

Heppia arenacea and *Lempholemma polycarpum*, two new species from southern Yemen and Socotra

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Abstract: *Heppia arenacea* M. Schultz and *Lempholemma polycarpum* M. Schultz are described as new and placed in the *Lichinaceae*. *Heppia arenacea* occurs in soil-crust communities in southern Yemen and on Socotra. It colonizes both calcareous soil-crusts over limestone as well as soils originating from basaltic rocks. The sand-coloured, squamulose thallus, the erumpent, dark red apothecia and the incorporation of soil material into the thallus are diagnostic characters. *Lempholemma polycarpum* occurs on inclined limestone boulders in south-eastern Yemen. It is characterized by an umbilicate-lobate thallus with radiating, tongue-shaped, furcate lobes which bear numerous, small, immersed apothecia with punctiform discs.

Key words: lichenized cyanobacterium, *Lichinaceae*, soil-crusts

Introduction

During three visits to southern Yemen and the Yemeni island Socotra in 1997, 2001, and 2002, an inconspicuous, squamulose soil lichen was discovered at several distant localities. The species is hard to recognize as a lichen in the field since the pale sand coloured to pale ochre colouration of the thallus equals that of the underlying or bare surrounding soil. The heteromerous thallus anatomy, the presence of apothecia with dark red discs, asci containing eight simple spores, and a *Scytonema*-like, filamentous, cyanobacterial photobiont identify this species as a member of the genus *Heppia* Naeg. ex A. Massal. A second new species was discovered in SE Yemen in 2001. It occurs on rocky slopes on inclined limestone boulders in open tropical, deciduous dry forest vegetation. The thallus is black, umbilicate-lobate with radiating lobes. The lobes are tongue-shaped, convex and moderately furcate. Mature thalli have lobes bearing numerous, small apothecia with

punctiform discs. The prototunicate asci containing 8, simple spores, the type of ascoma ontogeny, pycnidia and conidiophores as well as the presence of *Nostoc*-photobionts assign this species to the genus *Lempholemma* Körb. of the *Lichinaceae*.

Material and Methods

Cryotome sections (16–20 µm thick) were stained with lactophenol cotton blue. Anatomical measurements were made using semi-permanent mounts. The iodine reaction was tested after pretreatment with KOH. In order to remove at least part of the soil material, which is abundantly incorporated in the thalli of *Heppia arenacea*, individual thallus squamules were washed in water prior to sectioning using some soap and subsequently treated with diluted hydrochloric acid. After cutting, the sections were washed again. Micrographs were taken with a Zeiss (Jena) compound microscope. Macrographs were taken with a Canon T70 camera using a Canon 3.5/35 mm macro lense mounted on bellows and an electronic flash.

The Species

Heppia arenacea M. Schultz sp. nov.

Thallus squamulosus, arenaceus. Squamulis rotundatis vel angulosis, planis vel concavis, 0.6–2.5 mm latis. Thallus heteromerus; cortex superius paraplectenchymaticus, hyphis in strato algarum periclinis vel irregu-

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laris. Cyanobacteria pluricellularia, filamentosa, *Scytonematis* similis. Apothecia rotundata, erumpentia; discus rubro-niger, planus. Margo thallinus indistinctus. Hymenium hyalinum, in iodo caerulescens; excipulum proprium distinctum. Asci octospori, cylindricei, in iodo non tincti, leptodermati. Ascospores unicellulares, hyalinae, ellipsoideae, $17.4 (\pm 2.7) \times 7.5 (\pm 0.6) \mu\text{m}$ ($n=25$). Pycnidia immersa, globosa; conidia bacillaria, $3-3.5 \times 1-1.5 \mu\text{m}$.

Typus: Yemen, Governorate Abyan, Jabal Arays, Wadi Asariah, below *Anisotes trisulcus* shrub, on exposed soil over basaltic rock, c. 600 m, $13^{\circ}28'N$, $45^{\circ}55'E$, 16 March 2002, M. Schultz 14238a (HBG—holotypus; B, herb. M. Schultz—isotypi).

