ad brunneae, prope locum colligationis tenuiter coartatae. *Porus* minor 1–4 μm lato, sine septo.

Spores hypogeous globose 50–75 μm diam, light brown to brown formed in loose sporocarps up to 1 mm across. *Peridium* lacking. *Spore wall* double, outer colourless, 1–1.5 μm thick, inner light brown to brown, 3–6 μm thick. *Outer wall* extending down the subtending hypha for up to 100 μm . Walls inseparable. *Subtending hyphae* 6–13 μm diam, colourless to brown, slightly pinched-in at the point of attachment. *Pore* 1–4 μm wide, without septum.

Specimens examined. Invermay, New Zealand, Hall 425 holotype; Long Beach, Dunedin, New Zealand, Hall 256.

Mycorrhizal associations unknown but spores associated with *Trifolium repens* L.

Glomus infrequens Hall, sp.nov. (Figs. 7, 8, Slides 4.10.1-6)

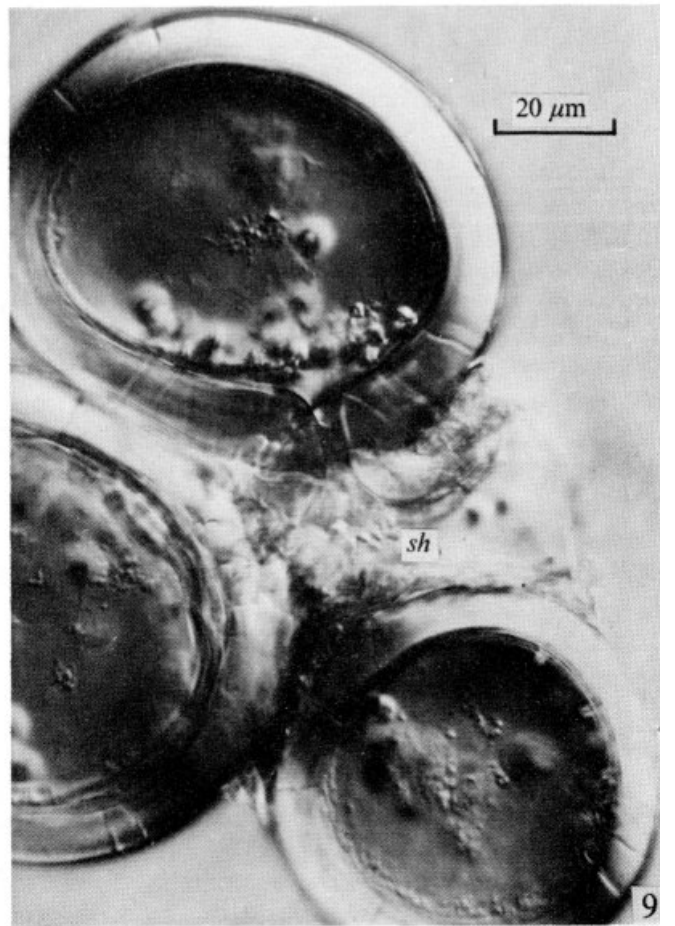
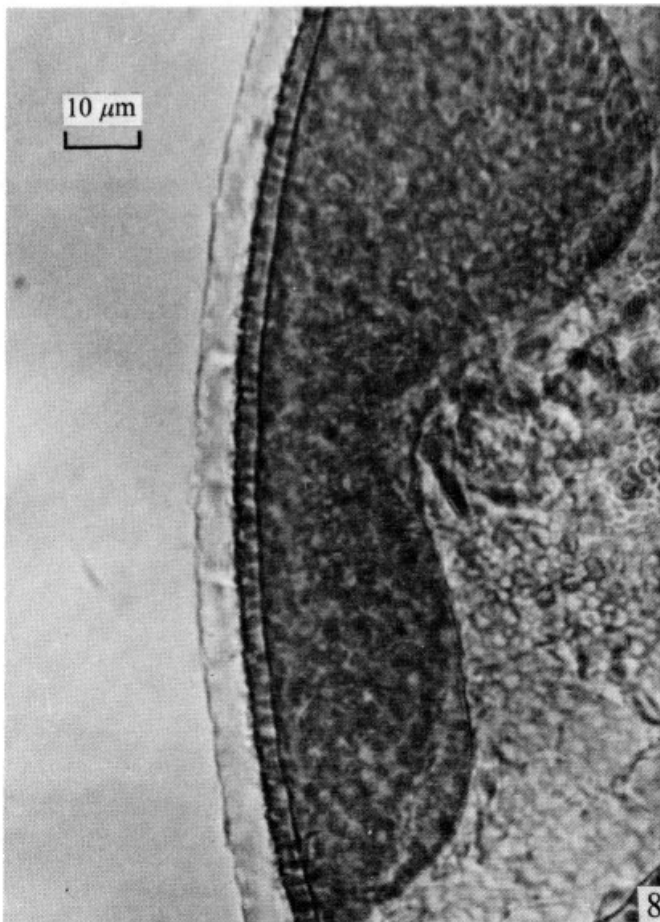
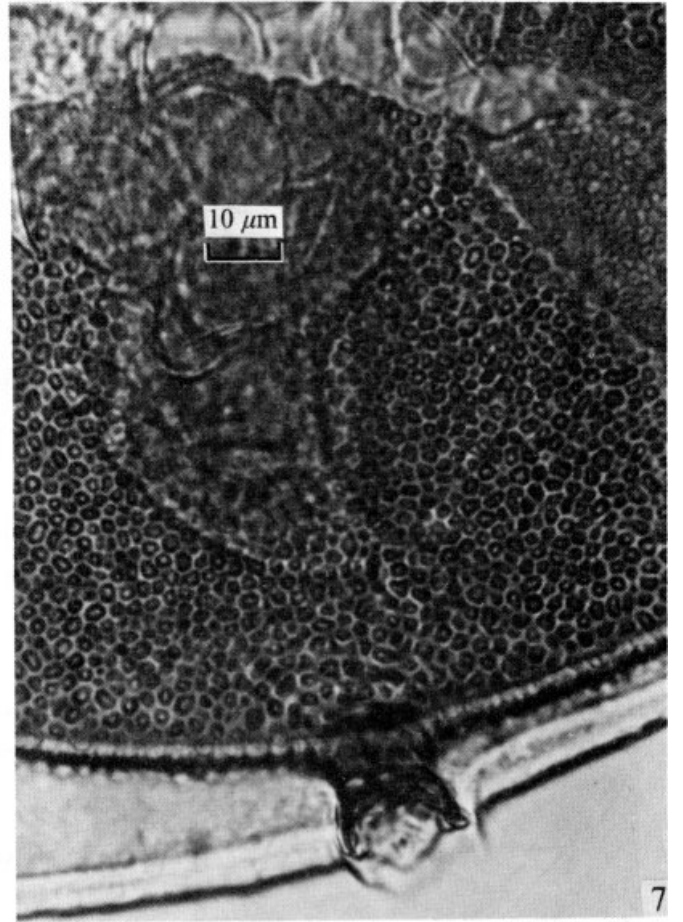
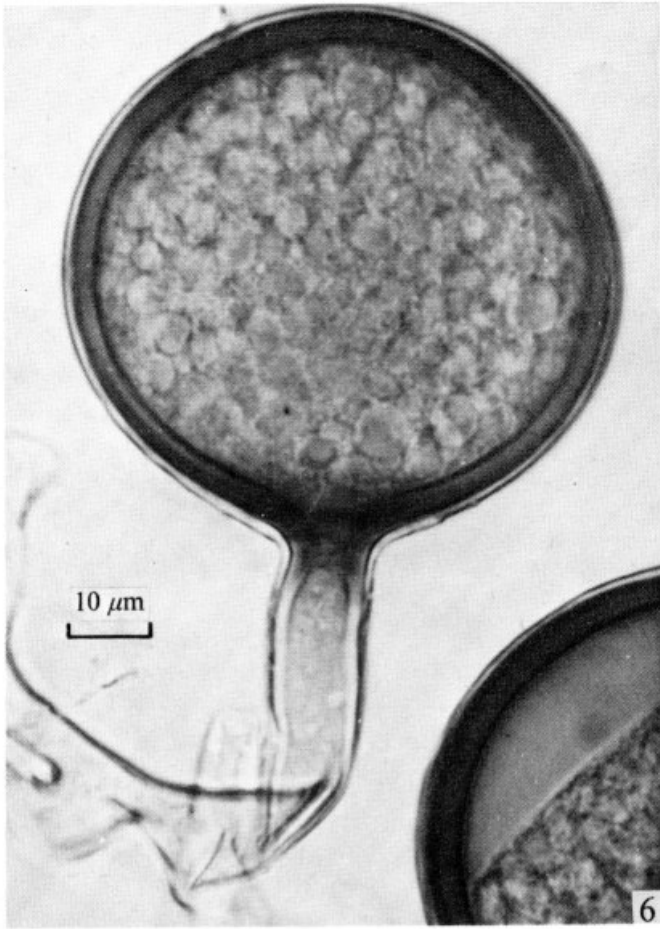
Etymology: *infrequens* – rare, refers to the limited number of spores in the soil of the type locality.

