

ADDITIONS TO THE HYPOGEOUS MYCOFLORA OF THE CANARY ISLANDS AND MADEIRA

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Mycological investigations in Macaronesia (Canary Islands, Madeira, Cape Verde Islands, Azores) have produced few records of hypogeous fungi. Of the Basidiomycotina, only *Hymenogaster vulgaris* Tul. var. *madeirensis* Torrend has been reported from Madeira (Torrend 1912). Reported collections from the Canaries include *Hydnangium carneum* Wallr. in Dietr. (Calonge and Demoulin 1975, Eckblad 1975), *Rhizopogon luteolus* Fr. em. Tul. (Calonge and Demoulin 1975, Eckblad 1975), and *Rhizopogon vulgaris* (Vitt.) M. Lange (Calonge and Demoulin 1975). *Hymenogaster maurus* Maire is the only hypogeous basidiomycete reported from the Azores (Dennis et al. 1977). No hypogeous Ascomycotina or Endogonaceae have been reported from Macaronesia.

Nearly all of the hypogeous fungi described herein were collected during an expedition to Madeira and the islands of Tenerife, Gomera, and Hierro in the Canary Islands archipelago during December 1976 and January 1977. The steep topography of these islands, decreased precipitation from west to east, and both endemic and exotic mycorrhizal hosts combine to create an amazing variety of potential habitats for hypogeous fungi.

The Canarian vascular plant flora totals some 1,750 species of which 550 are endemic (Bramwell and Bramwell 1974). The dense native evergreen hardwood forest is dominated by presumed endomycorrhizal hosts: *Laurus azorica* (Seub.) Franco, *Apollonias barbujana* (Cav.) Bornm., *Ocotea foetens* (Aiton) Benth., and *Persea indica* (L.) Spreng. The native ectomycorrhizal *Pinus canariensis* Chr. Sm. ex DC. forest is an open, savanna-like formation resembling the ponderosa pine forest in central Oregon. In addition to the native forests, stands of exotic *Picea*, *Pinus*, and *Eucalyptus* have been introduced in reforestation (Kunkel 1976).

The native evergreen hardwood forest of Madeira is similar to that of the Canaries with exotic *Pinus*, *Eucalyptus*, and *Pseudotsuga menziesii* (Mirb.) Franco also introduced for timber production and regulation of the island's water economy.

Only new records of hypogeous fungi for Macaronesia are fully described here. Hypogeous fungi were collected by raking away the humus and then a few cm into the mineral soil. After specimens were dried in repeated changes of activated silica gel, free-hand sections mounted in 3% KOH, lactophenol-cotton blue, or Melzer's reagent were used for observation of microscopic features. Colors of sporocarps were determined by use of the ISCC-NBS color charts (Kelly and Judd 1965). Collections are deposited in the herbaria of Cornell University (CUP), Oregon State University (OSC), and Universidad de La Laguna, Tenerife, Canary Islands (LAG).

ZYGOMYCOTINA

1. *Endogone flammicorona* Trappe & Gerdemann, Trans. Br. Mycol. Soc. 59: 403–407. 1972.

Material examined: MADEIRA: leg. Korf et al. MM1509 (CUP, OSC).

Habitat and season: hypogeous under *Pseudotsuga menziesii* in January.

Sporocarps up to 7×3 mm, globose to subglobose, pale orange yellow to brownish orange. *Zygosporos* $45-55 \times 57-63$ μm , globose to ellipsoid or obovoid, deep yellow; spore wall up to 4 μm thick. Spores enclosed in a hyphal mantle, up to 11 μm thick, hyphae encircling spore in a spiral manner; in cross section thickened lateral walls of two adjacent hyphae coalesce to form pointed, flame-shaped projections from the spore.

Gerdemann and Trappe (1974) have described this species in detail and give its distribution as widespread but infrequent in North America and Europe. Fassi and Palenzona (1969) have demonstrated it to form ectomycorrhizae with Pinaceae; it may have been introduced with *Pseudotsuga menziesii*.

2. *Glomus fasciculatus* (Thaxter) Gerdemann & Trappe, Mycol. Mem. No. 5, p. 51-53. 1974.