(Figs 1 & 2)

Thallus sand-coloured to pale ochre, depending on the colour of the underlying soil, sometimes slightly greyish-white pruinose, somewhat gelatinous when wet. Thallus squamulose but resembling an areolate crust; squamules angulose to roundish (Figs. 1A–C), 0.6–2.5 mm wide, at first \pm plane, later often somewhat concave with the margins lifted up from the substratum. Squamules attached to the substratum by thick rhizohyphae originating from the entire lower surface, sometimes also with rhizines composed of strands of up to 10 hyphae, 12.5–15 μm thick. Thallus anatomy heteromerous (Fig. 2D), *upper cortex* 20–35 μm thick, paraplectenchymatous, cells angulate to roundish, small, 3–5 μm wide, overlain by a continuous epinecral layer, 10–50 μm thick. *Photobiont* layer 75–150 μm thick, composed of \pm vertical or irregular reticulate hyphae, cells short to elongated, $7.5-12.5 \times 2.5-3 \mu\text{m}$. *Photobiont* is a filamentous cyanobacterium (*Scytonema*), filaments short and contorted or \pm split into individual cells (Figs 2B & D). Cyanobacterial filaments straighter and less bent and twisted in the lower parts of the photobiont layer. Filament cells 7.5–12.5 μm wide without sheath, 10–17.5 μm wide including sheath. *Lower cortex* and *medulla* lacking. Abundant soil particles are incorporated in all parts of the thallus and apothecium except the hymenium and subhymenium (Figs 2A & B).

Apothecia usually abundant, 0.6–0.8(–1) mm wide, 1–2(–3) per squamule, immersed to semi-immersed (Figs 1A–D).

Apothecia having a cracked, \pm crater-like margin after the discs break through the thallus surface; hence, the thalline margin is cracked and reduced to small, ascending, \pm triangle-like appendages (Figs 1A & B). Apothecial discs flat and open, dark red to reddish black, at first smooth, becoming rough and multiple umbonate with age (Figs 1D & 2A). Upper parts of the hymenium reddish brown, up to 10 μm high, K–. *Hymenium* hyaline, IKI+ blue, up to 175 μm high, finally divided into several partial hymenia by intrusion of sterile hyphal material (Fig. 2A) causing the multiple umbonate appearance of old apothecial discs. *Subhymenium* hyaline, 10–25 μm high, IKI+ blue. *Paraphyses* straight, somewhat branched and anastomosing, distinctly septate, cells 3–7.5 \times 1.5–2 μm ; apical cells becoming thickened, 3–3.5 \times 5 μm wide. *Excipulum proprium* (Fig. 2B) distinct, hyaline, apical parts yellowish brown, up to 50 μm wide, composed of thin, gelatinous, interwoven hyphae. *Asci* (Fig. 2C) cylindrical to narrowly clavate, 75–100 \times 12.5–15 μm , ascus wall thin throughout, IKI–. *Ascospores* 8, simple, hyaline, ellipsoid, $17.4 (\pm 2.7) \times 7.5 (\pm 0.6) \mu\text{m}$ ($n=25$), spore wall thin (Fig. 2C).

Pycnidia immersed, globose, colourless, up to 150 μm wide, wall simple at first, finally cerebiform, ostium dark coloured. *Conidia* simple, hyaline, bacilliform, $3-3.5 \times 1-1.5 \mu\text{m}$, produced terminally on simple *conidiophores*.

Ontogeny. Ascumata develop from coiled ascogonia formed in a tangle of \pm vertically arranged generative hyphae.

Etymology. The species name refers to the thallus colour which equals that of the soil it colonizes.

Ecology and distribution. *Heppia arenacea* grows in soil crust communities over limestone and basaltic rock. It occurs in fully exposed situations in desert habitats from 200–2100 m elevation as well as in somewhat sheltered localities between large boulders in the understory of *Sterculia africana*