Fig. 2. *Glomus pallidus*. Small lobed epigeous sporocarp damaged by nematodes (*n*).

Fig. 3. *G. pallidus*. Germinating spore. Nomarski Interference.

Fig. 4. *G. pallidus*. Rhizomorphs and hyphae on the surface of a *Coprosma robusta* root.

Fig. 5. *Glomus magnicaulis*. A plug has formed in the pore between the spore and subtending hypha. The thin inner wall is just visible.



Sporae ectocarpae, globosae 170–225 μm diametro. *Tunicae* duplices, tunica externa incolor 4–10 μm crassa et interna pallide vel obscure brunnea 2–4 μm crassa; senescentes tenerascentes degenerantesque in sporis veteribus. Duae tunicae reticulo tunicae materiae, 1–3(–4) μm alto in superficie externa tunicae internae separantur. *Prominentiae* polygoniae a superficie visae ad 2 μm crassa, cum depressione in summis prominentiis. *Hyphae subtendentes* 14–18 μm diametro, pallide brunneae ad brunneae. *Septum* nullum.

Spores ectocarpic, globose 170–225 μm diam. *Walls* double with colourless outer layer, 4–10 μm thick and light to dark brown, inner 2–4 μm thick, decaying and becoming thin and degenerate in old spores. Projections of wall-like material 1–3(–4) μm high on the outer surface of the inner wall separates the two walls. *Projections* polygonal in surface view and up to 2 μm wide with a depression in their tops. *Subtending hyphae* 14–18 μm diam, pale brown to brown. *Septum* lacking.

Specimens examined. Leith Saddle, New Zealand, Hall 437 holotype; Long Bush, New Zealand, Hall 1, and House Road, Akatore Forest, New Zealand, Hall 130.

Mycorrhizal associations unknown.

GLOMUS CALEDONIUS (Nicol. & Gerdemann) Trappe & Gerdemann, *Mycologia Mem.* 5: 56 (1974). (Slides 4.2.1–2)

Spores ectocarpic and hypogeous or rarely in yellow epigeous sporocarps up to 500 μm diam. *Spores* globose yellow to light brown, 180–282 μm diam. *Spore wall* double; outer hyaline to pale yellow, 1–3 μm thick and easily removed; inner laminated and yellow to light brown, 6–11 μm thick. *Subtending hyphae* 10–24 μm diam. *Outer wall* forms a loose sleeve which may extend up to 35 μm down the subtending hypha. Cup shaped septum forms in the neck of subtending hypha towards maturity.

Collected from Orongorongo (Hall 266), Earthquakes (Hall, 99, 248), Tautuku Beach (Hall 226), and Lake Wilkie (Hall 178, 289).

GLOMUS CONVOLUTUS Gerdemann & Trappe, *Mycologia Mem.* 5: 42 (1974). (Slides 4.4.1–3)
Spores in bright yellow epigeous sporocarps up to

10 mm across, waxy when fresh, brittle when dry. Spores surrounded by a tightly woven mantle of hyphae up to 30 μm thick. *Spores* 45–105 μm diam with a colourless, finely laminated wall, 5–8(–12) μm thick. Spores filled with a yellow oil. *Subtending hyphae* 8–15 μm wide not expanded at the point of attachment; septum lacking but pore occluded in mature spores.

Specimen examined. Tautuku Beach, New Zealand, Hall 350.

Sporocarps collected from Rotokawau and Tikitere Thermal area (Hall 353 = McNabb 1856a) contain spores 40–75 μm diam, surrounded by mantles 7–20 μm thick. The mature spores tend to be in clusters which are separated by hyphae and immature spores. In all other respects these sporocarps resemble *G. convolutus* and it is considered that they are a small spored variety of this species.

GLOMUS FASCICULATUS (Thaxter sensu Gerdemann) Gerdemann & Trappe, *Mycologia Mem.* 5: 51 (1974). (Slides 4.5.1–10)

Spores hypogeous, formed singly, in loose aggregations or in brown compact or irregular sporocarps, sometimes formed in seed coats or in the carapaces of insects in the soil. *Sporocarps* up to 5 mm diam. *Spores* yellow to brown, globose, 70–120 μm diam. *Walls* 4–14 μm thick, not laminated. *Subtending hyphae* 8–16 μm diam. *Pore* 4–12 μm diam, not closed by a septum but partially occluded by the thickened walls of the spore and the subtending hypha.

