DOI 10.12905/0380.sydowia73-2020-0185 Published online 23 December 2020

Three new *Entoloma* species of the Cyanula clade from (sub)alpine habitats in Northern Norway and Sweden

Machiel Evert Noordeloos[1], Jostein Lorås[2], Siw Elin Eidissen[2], Tor Erik Brandrud[3], Egil Bendiksen[3], Olga Morozova[4], John Bjarne Jordal[5] Øyvind Weholt[2], Gerrit Maarten Jansen[1], Ellen Larsson[6,7] & Bálint Dima[8,*]

[1] Naturalis Biodiversity Center, P.O. Box 9517, 2300 RA, Leiden, The Netherlands
[2] Nord University, Nesna, NO-8700 Nesna, Norway
[3] Norwegian Institute for Nature Research (NINA), Sognsveien 68, NO-0855 Oslo, Norway
[4] Komarov Botanical Institute of the Russian Academy of Sciences, 2 Prof. Popov Str., RUS-197376 St Petersburg, Russia
[5] Biolog J.B. Jordal, Skrøovegen 21, NO-6610 Øksendal, Norway
[6] Department of Biological and Environmental Sciences, [7]Gothenburg Global Biodiversity Centre, University of Gothenburg, P.O. Box 461, SE 405 30 Göteborg, Sweden
[8] Department of Plant Anatomy, Institute of Biology, Eötvös Loránd University, Pázmány Péter sétány 1/c, H-1117 Budapest, Hungary

* e-mail: cortinarius1@gmail.com

Noordeloos M.E., Lorås J., Eidissen S.E., Brandrud T.E., Bendiksen E., Morozova O., Jordal J.B., Weholt Ø., Jansen G.M., Larsson E. & Dima B. (2020) Three new *Entoloma* species of the *Cyanula* clade (Entolomataceae, Agaricales) from (sub)alpine habitats in Northern Norway and Sweden. - Sydowia 73: 185–196.

Three *Entoloma* species belonging to the Cyanula clade from (middle-) northern boreal and alpine areas are described as new to science. *Entoloma montanum*, *E. nordlandicum*, and *E. septentrionale*, recorded from the Holmvassdalen area at Grane, Northern Norway while *E. montanum* shows a wide distribution in Northern Scandinavia and the Caucasus. *Entoloma nordlandicum*, however, has recently been recorded also from the Netherlands. The three species are phylogenetically well defined based on analysis of the nrDNA ITS region and they are distant from their closest relatives. Morphological descriptions of each species are given, as well as their ecology, distribution and relationships towards similar species are discussed.

Keywords: Entolomataceae, Agaricales, Basidiomycota, ITS phylogeny, taxonomy. – 3 new species.

This study is part of a large-scale molecular phylogenetic and morphological study of the Cyanula clade in genus *Entoloma* in Europe to be published in due course. The clade/group Cyanula is here taken in a wide sense, including all clampless, often vividly bluish coloured species, formerly included in subgen. *Leptonia*, but shown to be phylogenetically quite distant from the clamped *Leptonia* s. str. taxa (Morozova et al. 2014).

The present study is also part of mycological research currently going on in the vast, largely little visited higher altitude forests and alpine habitats of Northern Norway and Northern Sweden. Particularly the calcareous Holmvassdalen Nature Reserve in Grane, Nordland, Norway, appears a rich hotspot for *Entoloma* species, including some apparently northern species, documented recently in a series of papers based on 10 years of intensive studies (Lorås & Eidissen 2011; Lorås et al. 2014; Noordeloos et al. 2018; Weholt et al. 2014, 2015, 2016). The hotspots here are found mainly in calcareous, subalpine/northern boreal *Picea abies* forests, sometimes also in alpine or middle boreal sites. Preliminary results from expeditions to some alpine, calcareous sites in adjacent northern Sweden revealed a similarly rich diversity in *Entoloma* with a number of unpublished species. The current paper deals with three, apparently northern boreal-alpine species new to science, found in northern Scandinavia, and belonging to the Cyanula clade.

Material and methods

Morphological study

All collections studied were photographed in the field, where also much attention was paid to characterize the surrounding vegetation and ecology. The material was described straight after collecting to fix the ephemeral macroscopical characters, dried and stored in the herbarium. Microscopical characters were studied with a Leica DMLS microscope, using a drawing tube and a Touptek Photo-

tronics camera and a Zeiss Axiophot microscope with DC controlled Cree XP-G3 R3 CRI 90+ LED illumination, Plan Neofluar objectives 40×/1.30 Oil, 100×/1.30 Oil, differential interference contrast (DIC) and 12MP Touptek video camera with SONY Exmor IMX226 CMOS sensor, Toupview advanced video & image processing application. Spores, basidia and cystidia were observed in squash preparations of small parts of the lamellae in 5 % KOH or 1 % Congo Red in concentrated NH_4OH. The pileipellis was examined on a radial section of the pileus in water. Basidiospore dimensions are based on observation of 20 spores, cystidia and basidia dimensions on observation of at least 10 elements per collection. Basidia were measured without sterigmata, and the spores without hilum. Spore length to width ratios are reported as Q. Unless otherwise stated, all material is deposited in the herbarium of the Botanical Museum, Oslo, Norway (O).