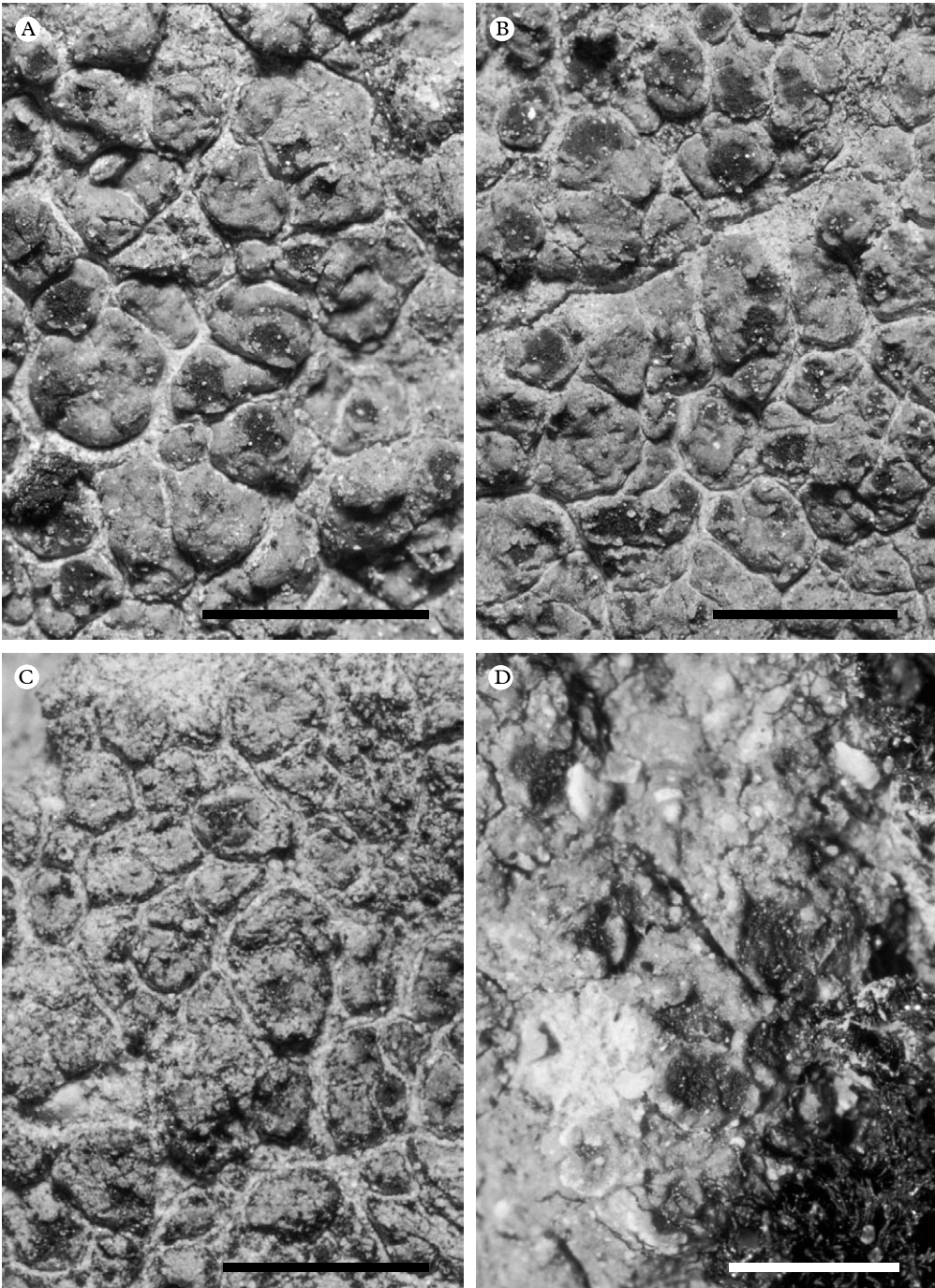


FIG. 1. *Heppia arenacea* external thallus morphology, thallus squamules with erumpent apothecia. A, holotype; B, isotype (hb. Schultz); C, juvenile thallus with small, slightly pruinose squamules and apothecial disc breaking through the surface (Schultz 14069a); D, large apothecia with rough discs due to protruding bands of sterile hyphae in the hymenium (Schultz 14064e). Scales: A & B=2 mm, C & D=1 mm.