Specimens examined. Long Bush, New Zealand, Hall 2; Tautuku Bay, New Zealand, Hall 170, 212, 317; Leith Saddle, New Zealand, Hall 37; Rock and Pillar Range, Orongorongo Valley, New Zealand, Hall 259, 262; Pineapple Track, Dunedin, New Zealand, Hall 61; Earthquakes, New Zealand, Hall 107; McLennan, New Zealand, Hall 344; House Road, New Zealand, Hall 124.

Lignituber-like ingrowths similar to those observed in *Glomus macrocarpus* var. *macrocarpus* (q.v.) are often observed in spores of this species and are probably due to attack by parasitic fungi. Ingrowths are not formed when dead or moribund spores are attacked.

Fig. 6. *Glomus invermaius*. Spore and subtending hypha showing thin, translucent outer wall and thick, coloured inner wall.

Fig. 7. *Glomus infrequens*. Base of spore showing subtending hypha and inner wall with surface polygonal projections.

Fig. 8. *G. infrequens*. Detail of two-layered wall showing thick, colourless outer and thinner, coloured inner.

Fig. 9. *Glomus fuegianus*. Sporocarp showing attachment of spores to the subtending hypha (*sh*). A plug is visible in the pore of one spore. Nomarski Interference.

Infections produced by *Glomus fasciculatus* spores from Tautuku Beach in *Coprosma robusta* growing in a soil low in P were generally composed of intercellular hyphae and arbuscles with few vesicles. However, those formed by spores from Campbell Island in the same soil and host were rather limited, with vesicles frequent and arbuscles rare.

The *Endogone fasciculata* described by Mosse & Bowen (1968a) for N.Z. is probably a species of *Sclerocystis*.

GLOMUS FUEGIANUS (Spegazzini) Trappe & Gerdemann, *Mycologia Mem.* 5: 58 (1974). (Fig. 9, Slides 4.8.1-4)

Spores formed in light brown to brown hypogeous sporocarps 145-300 μm diam, containing up to 15 spores. *Peridium* up to 50 μm thick composed of thick walled light brown hyphae up to 15 μm wide. *Spores* light brown to brown, globose to subglobose, 50-85 μm diam. *Spore walls* double; outer coloured 9-17 μm thick; inner colourless to light brown, up to 3 μm thick but not always obvious in young spores. Clusters of three to eight spores borne sessilely or on short hyphal stalks on a common subtending hypha. *Subtending hypha* irregular in shape due to appressed spores but up to 80 μm wide at its widest. Where a sporocarp contains more than one cluster of spores clusters separated by glebal hyphae.

Specimens examined. Akatore Forest, New Zealand, Hall 136; Lake Wilkie, New Zealand, Hall 139; Leith Saddle, New Zealand, Hall, 306, 457.

GLOMUS MACROCARPUS Tul. & Tul., *Giorn. Bot. Ital. Pl.* 1, 2: 63 (1845) var. **MACROCARPUS** (Slides 4.13.1-11 and 4.14.1-6)

Spores in small epigeous sporocarps or formed singly in the soil, usually globose, 100-350 μm diam. *Spore wall* yellow to brown, double in mature spores. Outer wall not separable from the inner. Outer wall 1-3 μm thick, inner 4-14 μm , not laminated. *Subtending hyphae* 12-25 μm diam, septum lacking.

Specimens examined. Earthquakes, New Zealand, Hall 291, 100; Akatore Forest, New Zealand, Hall 117; Tautuku Beach, New Zealand, Hall, 222, 184, 274, 332; Grey's Bush Lookout, New Zealand, Hall 237; Rock and Pillar Range, New Zealand, Hall 271; Invermay Farm, New Zealand, Hall 415; Duntroon, New Zealand, Hall 113; Pineapple Track, Dunedin, New Zealand, Hall 66; Leith Saddle, New Zealand, Hall 40.

Spores and subtending hyphae with viable contents resist infection by parasitic fungi by laying down wall-like material on the inner surfaces of their walls in front of the advancing infection pegs leading to the formation of ingrowths of the spore wall.

Collections of spores from Arthur's Pass (Hall 243A, 243B) have the following characteristics: spores in bright yellow sporocarps 1 mm diam or single and ectocarpic. *Spores* yellow, 120-200 μm diam. *Spore wall* 5-16 μm thick, finely laminated. *Subtending hypha* 25-36 μm wide at the point where it joins the spore. *Pore* 3-10 μm diam. Laminations on the outer surfaces of mature spores and old hyphae flake off as new material laid down on inner surface. Spores contain many small oil globules giving cytoplasm a reticulate appearance. Spores often filled with hyphae. *Hyphae* dimorphic, laterals septate and ephemeral and shed along with the outer laminations. Laterals not laminated. Mature spores often filled with hyphae. These spores failed to form VAM in a single set of inoculations onto *C. robusta*.

Gerdemann & Trappe (1974, pers. comm.) consider that the activity of soil micro-organisms on endogonaceous hyphae and spores can lead to outer layers being modified or detached. Also *G. macrocarpus* var. *macrocarpus* includes collections of spores with a wide range in morphology, such as small spored variants (Gerdemann & Trappe, 1974) and spores with distinct double walls and wide subtending hyphae (Farlow Herbarium 5218). Hence the erection of a new variety to accommodate the collection with flaking spores does not seem to be justified.

GLOMUS MACROCARPUS var. **GEOSPORUS** (Nicol. & Gerd.) Gerdemann & Trappe, *Mycologia Mem.* 5: 55 (1974). (Slides 4.15.1-2)

Spores not common, single in soil, ellipsoid, 180-260 \times 190-220 μm . Wall single dark brown to black up to 18 μm thick, outer surface degenerate in old spores. *Subtending hyphae* light to dark brown with thick walls up to 200 μm from the point of attachment; 10-25 μm wide.

Specimens examined. Orongorongo Valley, New Zealand, Hall 349; Tautuku Beach, New Zealand.