Material examined: CANARY ISLANDS: TENERIFE, leg. Korf et al. MM1247 (CUP, OSC). MADEIRA: leg. Korf et al. MM1571 (CUP, OSC).

Habitat and season: on soil under *Eucalyptus* sp. and *Cupressus* sp. in January.

Sporocarps up to 4×2 mm, flattened, tuberculate, light orange yellow. Peridium lacking. *Gleba* light orange yellow. *Chlamydospores* $55-73 \times 53-70$ μm , subglobose, smooth, light yellow; spore wall up to 7 μm thick.

Gerdemann and Trappe (1974) have described this species and its distribution as North America, Europe, and Australia, and indicate that it is probably associated with most of the endomycorrhizal hosts where it occurs.

3. *Glomus macrocarpus* Tul., Giorn. Bot. Ital. I, 2: 63. 1845 var. *macrocarpus*.

Material examined: CANARY ISLANDS: GOMERA, leg. Korf et al. MM1369, MM1370 (CUP, OSC).

Habitat and season: in mixed forests under *Ilex canariensis* Poir. in January.

Sporocarps up to 8×6 mm, irregularly globose, containing a considerable proportion of soil in the lower portion, light orange yellow as dried, exterior covered with soil particles. Peridium thin. *Gleba* light orange yellow. *Chlamydospores* $148-222 \times 136-171$ μm , globose to subglobose, smooth, yellow brown; spore wall up to 17 μm thick.

Gerdemann and Trappe (1974) indicate this species is widely distributed over much of the world, associated with a wide variety of endomycorrhizal hosts.

4. *Glomus microcarpus* Tul., Giorn. Bot. Ital. I, 2: 63. 1845.

Material examined: MADEIRA: leg. Korf et al. MM1500 (CUP, OSC).

Habitat and season: in leaf mold in mixed *Laurus* spp. forest in January.

Sporocarps up to 5×2 mm, irregularly globose, white to pale orange yellow as dried. Peridium thin. *Gleba* moderate yellow. *Chlamydospores* $33-40 \times 30-39$ μm , globose to subglobose, smooth, light yellow; spore wall up to 5 μm thick.

Reported from Europe, North America, and Tasmania (Gerdemann and Trappe 1974).

ASCOMYCOTINA

5. *Geopora clausa* (Tul.) Burdsall, Mycologia 60: 507. 1968 ssp. *clausa* f. *clausa*.

Material examined: CANARY ISLANDS: GOMERA, Gro-Gulden 75/73 (CUP).

Habitat and season: hypogeous in a *Pinus canariensis* - *Erica* stand during January, elevation ca. 1350 m.

Ascocarps 7 × 4 mm as dried, subglobose, attached by a basal tuft of brown mycelium; outer surface grayish brown, verrucose, the warts pyramidal, 0.5 mm broad at base; excipular hairs abundant over lower surface, superficial, 10–11 µm broad, thick-walled (1–4 µm thick), septate, smooth-walled, flexuous, yellowish brown, simple or branched, arising from outer cells of outer ectal excipulum, terminating in an obtuse tip; interior surface smooth, white. *Spores* (23–) 24–26 (–28) × (15–) 17–20 µm, broadly ellipsoid, mean length-width ratio 1.4, smooth, hyaline, uniseriably arranged in asci. *Asci* in a hymenium among paraphyses, 170–250 × 15–20 µm, cylindrical, long-tapered below the basal spore to a croziered base ± 5 µm broad, hyaline, thin-walled, 8-spored, operculate, not bluing in Melzer's reagent. *Paraphyses* 150–250 × 3–5 µm, filiform, terminal cell swollen to 5–8 µm broad, hyaline, thin-walled, septate. *Outer ectal excipulum* 20–50 µm thick, textura angularis, cells 18–45 × 20–25 µm, walls 2–5 µm thick, dark yellowish brown, lighter in interior cells. *Inner ectal excipulum* 200–900 µm thick, textura intricata, of hyaline, thin-walled, 5–7 µm broad hyphae becoming inflated to 20–25 µm, appearing pseudoparenchymatous in some areas.