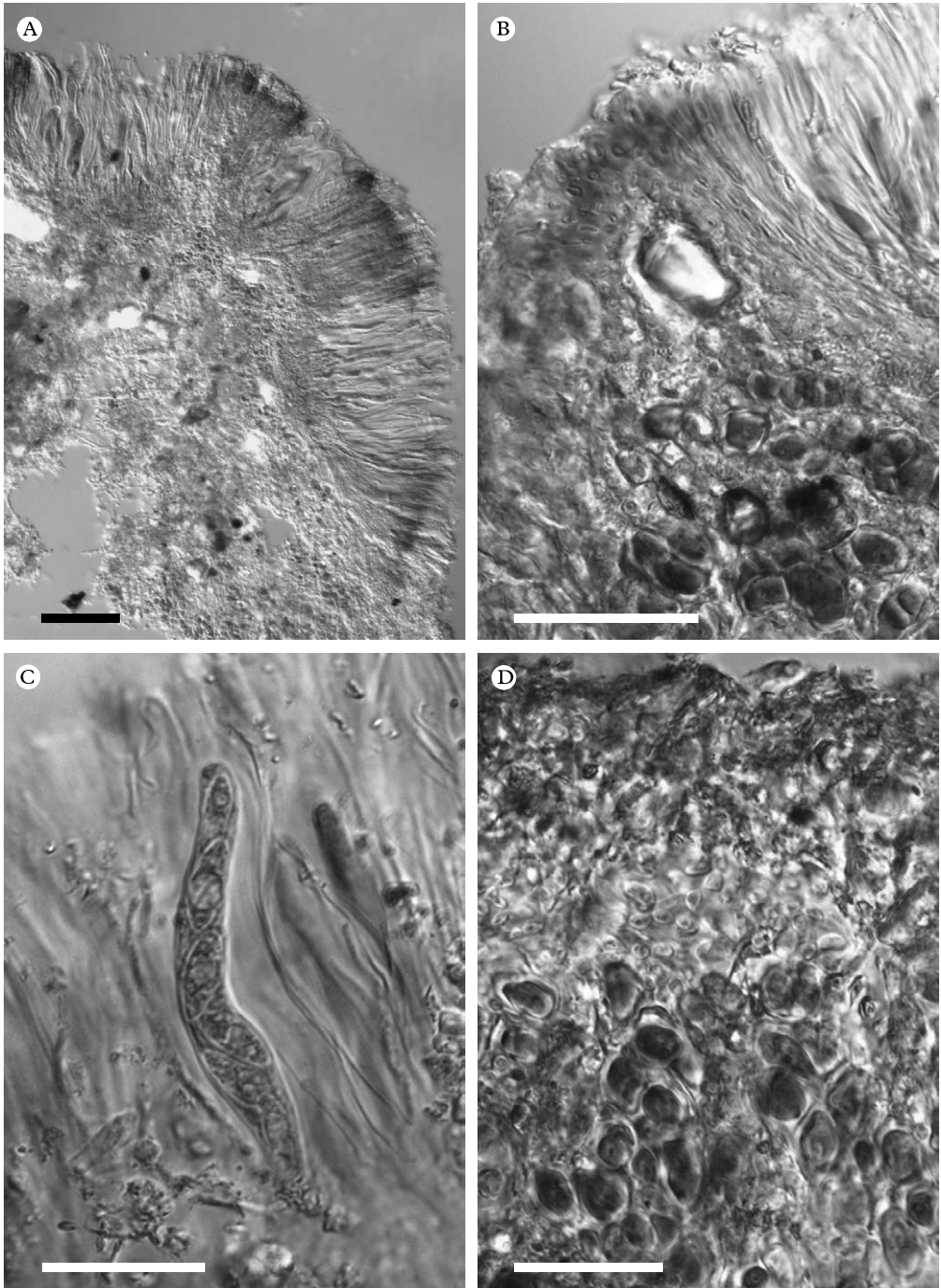


FIG. 2. *Heppia arenacea*. A, multiple divided hymenium of old apothecium (holotype); B, excipulum proprium with incorporated soil particle, hymenium and photobiont cells (Schultz 14235a); C, cylindrical ascus with ellipsoid spores (Schultz 14203a); D, stratified thallus anatomy with epinecral layer, upper cortex and photobiont layer (holotype). Scales: A=200 μ m, B–D=25 μ m.

subsp. *arabica* woodlands of the upper Wadi Asariah (Jabal Arays). *Heppia arenacea* is known from four distant localities in southern Yemen (Djaul plateau, Ras Fartak, Jabal Arays, Wadi Raiwa) and another locality on Socotra (Hamaderoh Mts). The species may well be expected in similar habitats in Oman or Saudi Arabia as well as in Eritrea and Somalia on the African continent. *Heppia arenacea* is usually accompanied by free-living cyanobacteria (*Scytonema*), riccioid and marchantioid liverworts (see Kürschner 2003) and various soil lichens such as *Collema coccophorum* Tuck., *Psora decipiens* (Hedw.) Hoffm., *Placidium* spp., *Toninia* spp., *Heppia* spp., *Peltula* spp., and *Gloeoheppia turgida* (Ach.) Gyeln. Four species of *Heppia* have hitherto been reported from the Arabian Peninsula: *Heppia adglutinata* (Kremp.) A. Massal., *H. despreauxii* (Mont.) Tuck., *H. solorinoides* (Nyl.) Nyl. and *Heppia conchiloba* Tuck. The last species was reported by Schultz (1998) from southern Yemen, however, this record actually refers to the new species described here. *Heppia exigua* (Müll. Arg.) Müll. Arg. described from Socotra is unlikely to belong to *Heppia* (Schultz & Mies 2003: 77).