GLOMUS laminated spores cf. *macrocarpus* var. *macrocarpus* (Slides 4.16.1-8)

Spores ectocarpic, formed singly or in loose clusters with some adhering material including bacterial aggregations, pale green when young turning brown with age, (90-)110-235 μm diam. *Walls* laminated, laminations separable in old spores and

in young spores of some collections. *Spore walls* (5–)8–14(–16) μm thick, each lamination about 1 μm thick. Laminations extending down the subtending hypha. Small projections approximately 1 μm high, sometimes formed on the inner surface of the wall. *Subtending hyphae* similar to *G. macrocarpus*, 9–18(–24) μm diam. *Pore* 0.5–7 μm diam not closed by a septum, but ultimately obliterated by the laminations. Hyphae in soil dimorphic and laminated. *Main hyphae* sparsely septate up to 45 μm diam sometimes with trabeculae in the lumen. *Lateral hyphae* sparsely to highly septate and 2–14 μm diam. Internal spores sometimes result from the growth of a hypha through the pore in the subtending hypha (Hall 244) similar to the hyphal proliferations of Type 5 spores of Gilmore (1968)

Specimens examined. Lake Wilkie, New Zealand, Hall 289; Tautuku Beach, New Zealand, Hall 286, 288, 328; Otago University Botany Department Garden, New Zealand, Hall 310, 427.

These spores differ from Mosse & Bowen's 'red brown laminate' (1968*a*) in lacking a membrane across the pore and being ectocarpic in origin. Mosse & Bowen consider that their red-brown laminate is similar to Gerdemann & Nicolson's Type 3 spores (1963) which was later named *Glomus macrocarpus* var. *geosporus* (Gerdemann & Trappe, 1974). The laminated spores reported here do not belong to this variety. Gerdemann (pers. comm.), however, has suggested that they may best be placed in *Glomus macrocarpus* var. *macrocarpus*, a highly variable taxon.

Glomus laminated spores cf. *macrocarpus* var. *macrocarpus* formed VAM in repeated inoculation trials with *Coprosma robusta*, *Weinmannia racemosa*, and *Metrosideros umbellata*.

GLOMUS MONOSPORUS Gerdemann & Trappe, *Mycologia Mem.* 5: 41 (1974). (Slides 4.10.1–8)

Sporocarps containing 1–2(–3) spores; up to 500 μm across, or spores formed singly and ectocarpically in soil. *Peridium* of loosely woven, light brown to brown hyphae up to 23 μm wide, arising from subtending hypha and obscuring where it joins the spore. *Spores* globose, 155–215(–250) μm diam, light brown to brown. *Spore wall* double; outer colourless c. 1 μm thick, inner 3–15 μm thick and finely laminated, laminations not separable. Outer and inner walls separated by closely set echinulations arising from the inner wall, 1–3 μm high and less than 0.5 μm wide. Echinulations not obvious in immature spores. *Subtending hyphae* funnel shaped up to 26 μm wide at point of attachment to

spore; cup-shaped septum forms in fully mature spores.

Ectocarpic spores collected from Tautuku Beach (Hall 225), Motu (Hall 336) and Invermay. Sporocarps present only in the Invermay collections (Hall 402, 441). The New Zealand collection of *G. monosporus* differs from Gerdemann & Trappe's descriptions by having spores with funnel-shaped subtending hyphae. However, this is not considered sufficient grounds for the erection of a new species. In many respects immature spores of *G. monosporus* resemble mature spores of *G. mosseae*. However, mature spores of the two may be distinguished by the echinulations on the inner walls of *G. monosporus*. Young spores in the Invermay collections have funnel shaped subtending hyphae similar in size and detail to Mosse & Bowen's (1968*a*) funnel-shaped spores although Mosse & Bowen do not describe sporocarps for funnel shaped spores.

GLOMUS MOSSEAE (Nicol. and Gerd.) Gerdemann & Trappe, *Mycologia Mem.* 5: 40 (1974). (Slides 4.20.1–8)

Spores ectocarpic, globose or more rarely polymorphic, 172–345 μm diam. *Spore wall* double, outer c. 1 μm thick, colourless and often not obvious, inner wall yellow to light brown, 2–7(–9) μm thick in mature spores. *Subtending hyphae* funnel shaped or tapering, yellow to light brown, 18–28(–35) μm diam at the point where it joins the spore, closed by a cup-shaped septum in mature spores. Walls of the subtending hyphae 1–3 μm thick.

Specimens examined. Duntroon, New Zealand, Hall 109; Pineapple Track, Dunedin, New Zealand, Hall 68; Tautuku Beach, New Zealand, Hall 163.

A wide range of spore form has been commented on by Mosse & Bowen (1968*a*). Some spore variants have been observed (Hall 163) but they were rare. Spore variants could have walls up to 13 μm thick, subtending hyphae with parallel walls, and the walls of degenerate spores separating into three or four layers.

GLOMUS PULVINATUS (Hennings) Trappe & Gerdemann, *Mycologia Mem.* 5: 59 (1974). (Slides 4.24.1–4)

Spores in epigeous sporocarps; globose to ellipsoid 48–90 \times 45–85 μm , colourless to pale yellow. Spores terminal or very rarely intercalary. *Spore wall* single, 2–5 μm thick, colourless. *Subtending hyphae* 5–12(–16) μm wide, with septum.

Specimen examined. Titirangi, New Zealand, Plant Diseases Division 29715.

Glomus tenuis (Greenall) Hall comb.nov. (Figs. 10–11, Slides 8.1.1–3)

Rhizophagus tenuis Greenall, *N.Z. Jl. Bot.* 1: 398 (1963).

Pot cultures on *Coprosma robusta* of a fine endophyte (Greenall, 1963) were made and kept in a glasshouse for two and a half years. After this time it was found that very heavy infections had become established and a few small spores had been formed in the rhizospheres.

Mature spores 10–12 μm diam, colourless when young staining with lactophenol trypan blue, turning dark brown with age and no longer stainable. *Immature spores* indistinguishable from vesicles within the roots. *Walls* up to 2.5 μm thick, appearing homogenous when observed with a Nomarski Interference light microscope. *Subtending hypha* swollen approximately into a sphere 1.5 μm diam, associated with a hypha about 0.5 μm thick and attached to fine endophyte infections. Germ-tube seems to emerge from the pore in the subtending hypha. Infections essentially are as described by Greenall (1963), however, irregular intercellular fan-shaped structures were sometimes formed.

Dangeard (1900) applied the name *Rhizophagus populinus* to the type of infection that is now known to be formed by species of *Glomus* (Gerdemann & Trappe, 1974) and Gerdemann & Trappe have therefore suggested that *Glomus* and *Rhizophagus* are synonymous. Greenall (1963) applied the name *R. tenuis* to cover fine endophyte infections. The spores and infections of the fine endophyte are quite distinct from *Glomus* and those of the other genera in the Endogonaceae and probably should not be grouped with any of them. There is some evidence to suggest fungi other than members of the Endogonaceae can form vesicular endomycorrhizas (Cooper, 1976; Hawker, 1962). Similarly the fine endophyte too may not belong in the Endogonaceae. However, because of the limited number of morphological features fine endophyte spores and infections possess, it seems unwise to place the fine endophyte in another family or to erect a new genus in the Endogonaceae.