Burdsall (1968) cites collections of this species from France, Italy, and Portugal. This form differs from *Geopora clausa* f. *ellipsospora* in having broadly ellipsoid (L/W = 1.4) rather than ellipsoid spores (L/W = 1.7–1.8) and in having abundant excipular hairs.

6. *Geopora clausa* (Tul.) Burdsall ssp. *clausa* f. *ellipsospora* Burdsall, Mycologia 60: 511. 1968.

Material examined: CANARY ISLANDS: *HIERRO*, leg. Korf et al. MM1432, MM1433 (CUP, OSC).

Habitat and season: hypogeous to partly emergent under *Pinus* sp. in January.

Ascocarps up to 35 × 20 mm, irregularly lobed, attached by a basal tuft of brown mycelium; outer surface grayish brown to pale orange yellow, verrucose, the warts pyramidal, 0.5 mm broad at base; excipular hairs scarce; interior surface smooth, white. *Spores* (20–) 22–24 × 12–14 (–15) µm, ellipsoid, mean length-width ratio 1.7–1.8, smooth, hyaline, uniseriably arranged in asci. *Asci* in a hymenium among paraphyses, 130–200 × 15–17 µm, cylindrical, long-tapered below the basal spore to a croziered base ± 5 µm broad, hyaline, thin-walled, 8-spored, operculate, not bluing in Melzer's reagent. *Paraphyses* 150–200 × 5–8 µm, filiform, terminal cell swollen to 8–12 µm, hyaline, thin-walled, septate. *Outer ectal excipulum* 25–40 µm thick, textura angularis, cells 20–40 × 20–25 µm, walls 2–4 µm thick, dark yellowish brown, lighter in interior cells. *Inner ectal excipulum* 200–400 µm thick, textura intricata, of hyaline, thin-walled, 5–7 µm broad, periclinal hyphae becoming inflated to 20–25 µm, appearing pseudoparenchymatous in some areas.

Burdsall (1968) has described this species in detail from material collected in Portugal under *Pinus*. The Canary Islands collections differ from his description in having larger paraphysis tips and sparse rather than abundant excipular hairs.

7. *Terfezia olbiensis* (Tul.) Tul., Fungi Hypogaei, p. 176. 1851.

Material examined: CANARY ISLANDS: *TENERIFE*, leg. Korf et al. MM330 (CUP, OSC), MM1325 (CUP, OSC, LAG), Wildpret and Eckblad MM1133 (CUP, OSC). *HIERRO*, leg. Korf et al. MM1434 (CUP, OSC), MM1440 (CUP, OSC, LAG).

Habitat and season: hypogeous under *Pinus* sp. from January to April.

Ascocarps up to 30 × 19 mm, subglobose to reniform, attached by a basal tuft of hyphae emerging from a short (2 × 3 mm), pulvinate, sterile base; surface minutely pubescent, light orange, grading to gray where exposed. *Gleba* composed of brown pockets of fertile tissue separated by white tramal veins, pockets 2 mm in diam;

consistency extremely hard as dried. Odor not recorded. *Spores* 14–17 × 12–16 μm excluding ornamentation, subglobose, hyaline in youth, becoming brownish yellow at maturity; in youth, with spines 1.5 × 0.25 μm , not joined by lines, by maturity the spines 1–2 × 1 μm broad at base and joined by short lines between 2 or 3 spines. *Asci* 65–70 × 54–61 μm , obovoid, broadly ellipsoidal, or irregular due to mutual pressure, hyaline, not bluing in Melzer's reagent, 8-spored, thick-walled in youth, becoming thin-walled at maturity, immature asci orange in Melzer's reagent. *Trama* of interwoven, hyaline, thick-walled (0.8 μm) hyphae 6–8 μm in diam, cells becoming inflated to 19 μm . Hyphae of fertile pockets hyaline, thin-walled, elongated to spherical cells 8–24 μm in diam. *Outer ectal excipulum* 160–185 μm thick, of periclinal, thick-walled (1 μm), 7–19 μm broad hyphae which become progressively more inflated toward gleba. *Inner ectal excipulum* 340–420 μm thick, differentiated as smaller, thick-walled, less pigmented cells, becoming inflated to 35 μm in diam and \pm isodiametric.