Notes. The new species is most distinctive because of its sand-coloured thallus with numerous soil particles incorporated into all parts of the vegetative thallus. Sometimes, soil grains even become incorporated in the excipulum proprium (Fig. 2B). The reddish black, erumpent apothecia have a thin, pale proper margin with erect, \pm triangle-like appendages (i.e. remnants of the receding thalline margin). However, finally the appendages break off and the apothecia are immersed with flat or somewhat sunken discs, as usually observed in the genus. Such appendages may commonly occur during the apothecial development in *Heppia* (see Büdel 1987; Marton & Galun 1981; Henssen 1994; Henssen 1995). However, these appendages were absent or very inconspicuous in the fertile material of *H. adglutinata*, *H. despreauxii* and *H. solorinoides* studied by the author for comparison. The new species resembles *Heppia despreauxii*, *H.*

conchiloba and *H. solorinoides* in the presence of an epinecral layer, a distinct upper cortex and in the lack of a lower cortex. However, all *Heppia* species usually have a thallus colour (white, grey, shades of olive or almost black) that is distinctly different from that of the soil colonized. Furthermore, the extensive incorporation of soil material into an otherwise completely healthy and richly fertile thallus as observed in *Heppia arenacea* has not previously been reported for the genus and has not been observed by the author in any other species of *Heppia* studied so far.

Additional material studied. **Yemen:** *Governate Abyan:* Jabal Arays, Wadi Asariah, below *Anisotes trisulcus* shrub, on exposed soil over basaltic rock, c. 600 m 13°28'N, 45°55'E, 2002 M. Schultz 14235a (hb. M. Schultz). *Governorate Hadhramout:* plateau of Djaul Mts., W of road from Riyān into the Wadi Hadhramout, upper valley slope with uprising clouds, c. 2000 m, in exposed calcareous soil crusts and in sheltered, sand-filled rock clefts, 14°49.43'N, 48°48.57'E, 1997, M. Schultz 14069a, 14070g (hb. M. Schultz). *Governorate Hadhramout:* Socotra, Hamaderoh Mts., c. 28 km E of Hadibu, steep upper valley slope, between limestone boulders, c. 450 m, 12°36'N, 54°16.9'E, 1997, M. Schultz 14064e (hb. M. Schultz). *Governorate Al-Mahra:* Ras Fartak, plateau area, upper part of mountain slope, in sheltered clefts in calcareous soil crust, 480 m, 15°53'N, 51°58.7'E, 2001, M. Schultz (14117c) (hb. M. Schultz). *Governorate Abian:* Jabal Arays, lower Wadi Asariah, soil crust below small volcanic boulders in wadi slope, E-exposed, sheltered, c. 200 m, 13°26'33.3"N, 45°23'E, 2002, M. Schultz 14249a, 14250b (hb. M. Schultz). Wadi Raiwa, Straße von Lawdar nach Harnap, Boden über quarzitischem Fels, 2100 m, 14°01'N, 46°43'E, 1998, B. Mies (14420) (hb. B. Mies, duplicate hb. M. Schultz).

Lempholemma polycarpum M. Schultz sp. nov.

Thallus nigricans, gelatinosus, umbilicatus, lobatus, 3–6 mm latus. Lobi homoiomeri, ecorticati, lingulati, furcati, elongati, convexi; hyphis reticulatis, cellulis cylindraceis. Algae *Nostoc* sunt. Apothecia immersa vel semi-sessilia, parva, usque ad 0.25 mm lata, disco punctiformo, margine thalino indistincto, excipuloque proprio distincto, hyalino, tenui. Hymenium in iodo caerulescens. Paraphyses simplices vel ramosae. Asci octospori, cylindracei ad anguste clavati, in iodo non tincti, leptodermati. Ascospores non septatae, hyalinae, ellipsoideae, $12.4(\pm 1.3) \times 6.5(\pm 0.9) \mu\text{m}$ ($n=25$). Pycnidia immersa vel semi-immersa, 0.075–0.1 \times 0.1 mm; conidia bacillaria vel biguttulata, 3.5–4 \times 1–1.5 μm .

Typus: Yemen, Governorate Al-Mahra, Damkaut, Shah-ot, open forest vegetation, on small inclined limestone boulders, 680 m, 16°33.9'N, 52°46.4'E, 17 October 2001, M. Schultz (14138a) (HBG—holotypus; B, hb. M. Schultz— isotypi).