Baiting experiments have shown that the fine endophyte is present in Te Anau and Tautuku soils (Hall, 1973), tussock grassland soils (Crush, 1973), and in Warepa silt loam (Hall, unpublished information). The fine endophyte has formed VAM with *Poa colensoi* Hook. f., *Zea mays* L., *Lolium perenne* L., *Coprosma robusta*, *Leptospermum scoparium*, *L. ericoides*, *Metrosideros umbellata*, *Weinmannia racemosa*, *Solanum laciniatum*, *S. aviculare*, *S. nigrum*, *Griselinia littoralis* Raoul, *Trifolium repens* L., *Pteridium aquilinum* var.

esculentum (Forst. f.) Diels, and *Histiopteris incisa* (Thunb.) J. Smith. Deposited collections are Hall 501 and 502.

GLOMUS VESICULIFER (Thaxter) Gerdemann & Trappe, *Mycologia Mem.* 5: 49 (1974). (Slides 4.26.1–3)

Sporocarps white to light brown, up to 10 mm across forming a mat on the soil surface. *Spores* globose to ellipsoid 80–155 \times 80–140 μm , interspersed and overlaid with thin-walled, globose to ellipsoid vesicles, 80–424 μm diam. *Spore wall* colourless to light brown, 6–15 μm thick, laminated; an outer wall c. 1 μm thick sometimes present. *Subtending hyphae* 8–12 μm wide, septum lacking. *Vesicles* colourless with walls up to 2 μm thick.

Specimen examined. Under ferns, Rotokawau and Tikitere Thermal area, New Zealand, Hall 345 (= McNabb 1856b). Also collected in open pot culture (Johnson, 1973). It forms VAM with *Griselinia littoralis*.

SCLEROCYSTIS Berk. & Broome

SCLEROCYSTIS RUBIFORMIS Gerdemann & Trappe, *Mycologia Mem.* 5: 60 (1974). (Slides 5.2.1–5)

Spores in naked epigeous or hypogeous sporocarps, 200–500 μm diam. *Sporocarps* often aggregating into mats, up to 20 mm diam, incorporating varying amounts of soil. Spores ovoid, pale to dark brown. In all but those sporocarps collected from McLennan (Hall 341) and Leith Saddle (Hall 308) spores were similar to Gerdemann & Trappe's (1974) descriptions: 38–105 \times 45–120 μm , spore walls finely laminated 2.5–8 μm thick, thickest at spore base. Spores from McLennan and Leith Saddle (Hall 308): 34–55 \times 37–65 μm , walls 2.5 μm thick. *Subtending hyphae* for both types of spore were similar: (3–)5–12(–16) μm diam, pore often completely occluded by the thick walls of the subtending hyphae and spore base.

Specimens examined. Earthquakes, New Zealand, Hall 96, 296; Tautuku Beach, New Zealand, Hall 217, 281, 318; Invermay Farm, New Zealand, Hall 407; Leith Saddle, New Zealand, Hall 308; and a site two miles south of McLennan, New Zealand Hall 341.

The descriptions of Mosse & Bowen (1968a) of 'blackberry-like sporocarps' containing spores 30 μm in diam are probably of the small spored variety of *S. rubiformis*. This species formed VAM with *C. robusta*, *Lolium perenne* and *Lotus pedunculatus* Cav. Slides 5.2.4–5 show the infections produced by *S. rubiformis* in *L. perenne* and

L. pedunculatus grown in a soil with 10 µg Truog extractable P/ml of soil. Unlike infection in *Lotus*, arbuscles were rare in *Lolium* and vesicles common.

SCLEROCYSTIS COREMIOIDES Berk. & Broome, f.
Linn. Soc., Bot. 14: 137 (1875). (Slides 5.1.1-3)

Spores in sporocarps 0.2-0.6 mm diam with a poorly developed peridium. *Spores* ovoid to subglobose, 65-107 × 55-104 µm. *Spore walls* brown, 2-6 µm thick but up to 11 µm thick near the base. *Subtending hyphae* 7-17 µm wide, septum often present.

Collected from Tautuku Beach (Hall 325, 333), and a site two miles south of McLennan (Hall 340). The N.Z. collection failed to form mycorrhizas when inoculated onto *Coprosma robusta* and *Lycopersicon esculentum*.

GIGASPORA Gerdemann & Trappe

Gigaspora aurigloba Hall, sp.nov. (Figs.12-13; Slides 2.7.1-15)

Etymology: *aurigloba* - golden orbled, refers to the spherical golden spores.

Sporae ectocarphae, globosae vel polymorphae rarius, 200-400(-520) × 130-420(-520) µm, pallide fulvae, novae hyalinae lucentesque, maturae fulvae hebescentesque. *Sporae* moribundae brunneae. *Tunicae* spora distromaticae ad tetrastrumaticae; tunica externa colorata, 6-16 µm crassa, tunicae internae circum 1 µm crassae incoloratae ad fulvae. *Sporae* bulboso suspensore 40-70 µm diametro formatae. *Tunicae* hyphae subtendentis 3-10 µm crassae, fulvae ad pallide brunneae. *Hypha subtendens* cum prominentia laterale aliquando bene vel male formata. *Porus* circum 4 µm diametro, sine septo. *Cupula* vel septa tholiformia in hypha subtendenti saepe formata. *Germinatio* hiatibus inter tunicas internas tertiam partem peripheriae aliquando circumiens. *Hic tunicae* usque ad 27 µm crassae, hiatus ad 10 µm alti et 65 µm lati. *Vesiculae* incolorae ad fulvae in solo ad 100 µm diametro globis laxis hypha circinata aliquando latae; novae echinulatae ad nodosae, senescentes polymorphae.

Spores ectocarpic, globose or more rarely polymorphic, 200-420(-520) × 130-420(-520) µm diam, pale yellow, transparent and shining when young turning yellow and becoming dull at maturity. *Moribund* spores brown. *Spore wall* 2- to 4-layered, outer wall coloured, 6-16 µm thick, inner walls c. 1 µm thick, colourless to yellow. *Spores* formed on a bulbous suspensor 40-70 µm diam. *Walls* of subtending hypha 3-10 µm thick, yellow to light brown. *Subtending hypha* sometimes with a well to poorly developed lateral projection. *Pore* c. 4 µm diam without a septum. *Cup-* or dome-shaped

septa often form in the subtending hypha. *Germination* from chambers that develop between the inner walls sometimes extending around one third of the circumference. *Walls* in these regions up to 27 µm thick. *Chambers* up to 10 µm deep and 65 µm wide. *Vesicles* in soil colourless to pale yellow up to 100 µm diam, borne in loose clusters sometimes on a coiled hypha; echinulate to knobby when young becoming polymorphic with age.