The spore color and ornamentation of the Canary Islands collections suggest that *Terfezia olbiensis* and the closely related species *T. leptoderma* (Tul.) Tul. may represent different developmental stages of the same species. *T. olbiensis* is characterized by having spherical, echinulate, non-reticulate, slightly colored spores, 13–16 μm in diam (Tulasne and Tulasne 1851). *T. leptoderma* is described as having spherical, echinulate, partly reticulate, slightly colored spores, 16–19 μm in diam (Tulasne and Tulasne 1851). Spores within the same sporocarp from the Canary Islands show a progression from hyaline spores with separate spines through brownish yellow spores with short lines joining 2 or 3 spines.

BASIDIOMYCOTINA

8. *Hydnangium carneum* Wallr. in Dietr., Flor. Boruss. VII, p. 465. 1839.

Material examined: CANARY ISLANDS: TENERIFE, leg. Korf et al. MM1246, MM1251 (CUP, OSC, LAG), MM1285 (CUP, OSC), MM1303 (CUP). HIERRO, leg. Korf et al. MM1437, MM1439 (CUP, OSC, LAG). MADEIRA: leg. Korf et al. MM1543 (CUP, OSC).

Habitat and season: on soil under *Eucalyptus* sp. during December and January.

Previously reported from Tenerife under *Eucalyptus* (Calonge and Demoulin 1975) and widely distributed worldwide.

9. *Hymenogaster maurus* Maire, Bull. Soc. Hist. Nat. Afr. Nord 22: 18. 1931.

Material examined: CANARY ISLANDS: TENERIFE, leg. Korf et al. MM1286, MM1287 (CUP, OSC, LAG). MADEIRA: leg. Korf et al. MM1555 (CUP, OSC, LAG).

Habitat and season: hypogeous under *Viburnum tinus* L. ssp. *rigidum* (Vent.) P. Silva in a stand with *Prunus lusitanica* L. overstory and in a mixed stand of *Pinus*, *Eucalyptus*, and *Mimosa* spp. during December and January.

Basidiocarps up to 21 × 14 mm, subglobose to irregularly lobed, no obvious rhizomorphs; peridium tomentose, with adherent debris, white with pallid yellow stains, finally pale yellow. *Gleba* strong reddish brown; locules labyrinthiform, 0.1 to 0.5 mm broad; consistency spongy. Odor farinaceous. Chemical reactions of fresh peridium: KOH, pink; Melzer's reagent negative. *Spores* 16–19 (–22) × 8–9 μm including ornamentation, ellipsoid to citriform, yellowish brown, immature dextrinoid; with embedded rods 0.8–1.5 μm tall at medial axis, shorter toward apex, joined by incomplete lines on spore surface, apex papillate. *Basidia* in a hymenium with basidioles, 23–25 × \pm 10 μm , cylindrical, hyaline, thin-walled, 2-spored; sterigmata conical, up to 4 × 4 μm . *Basidioles* 23–25 × 8–9 μm , cylindrical, hyaline, thin-walled. *Subhymenium* of hyaline, thin-walled, spherical cells 5–7 μm in diam. *Tramal plates* 70–80 μm wide,

trama 30–35 μm wide, of subparallel, hyaline, thin-walled hyphae 4–5 μm in diam. No clamp connections observed. *Peridial epicutis* 30–40 μm thick, of loosely interwoven, subhyaline, thin-walled hyphae 5–10 μm in diam with clamp connections. *Subcutis* 120–130 μm thick, of loosely interwoven to periclinal, hyaline, thin-walled hyphae 4–6 μm in diam; no clamp connections observed.

Previously reported from southern France, the Azores (Dennis et al. 1977), Algeria and Morocco (Malencon 1975). All of the reported collections were made in *Eucalyptus* stands, although the Tenerife collections appeared to be associated with *Viburnum* in a stand with only a few, widely scattered *Eucalyptus*.

10. *Phlebogaster laurisylvicola* Fogel, gen. et sp. nov.

Figs. 1–5.