(Figs 3 & 4)

Thallus blackish, dull, rarely slightly pruinose, concolorous below, gelatinous when wet. Thalli consisting of individual, ± regular, umbilicate-lobate rosettes 3–6 mm in size (Figs 3A & B). Lobes radiating, free, tongue-shaped, convex, 1–2 times furcately branched with diverging tips, short, 1.5–2.5 mm long, 0.5–0.6 mm wide, 0.25–0.45 mm thick. Lobe surface smooth (Fig. 3A) becoming verrucose when numerous small apothecia are produced (Fig. 3C). *Thallus* ecorticate, anatomy homoiomerous (Fig. 4A) but a few strands of hyphae may be present in the centre and at the base of the lobes. Mycobiont forming a loose network of elongated hyphae which becomes denser towards the lobe margins, cells 10–17.5 × 1.5–2(–5) µm. *Photobiont* *Nostoc* with twisted and bent, bead-like chains of 5–20 globose to ellipsoid cells (Fig. 4A). *Photobiont* cells 3–5 µm wide without sheath, 10–12.5 µm wide including the sheath, gelatinous sheath hyaline in the thallus centre, yellowish brown towards the upper surface.

Apothecia usually abundant, 1–10 per lobe (Fig. 3C), very small, 200(–250) µm wide, immersed to semi-immersed with low thal-line margin, apothecial disc punctiform, depressed, finally open, 100(–150) µm wide, reddish black when dry, dark red when moist and usually surrounded by pale brownish proper margin. Apothecia leaving small pits when old hymenia fall off. Uppermost part of the *hymenium* reddish brown, K–. *Hymenium* hyaline, 100 µm high, IKI+ blue. *Subhymenium* hyaline, 20–25 µm high, IKI+ blue. *Paraphyses* straight, sparingly branched and anastomosing, distinctly septate, apical cell slightly thickened, 3.5(–5) µm wide. *Excipulum proprium* (Fig. 4B) thin, 7.5–12.5 µm wide, apically slightly widened and somewhat brownish, otherwise hyaline, composed of thin, interwoven hyphae. *Asci* (Fig. 4B) cylindrical to narrowly clavate, up

to 75 × 7.5–10 µm, ascus wall thin throughout, IKI–. *Ascospores* eight, simple, hyaline, broadly ellipsoid, 12.4(±1.3)–6.5(±0.9) µm (*n*=25); spore wall slightly thickened with age, up to 1.5 µm wide (Fig. 4C).

Pycnidia immersed to semi-immersed, ± globose to broad pyriform, 75–100 × 100 µm, wall simple, ostiolum dark coloured. *Conidia* simple, hyaline, bacilliform to slightly rod-shaped, 3.5–4 × 1–1.5 µm, produced terminally on simple *conidiophores*.

Ontogeny. Ascogones arise beneath pycnidia (pynoascocarps). Juvenile asci are formed in the pycnidial cavity when some of the conidiophores are still producing conidia, whereas other conidiophores become stretched, thus functioning as 'primary' paraphyses (Fig. 4C). In young apothecia remnants of conidiophores are often visible between the hymenium and the surrounding proper exciple (Fig. 4C).

Etymology. The species name refers to the abundantly produced, small apothecia.

Ecology and distribution. *Lempholemma polycarpum* grows on inclined limestone boulders. It occurs in rather exposed situations on rocky slopes with open forest vegetation. It is known from two localities in SE Yemen. *Lempholemma polycarpum* was accompanied by *Paulia aldabrensis* Henssen, *P. perforata* (Pers.) Asahina, *L. botryosum* (A. Massal.) Zahlbr. and a species of *Psorotichia* A. Massal. Three further species of *Lempholemma* are known to occur in the Arabian Peninsula and Socotra: *Lempholemma socotranum* M. Schultz and *L. intricatum* (Arnold) Zahlbr. were reported from Socotra (Schultz 2003; Schultz & Mies 2003). Recent records of *Lempholemma botryosum* from Al-Mahra Governorate in SE Yemen will be communicated in a forthcoming paper.

Notes. The new species is close to the Socotran *Lempholemma socotranum* which, however, differs in its umbilicate-squamulose thallus with incised to short-lobed margins, the larger apothecia with