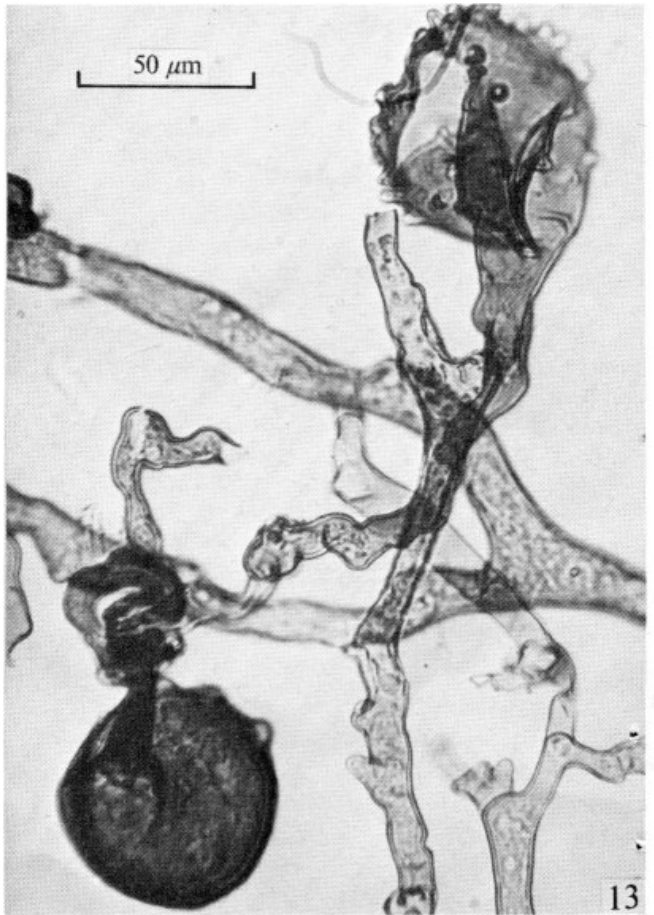
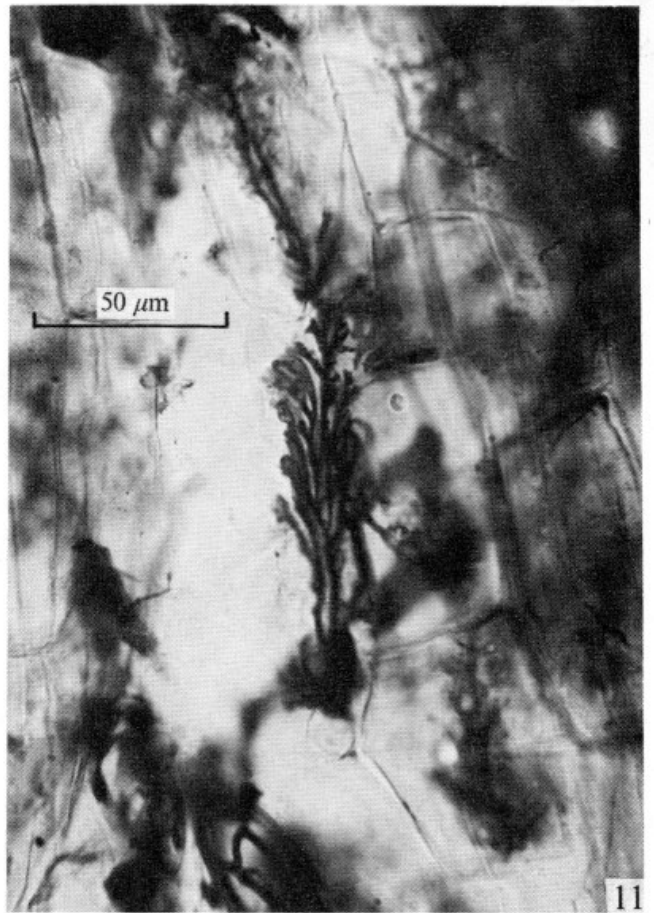
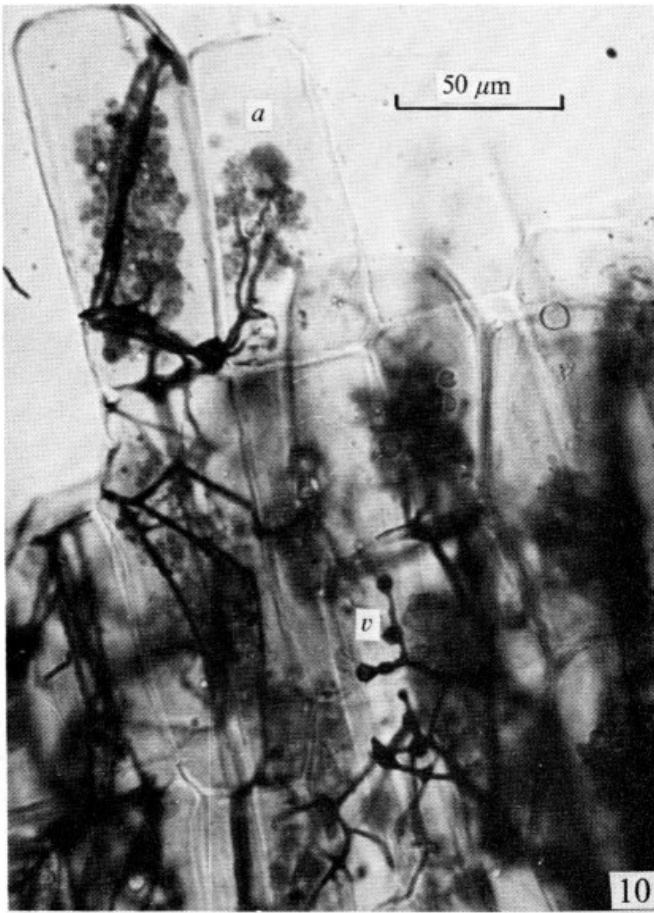
Specimens examined. Leith Saddle, New Zealand, Hall 475 holotype, 429, 24, 307; Tautuku Beach, New Zealand, Hall 22; Campbell Island, New Zealand, Hall 15; Pineapple Track, Dunedin, New Zealand, Hall 67; McLennan, New Zealand, Hall 343.