Molecular study and phylogenetic reconstruction

DNA extraction, PCR amplifications and sequencing were performed in the Norwegian Barcode of Life (NorBOL) project or followed Alvarado et al. (2015), Larsson & Jacobsson (2004) and Larsson et al. (2018). The primer pairs ITS1F/ITS4 (Gardes & Bruns 1993, White et al. 1990) were used in both PCR and sequencing reactions for nrDNA ITS barcoding region. Chromatograms were checked and edited with the CodonCode Aligner package (CodonCode Corp., Centerville, Massachusetts, USA). Sequence comparison with public and own databases followed Noordeloos et al. (2017). Newly generated sequences were submitted to GenBank (Tab. 1).

Our dataset composed of 55 nrDNA ITS sequences belonging to the Cyanula clade, carefully selected after an initial analysis using published and all our unpublished ITS sequences (data not shown). The dataset was aligned with MAFFT online v. 7 (http://mafft.cbrc.jp/alignment/server/), using the E-INS-i option (Katoh & Standley 2013). The alignment was checked and edited in SeaView 4 (Gouy et al. 2010). Maximum Likelihood analysis was performed in PhyML 3.1 (Guindon & Gascuel 2003) with the following settings: GTR+I+G model of evolution, gamma distribution of 10 rate categories, and tree topology search as SPR. Branch support was tested using the non-parametric, Shimodaira-Hasegawa version of the approximate likelihood-ratio test (SH-aLRT). The final tree was edited in MEGA 7 (Kumar et al. 2016).

Tab. 1. *Entoloma* nrDNA ITS sequences used in this study. * = not included in the phylogenetic analysis.

Species	Voucher	Country	Accession no.	Sequence origin
E. caesiellum aff.	SAAS1410	China	KP329587	GenBank
E. catalaunicum cf.	TU106338	Estonia	UDB011680	UNITE
E. ekaterinae	LE312053 holotype	Russia	MK693215	Crous et al. (2019)
E. erhardii	LE312051 holotype	Russia	MK693218	Crous et al. (2019)
E. exile	K(M)157760	Great Britain	MF977951	GenBank
E. foliocontusum cf. (as *Leptonia* cf. *foliocontusa*)	4954SL	USA	KX574457	GenBank
E. holmvassdalenense	O-F-75311 holotype	Norway	KM610321	Weholt et al. (2014)
E. incanum	K(M)190322	Great Britain	MF977955	GenBank
E. kauffmanii	KA13-1202	South Korea	KR673675	Kim et al. (2015)
E. largentii cf. (as *Leptonia* cf. *convexa*)	OSC144006	USA	KX574458	GenBank
E. longistriatum	PBM4018 / TENN070451	USA	KY744164	GenBank
E. montanum	O-F-252062 / EB80/09	Norway	MW340877	this study
E. montanum	O-F-293389 / HH111-10	Norway	MW340878	this study
E. montanum	O-F-257330 / JL40-11	Norway	MW340879	this study
E. montanum	O-F-249961 / JL192-11	Norway	MW340880	this study
E. montanum	O-F 249966 / JL110-13	Norway	MW340881	this study
E. montanum	O-F-254320 / JL53-14	Norway	MW340882	this study