Fructificationes subglobosae vel lobatae, candidae deinde luteae. Peridium in crassitie varians. Gleba areis ravis fecundis, venis albis sterilibus separatis; loculis vacuis, sphaericis, ± 0.2 mm in diam. Trama gelatinosa. Basidia cylindracea vel obpyriforma, in euhymeniis ordinata. Sporae 6–8 \times 5 μm , oblongae, apicibus obtusis, brunneae, verrucosae. Holotypus: Canary Islands, Tenerife, leg. R. P. Korf, R. Fogel, G. L. Hennebert, L. M. Kohn MM1289 (CUP).

Etymology: Greek, phlebo- (vein), gaster (stomach). Latin, laurisylvicola (a dweller in the laurel forest).

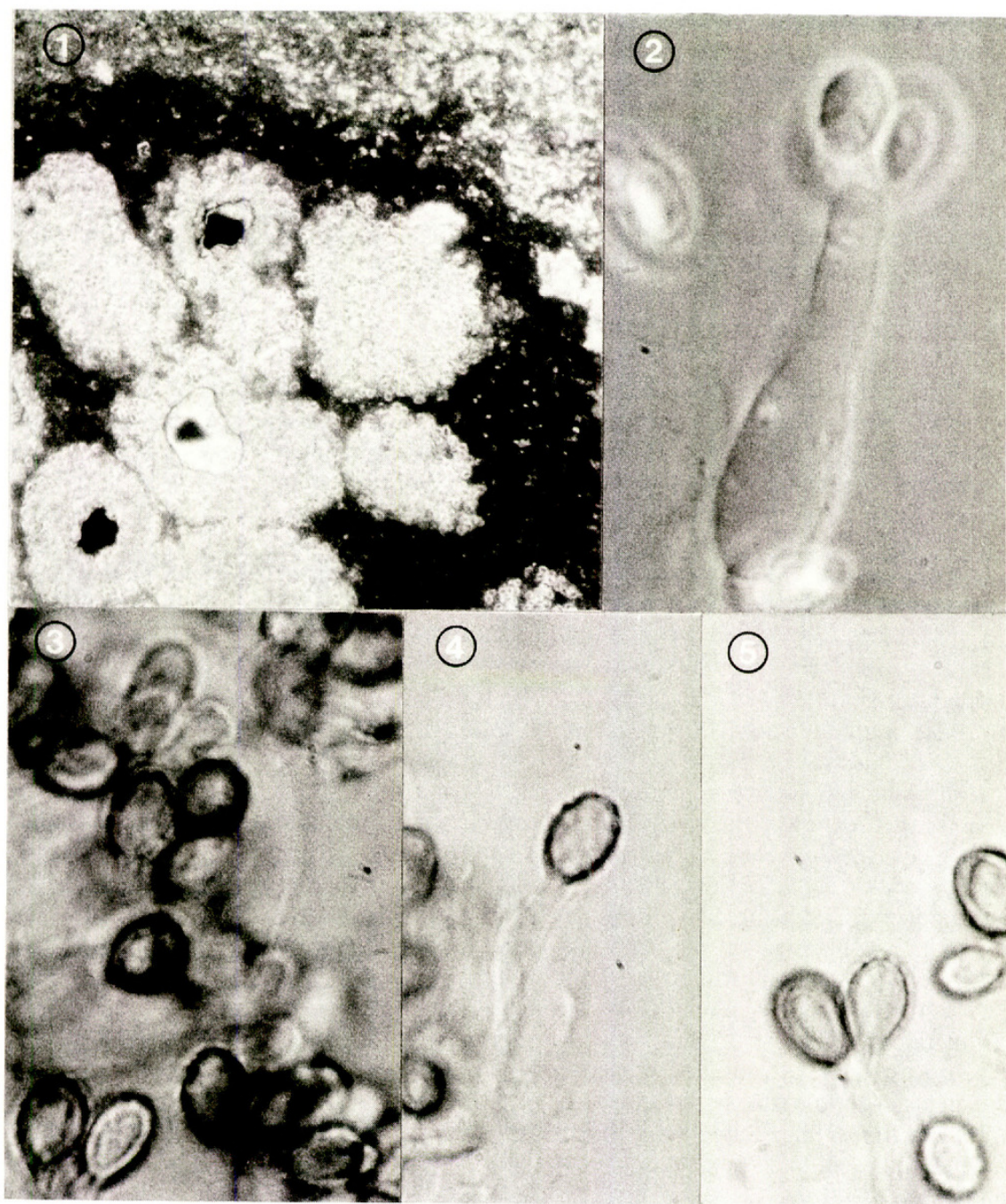
Material examined: CANARY ISLANDS: TENERIFE, Fuente de las Pulgas, Las Yedras, under *Laurus azorica*, 30 December 1976, leg. R. P. Korf, R. Fogel, G. L. Hennebert, L. M. Kohn MM1289 (Holotypus: CUP), leg. Korf et al. MM1290 (CUP, OSC).