Mycorrhizal associations unknown. A few spores with walls about 5 µm thick were collected from Leith Saddle and Campbell Island but they appeared degenerate. In other respects they resembled the above species. A collection of spores only a few metres from the type locality of *G. aurigloba* differed only in the colour of the spores - pale green when young and dark green to black at maturity. *Vesicles* were absent from this collection. *Spores* of this kind have been excluded from the type.

The cytoplasm in these spores varies from reticulate to vacuolate (Mosse & Bowen, 1968a) depending on the age of the spore. Mosse & Bowen's descriptions of bulbous vacuolate spores from N.Z. suggest that they may have belonged to this species although the Type B spores (Gerdemann, 1955), which they likened them to were later assigned the name *Gigaspora gigantea*. *Gigaspora aurigloba* differs from *G. gigantea* in the shape of the vesicles, the production of chambers before germination, and the structure of the spore wall. *Gigaspora aurigloba* resembles *G. gilmorei* Trappe & Gerdemann and an unnamed species from Nigeria (Old, Nicolson & Redhead, 1973) in forming germ-tubes from compartments in the spore wall. It differs from these two species, however, in colour, wall structure, and in the vesicles.

GIGASPORA MARGARITA Becker & Hall, *Mycotaxon* 4: 155-160 (1976). (Slides 2.6.1-15)

Spores formed singly in soil, 310-600 µm diam, white when young, slightly yellowish at maturity. *Spore wall* colourless and transparent in young spores with a thick outer and a thin inner layer. In older spores wall opaque with a thick outer layer and up to five thin inner layers; total thickness 8-25 µm. *Subtending hyphae* bulbous, 45-60 µm wide and colourless; sometimes with a branching lateral projection. *Clusters* of warts up to 10 µm



high develop on inner surface of innermost wall at maturity and germ tube emerges from between them.

The single New Zealand collection from a maize field in the Waikato, North Island (Hall 423), contains spores which are essentially similar to spores from pot cultures at the University of Illinois (Becker & Hall, 1976).

ACAULOSPORA Gerdemann & Trappe

ACAULOSPORA LAEVIS Gerdemann & Trappe, *Mycologia Mem.* 5: 33 (1974). (Slides 3.1.1-4)

Spores ectocarpic, 120-280 μm diam. Wall 4-8 μm thick formed of three layers: outer thick and yellow to brown, inner two colourless and membranous. Spores formed laterally on thin-walled hyphae terminating in a thin-walled mother spore (vesicle). Wall of mother spore 1-2 μm thick. Occasionally spores were formed inside roots or in loose clusters on the surface of roots.

Specimens examined. Leith Saddle, Tautuku Beach, New Zealand, Hall 211; House Road, Akatore Forest, New Zealand, Hall 420; Akatore Forest, Taieri Mouth, Invermay, New Zealand, Hall 401, 447; and from pot cultures derived from spores collected in the Te Anau Wilderness.

Previously described for N.Z. and Australian collections as 'honey-coloured sessile' (Mosse & Bowen, 1968a). A variant of *A. laevis* was collected from a clay bank two miles south of McLennan (Hall 337) and Invermay (Hall 410). Spore mother vesicle 150-220 μm diam; resting spore globose, pink when young turning red then reddish brown with age 180-290 μm diam. Wall of three layers, outer 2-6 μm thick and coloured, inner two membranous and colourless.

The typical species has formed VAM in the University of Otago Botany Department with: *Agathis australis* Salisb., *Podocarpus totara* G. Benn. ex D. Don, *Coprosma robusta*, *Weinmannia racemosa*, *Metrosideros umbellata*, *Griselinia littoralis* Raoul, *Solanum laciniatum* Ait., *S. aviculare* Forst. f., *S. nigrum* L., *Lolium perenne*, *Pittosporum tenuifolium* Sol. ex Gaertn., *Lycopersicon esculentum*, *Leptospermum scoparium*, and *L. ericoides* A.

Rich. The red variety has formed VAM with *Coprosma robusta*, *Lycopersicon esculentum*, *Aristotelia serrata* (J. R. et G. Forst.) W. R. B. Oliver, and *Pteridium aquilinum* (L.) Kuhn var. *esculentum* (Forst. f.) Diels.

Slides 3.1.3-4 illustrate *A. laevis* infections in *Coprosma robusta* growing in steamed Leith soil with 7 μg Truog extractable P per ml of soil and show the typically lobed vesicles.

ACAULOSPORA large red species.

Very little material is available of this species and a formal description of it will not therefore be made here. Spores formed in a manner similar to *A. laevis*. Resting spore deep red to reddish brown, spherical to ovoid, 288-520 \times 360-800 μm . Spore wall 8-12(-25) μm thick and composed of three layers; outer layer thick, inner layers membranous.

Specimens examined. In small numbers, Leith Saddle, New Zealand, Johnson 1973; McLennan, New Zealand, Hall 342; Orongorongo Valley, New Zealand, Hall 348.

Failed to produce infections when inoculated on to *Coprosma robusta*, *Metrosideros umbellata* and *Weinmannia racemosa*.

ACAULOSPORA perforate spores (Slides 3.3.1-4).

Spores 120-235 μm diam, pale green when young turning brown with age. Spore wall double, outer coloured and 3-8 μm thick, inner colourless and membranous. Outer walls regularly perforated even in young spores. Subtending hyphae were only rarely observed but in these the spores were formed in a manner similar to *Acaulospora*. Because the pores in the outer walls are present even in very young spores, are not associated with ingrowths of the wall, and are regularly distributed they are considered to be a valid feature and not merely produced by invading parasitic fungi. Similar spore types have been noted by Bakshi (1974).

This type of spore was found in almost every area studied: Long Bush (Hall 4), Campbell Island

Fig. 10. *Glomus tenuis*. Typical infection with arbuscles (a) and vesicles (v). Stained with lactophenol trypan blue.

Fig. 11. *G. tenuis*. Peculiar fan-shaped structures associated with mature infections. Stained with lactophenol trypan blue.

Fig. 12. *Gigaspora aurigloba*. Detail of spore wall showing the germination compartments between its layers. Nomarski Interference.

Fig. 13. *G. aurigloba*. Immature echinulate vesicles.

(Hall 16), Leith Saddle (Hall 31), Pineapple Track, Dunedin (Hall 59), House Road (Hall 127), and Tautuku Beach.

CRENULATE SPORES (Slides 9.1.1-4).

Previous and only description for New Zealand material that by Mosse & Bowen (1968*a*). Spores globose formed singly or in small loose clusters in the soil, (54-)80-125 μm diam. Wall double, inner colourless and membranous, outer white when young turning light then dark brown with age. Outer wall 3-7 μm thick with projections, 3 \times 4-8 μm on the outer surface. Subtending hyphae with 2-5 septa; where it joins the spore 10-22 μm diam. Subtending hypha the terminal portion of an aseptate hypha, 3-6 μm diam. These hyphae and the subtending hyphae bear projections similar to those on the spores. Pore in mature spores closed by wall thickenings of the spore.