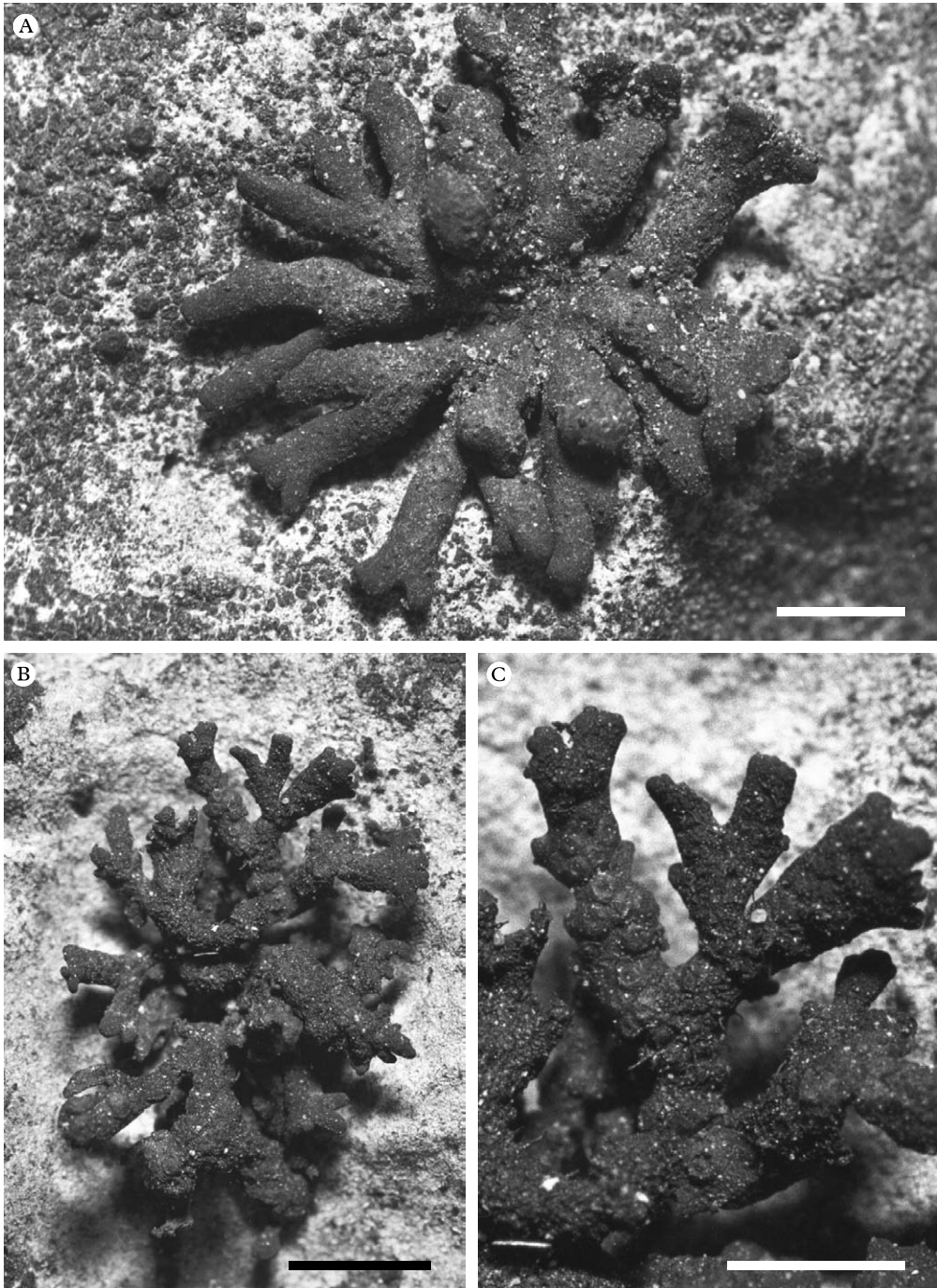


FIG. 3. *Lempholemma polycarpum*, external thallus morphology. A, lobate thallus rosette, lobes tongue-shaped, convex and shortly furcate (holotype); B, aged thallus rosette with more irregular growth (Schultz 14129b); C, apothecia small, immersed to semi-immersed, discs punctiform (Schultz 14129b). Scales: A & C=1 mm, B=2 mm.