Habitat and season: hypogeous under *Laurus azorica* in December.

Basidiocarps up to 10 \times 6 mm, subglobose to lobed, attached by several basal rhizomorphs ± 0.25 mm in diam; peridium 0.5 mm thick fresh, white, quickly staining yellow when exposed, then very deep red, drying yellowish white with strong pink stains, minutely tomentose with adhering debris. *Gleba* composed of grayish olive clusters of fertile locules separated by white sterile veins; locules empty, spherical to slightly elongate, ± 0.2 mm broad; consistency firm, sectioning easily after drying. Odor and macrochemical tests on the peridium not recorded. *Spores* oblong, apices obtuse, 6–8 \times 5 μm including the ornamentation, brown in mass (KOH), hyaline to moderate greenish yellow singly, nonamyloid, strongly cyanophilic when immature; walls 0.4 to 1 μm thick, two-layered: the inner layer verrucose, the warts largest toward the apex, 0.4 μm or less high, rounded, connected by faint lines, outer layer smooth; sterigmatal appendage central, straight, hyaline, 1.5–2 \times 1.6 μm , appearing flanged under phase contrast. *Basidia* cylindrical to obpyriform, 22–40 \times 4–5 (–8) μm , 4-spored, thin-walled, hyaline, in a euhymenium; sterigmata straight to slightly curved, 2 \times 1.5 μm . Basidioles not observed. *Trama* 20–37 μm wide, of hyaline, thin-walled, gelatinous, (2–) 5–9 μm broad, interwoven hyphae. *Peridium* variable in thickness: apex 120–155 μm thick, of periclinal, thin-walled hyphae 1.5–3 μm in diam, lacking obscuring pigment; at base 770 μm thick, two-layered, the epicutis 80–120 μm thick, of hyaline, thin-walled, periclinal hyphae 3–5 μm in diam; subcutis 500–650 μm thick, of randomly oriented, thin-walled, hyaline hyphae 6–9 μm in diam.

A few thick-walled (1.5 μm) hyaline hyphae 9–11 μm in diam and thick-walled spherocysts up to 62 \times 39 μm are present in the subcutis. These thick-walled elements may be homologous to the nodose hyphae in *Protuberia majacuja* Moell. (Imai and Kawamura 1958) or they may be hyphae of another fungus.

The greenish yellow, oblong spores, cartilaginous gleba, and lack of peridial sutures place *Phlebogaster* in the Hysterangiaceae. The sporocarps are subglobose to lobed and lack the prolonged, tapered, sterile base and raised ridges attaching the gleba to the peridium characteristic of *Phallo-gaster*. The greenish yellow spores and absence of a percurrent columella differentiate *Phlebogaster* and *Rhopalogaster*. The sectored gleba



FIGS. 1–5. *Phlebogaster laurisylvicola* (MM1289, CUP). 1. Section of the gleba and subcutis showing the locules and gelatinous hyphae completely enclosing the gleba. A portion of a large sterile vein is shown in the lower right-hand corner, $\times 160$ (interference contrast). 2. Obpyriform basidium bearing immature spores, $\times 1600$ (interference contrast). 3. Section of the hymenium showing the small, oblong basidiospores with verrucose ornamentation, $\times 1600$. 4. Upper focus of basidiospore still attached to the basidium. A faint reticulate pattern is evident, $\times 1600$. 5. Basidiospore in median section. The spore wall is two-layered: the outer layer is smooth and the inner layer ornamented, $\times 1600$.

separates *Phlebogaster* from *Hysterangium*. The small, ornamented spores may also be distinctive, although Malençon (1975) has described similar spore ornamentation, except for the very faint reticulation, in *Hysterangium cistophilum* (Tul.) Zeller & Dodge and in *H. rickenii* Soehner.