Found in one area of a disused garden, House Road (Hall 121). This spore has also been found in Australia (Mosse & Bowen, 1968*a*) and in Germany (Mosse, pers. comm.).

In inoculation trials onto *Coprosma robusta* and *Lycopersicon esculentum* crenulate spores failed to infect. Wilcox, Ganmore-Neumann & Wang (1974) have shown that an isolate belonging to the Ascomycetes and capable of forming ectendomycorrhizae produces spores in culture similar to the crenulate type. *Pinus radiata* D. Don was growing close to the site where crenulate spores were collected and it may be that the spores come from the rhizospheres of their roots. It seems unlikely that crenulate spores belong in the *Endogonaceae*.

SPORE NUMBERS IN THE AREAS STUDIED

Generally, spores were few or absent in mature native bush soils but numerous in those from disturbed areas such as roadsides, and from under seral vegetations. Mosse & Bowen (1968*b*) reported similar findings. There was no correlation between soil spore numbers and infection levels in adjacent hosts. Repeated sampling of soil from an area at Tautuku Beach during 1970 and 1971 and counting the numbers of spores in 50 ml subsamples, showed spore numbers to be highest in late autumn and early winter, and lowest in early summer. Similar findings have been reported by Hayman (1970), Mason (1964) and Sutton & Barron (1972).

DISCUSSION

The N.Z. members of the Endogonaceae

Species of *Endogone* (*sensu stricto*) and of the tropical genus *Glaziella* have yet to be found in

New Zealand. All the species of *Endogone* so far investigated have been found to form ectomycorrhizas (Fassi, 1965; Fassi & Palenzona, 1969; Fassi *et al.* 1969; Gerdemann & Trappe, 1974; Warcup, 1975). The apparent absence of *Endogone* from New Zealand may be because few New Zealand trees form ectomycorrhizas or because very few soil samples have been collected in areas where exotic ectomycorrhizal plants are growing. *Modiella malleola* (Thaxter, 1922) and white reticulate spores (Mosse & Bowen, 1968*a*) previously collected in New Zealand were not found in the present survey. This is not surprising as some species seem to have very limited distributions.

Spores and hyphae inside spores

Internal hyphae are common in spores of *Glomus monosporus* and *G. radiatus* (Gerdemann & Trappe, 1974). *Glomus macrocarpus* var. *macrocarpus* spores are sometimes filled with hyphae at maturity (Gerdemann, pers. comm.). Proliferation in Gilmore's E5 cultures (1968), *Glomus mosseae* (Mosse, 1959), and in laminated spores (q.v.) often leads to the formation of internal spores. However, spores of *G. macrocarpus* var. *macrocarpus* sometimes contain spores of *G. pallidus*. Mosse & Bowen (1968*a*) and Gilmore (1968) have reported similar findings.

Non-endogonaceous fungi found inside spores have been identified as *Cephalosporium* (Malençon, 1947), *Micromonospora* (Mosse, 1954), and as oidia producing fungi (Godfrey, 1957). Some of the hyphae found inside flaking spores of *G. macrocarpus* var. *macrocarpus* resembled *Rhizoctonia*. Some of these fungi are probably responsible for the ingrowths of spore walls seen in many spores. However, as *G. pallidus* forms infection pegs in the roots of *Coprosma robusta* that are almost fine enough to pass through the pores in the ingrowths, it seems possible that some ingrowths could be formed in response to attack by parasitic endogonaceous hyphae, which could result in spores containing endogonaceous hyphae as is true for *G. radiatus* (Gerdemann & Trappe 1974).

Spore numbers in sampled soils

That relatively few spores were found in N.Z. bush soils supports the findings of Mosse & Bowen (1968*b*), and the lack of a correlation between spore numbers and infection levels support Baylis's suggestion (1969) and the conclusion of Crush (1975) that some mycorrhizal fungi do not produce spores. In New Zealand native forests or wherever there is a similar permanent high density of roots in the soil, mycorrhizal infection would readily spread from root to root. In these

areas, mycorrhizal fungi which commit large quantities of metabolites to the production of unnecessary resting structures, seemingly would be less well adapted than non-sporing fungi.

Infections and the fungi producing them

Plants growing in unsteamed soils were rarely infected by a single endophyte. However, by comparing the range of species in these soils with infections in plants growing in them it was hoped to relate the two. This proved impracticable because some infections were not represented by spores and some spores could be related to several infections.

Mixed infections on plants which had been inoculated with a single species were also a problem. They were attributed to impure sporocarps, spores parasitized by another VAM fungus, or contamination in the glasshouse. Single spores formed infections in only 5% of seedlings inoculated. This was probably due to low viability of spores from the field or to the distance the spores were from an active section of root. Some of these plants had to be left for more than a year before good infections were formed. *Glomus pallidus* and the fine endophyte were particularly troublesome contaminants of such plants.

The form of an infection can be altered by the nutritional status of the host (Mosse, 1973). *Glomus pallidus* infections on *C. robusta* growing in a soil low in available P are composed of arbuscles and randomly arranged hyphae. Vesicles were relatively rare even in older infections. However, in soils with a higher available P level, vesicles were common and arbuscles few or absent. It follows that morphologically distinct infections could be formed by a single fungus, as has been claimed by Barrett (1961) and demonstrated by Gerdemann (1965), in hosts which differ in their reliance on VAM. With *Sclerocystis rubiformis*, arbuscles were common in *Lotus pedunculatus*, and absent from *Lolium perenne* where vesicles tended to be common (Slides 5.2.4-4). In the soil used, *Lotus* was more dependent on mycorrhizas for satisfactory growth than was *Lolium*.

It is generally assumed that arbuscles are the sites of mineral transfer to the host (Gerdemann, 1968). Mosse (1972a, b), Hall (1976) and Powell (1975) have shown that some endophytes are more efficient symbionts than others. It may therefore be instructive to compare arbuscle formation by endophytes varying in their efficiency, in one host and soil combination. The lack of arbuscles in infections (Slide 4.5.9) and the absence of a significant growth response produced by *Glomus fasciculatus* from Campbell Island on *C. robusta* growing in a soil where it is normally completely

dependent on the formation of VAM for growth, may be significant in this regard.

Because of host and soil imposed variations to infections it seems unlikely that the morphology of field infections can regularly be related to the species which produce them. Likewise, the addition of characteristics of the infecting mycelium to the descriptions of the endophyte species may be only occasionally worthwhile.

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