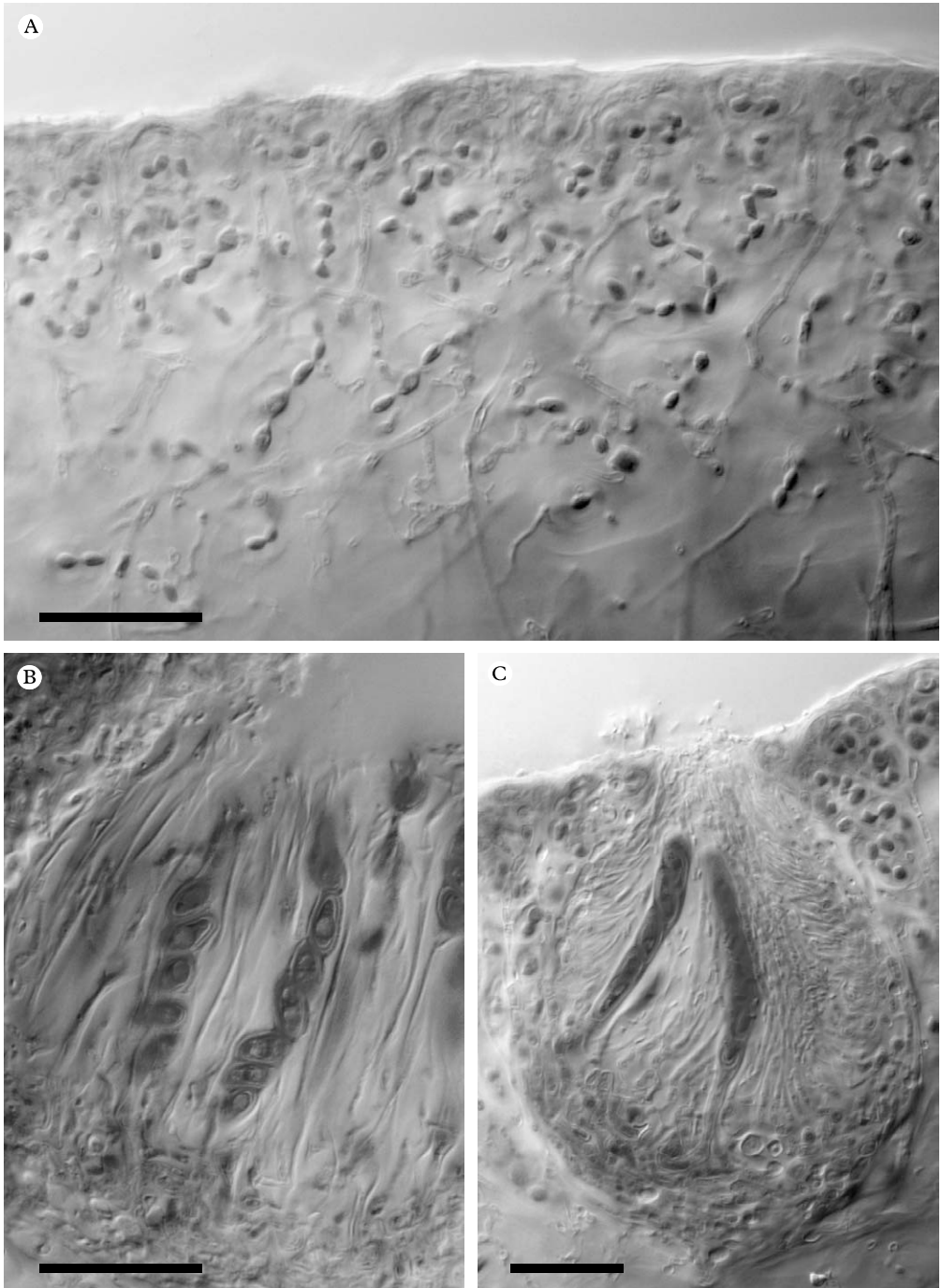


FIG. 4. *Lempholemma polycarpum*, anatomy (holotype). A, homoiomorous thallus anatomy with chains of *Nostoc* and reticulate hyphae. B, ellipsoid ascospores and part of excipulum proprium (top left). C, young pycnoascocarp with two asci, remnants of conidiophores situated laterally at the former pycnidial wall and elongated conidiophores transformed into primary paraphyses arising from the base of the former pycnidium. Scales: A–C=25 μ m.

wider, open discs and the smaller ascospores. *Lempholemma radiatum* (Sommerf.) Henssen is similar in the presence of elongated, radiating lobes but they are longitudinally ridged and plicate (Henssen 1968). It also differs in the presence of isidia, the type of ascoma ontogeny (spheroid tangle of generative hyphae) and a more or less arctic distribution. The Caribbean species *Lempholemma lingulatum* (Tuck.) Henssen is another distinctly lobate member of the genus. However, the lobes are distinctly tongue-shaped, apically widened and unbranched. *Lempholemma polycarpum* is also close to *Collema multipartitum* Tuck. and *C. fragile* Taylor, both of which occur in similar habitats on Socotra. The former species differs in the presence of eventually sessile apothecia, septate ascospores, amyloid ascus tips and finely striate lobes, however the latter differs mainly in the presence of laminal isidia on more stunted, shortly furcate lobes with usually pruinose tips.

Additional material studied. **Yemen:** Governorate Al-Mahra: W of Hawf close to the Omani border, camp at Jabal Quatam Jehzir, on S-exposed, 45° inclined, relatively open limestone boulders, open forest vegetation with *Anogeissus dhofarica* and *Maitenus dhofarensis*, c. 750 m, 16°38.9'N, 52°57.6'E, 2001, M. Schultz (14129b) (hb. M. Schultz).

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