11. *Rhizopogon rubescens* (Tul.) Tul., Giorn. Bot. Ital. I, 2: 58. 1844.

Material examined: MADEIRA: leg. Korf et al. MM1514, MM1518, MM1544, MM1570, MM1608, MM1609, MM1610 (CUP, OSC).

Habitat and season: hypogeous under *Pinus* spp. during January.

Smith and Zeller (1966) have been followed in retaining *R. rubescens* as distinct from *R. roseolus* (Corda) Fr. due to the pronounced yellow color of the peridium in the Madeira collections. *R. rubescens* has been collected in Europe and North America under *Pinus*.

12. *Rhizopogon subareolatus* Smith in Smith and Zeller, Mem. N. Y. Bot. Gard. 14: 81. 1966.

Material examined: MADEIRA: leg. Korf et al. MM1501, MM1502, MM1508 (CUP, OSC), MM1611 (CUP).

Habitat and season: hypogeous under *Pseudotsuga menziesii* in January.

Basidiocarps up to 29 × 19 mm, subglobose, attached by appressed basal rhizomorphs, concolorous with peridium; outer surface scabrous with grayish brown aerolate patches, ± 0.1 mm broad; peridium thin, light yellowish brown, flushing pink on exposure, dark red in cross section when bruised. *Gleba* moderate yellowish brown; locules labyrinthiform, 0.25–0.5 mm broad as dried; consistency firm. Odor not noted. Chemical reactions of peridium: KOH, green; FeSO₄ plus ethanol, dark green. *Spores* 6–7 × 2.5–3 µm, ellipsoid, thin-walled, pseudoseptate, hyaline singly, light brown in mass in Melzer's reagent. *Basidia* 15–20 × 4–6 µm, subcylindric, hyaline, thin-walled, 8-spored. Paraphyses 2–3 celled, terminal cell clavate or obclavate, 10–20 × 7–10 µm, hyaline, thin-walled. *Trama* 25–30 µm wide, of loosely interwoven, hyaline, gelatinous, 4–5 µm broad hyphae, simple septate. *Subhymenium* of hyaline, thin-walled, ± globose, 5–8 µm in diam cells. *Epicutis* 50–100 µm thick, of brown, thick-walled, simple-septate, loosely interwoven, 5–7 µm broad hyphae, apex of terminal cells rounded. *Subcutis* 50–70 µm thick, of periclinal, appressed, thin-walled, hyaline, 4–5 µm broad hyphae. Black granules in water or Melzer's solution scattered throughout the trama just below the subcutis, dissolving in KOH to produce a diffuse green pigment in the subcutis and adjacent locules. No clamp connections noted.

R. subareolatus is collected under *Pseudotsuga menziesii* in California, Oregon, and Washington. Presumably, it was introduced to Madeira with *P. menziesii*, but we were unable to determine the source and whether seed or seedlings had been imported.

13. *Rhizopogon vulgaris* (Vitt.) M. Lange sensu Smith in Smith and Zeller, Mem. N. Y. Bot. Gard. 14: 136. 1966.

Material examined: CANARY ISLANDS: TENERIFE, leg. Korf et al. MM1235, MM1236, MM1237, MM1238, MM1239, MM1240, MM1241, MM1248, MM1249, MM1250 (CUP, OSC, LAG). *HIERRO,* leg. Korf et al. MM1431, MM1435, MM1438 (CUP, OSC, LAG), MM1436, MM1442 (CUP, OSC).

Habitat and season: hypogeous to emergent under *Pinus canariensis* during December and January.

This species has previously been reported from Tenerife (Calonge and Demoulin 1975) and is widely distributed in Europe and North America.



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