Species	Voucher	Country	Accession no.	Sequence origin
E. montanum	O-F-254321 / JL75-14	Norway	MW340883	this study
E. montanum	O-F-76210 / JL108-16	Norway	MW340884	this study
E. montanum	O-F-76209 / JL129-16	Norway	MW340885	this study
E. montanum	LE312479	Russia	MW340886	this study
E. montanum	GB-0191641 / PAM13-52	Sweden	MW340887	this study
E. montanum	GB-0191639 / GG160811	Sweden	MW340888	this study
E. montanum	GB-0191640 / GG160810	Sweden	MW340889	this study
E. montanum	GB-0191636 / JO160812	Sweden	MW340890	this study
E. montanum	GB-0191637 / JO160812	Sweden	MW340891	this study
E. montanum	GB-0191638 / JO160812	Sweden	MW340892	this study
E. montanum	GB-0191632 / SJ160816	Sweden	MW340893	this study
E. montanum	GB-0191634 / HC160816	Sweden	MW340894	this study
E. montanum	GB-0191630 / EL136-18	Sweden	MW340895	this study
E. montanum	GB-0191635 / EL143-18 holotype	Sweden	MW340896	this study
E. montanum	GB-0191631 / EL147-18	Sweden	MW340897	this study
E. montanum	GB-0191633 / EL153-18	Sweden	MW340898	this study
E. mougeotii	LE254352	Russia	KC898446	Morozova et al. (2014)
E. nigrovelutinum	LE295077 / holotype	Vietnam	MF898426	Crous et al. (2017)
E. nipponicum	TNS F70747 holotype	Japan	MK693223	Crous et al. (2019)
E. nordlandicum	O-F-76176 / JL99-14, holotype	Norway	MW340899	this study
E. nordlandicum	O-F-76177 / JL128-14	Norway	MW340900	this study
E. nordlandicum	O-F-257331 / JL35-16	Norway	MW340901	this study
E. nordlandicum	O-F-257332 / JL36-16	Norway	MW340902	this study
E. nordlandicum	L0607818 / M. Jagers 19032	The Netherlands	MW340903	this study*
E. ochromicaceum	TU120040	Estonia	UDB023715	UNITE
E. querquedula	18.XI.2011 TUR	Finland	LN850627	Kokkonen (2015)
E. roseotinctum	WU13070	Austria	LN850611	Kokkonen (2015)
E. sarcitulum	TUR-31-VII-1967	FIN	LN850562	Kokkonen (2015)
E. septentrionale	O-F-254295 / JL77-14 holotype	Norway	MW340904	this study
E. serrulatum	LE254361	Russia	KC898447	Morozova et al. (2014)
E. sp.	CM13-233	New Caledonia	KY774214	Carriconde et al. (2019)
E. sp.	MES-534	Chile	KY462681	Truong et al. (2017)
E. subcaesiellum	LE253776 holotype	Russia	MK693224	Noordeloos & Morozova (2010)
E. subcaesiocinctum	SAAS2238	China	KY711234	He et al. (2017)
E. subcorvinum	SAT1518905/TENN070435	USA	KY744169	GenBank
E. subfarinaceum	SAT1518702 / TENN070395	USA	KY777374	GenBank
E. turci	MCVE3882	Italy	JF907993	Osmundson et al. (2013)
E. unicolor cf.	PBM3995 / TENN070383	USA	KY777373	GenBank
E. yanacolor	QCAM 6312 holotype	Ecuador	MG947210	Crous et al. (2018)

Results and discussion

Phylogenetic analysis

The nucleotide alignment was 757 characters long including gaps. The Maximum Likelihood phylogenetic tree is illustrated in Fig. 1, and the evidence for statistical support (SH-aLRT > 70) is indicated at the branches. The sequences of the three new species, *Entoloma montanum*, *E. nordlandicum*, and *E. septentrionale* formed well-supported terminal clades (Fig. 1.). *Entoloma montanum* and *E. septentrionale* occupy rather isolated positions within Cyanula, while *E. nordlandicum* belongs to a well-supported clade together with e.g. *E. holmvassdalenense* Eidissen, Lorås & Weholt, a species recently described from similar habitats of the Holmvassdalen Nature Reserve (Weholt et al. 2014). Intraspecific variation in the ITS sequences was low (0–1 nucleotide difference) in the three new species. According to our unpublished data of a large-scale revision in the subgenus *Cyanula*, the intraspecific genetic distance of *E. montanum* and *E. nordlandicum* towards their known sister species is ca. 30 nucleotide and indel differences (5 %), while the isolated *E. septentrionale* has over 60 nucleotide and indel differences (10 %) from its closest relative.

Taxonomy

***Entoloma nordlandicum* Noordel., Lorås, Eidissen & Dima. spec. nov.** – Figs. 2–3.
MycoBank no.: MB 838101

Etymology. – The epithet refers to the region Nordland in Norway.

Holotype. – NORWAY. Nordland, Grane, Holmvassdalen Nature Reserve, 3 September 2014. *leg.* J. Lorås & S. E. Eidissen, JL99-14 (O-F-76176). GenBank ITS: MW340899.

Description. – Pileus 20–30 mm broad, convex with involute then deflexed margin, slightly depressed at centre, initially very dark brown with slight blue-violaceous tinge near margin, later on paler and more greyish to ochraceous brown, sometimes with radial dark stripes, not translucently striate, entirely minutely squamulose with slightly darker pointed squamules. – Lamellae moderately distant, L = about 20–28, l = 1–3, deeply emarginate, narrowly ventricose, white then pink, with concolorous, entire edge. – Stipe 60–70 × 1–3 mm, cylindrical, dark greyish blue fading to grey-blue, not polished but covered with dark blue fibrils and minute flocks all over. Smell indistinct then farinaceous when old. – Basidiospores 8.0–11.2 × 6.5–8.4 µm; Q=1.1–1.5; Qav.=1.29; Vav.=281; average 9.6 × 7.5 µm, heterodiametrical, 5–7-angled. – Basidia 22–40 × 6–14 µm, clavate, 4-spored. – Lamella edge sterile, of the serrulatum-type. – Cheilocystidia 15–25 × 4–14 µm, irregularly distributed on gill edge, in tufts, but not intermixed with basidia, ellipsoid, cylindrical, often in short chains of 2 or 3 cells. – Hymenophoral trama regular to intermixed thin cylindrical hyphae 3–7 µm wide and more inflated hyphae, elements 80–120 × 6–20 µm. – Pileipellis a cutis with sparse trichodermal tufts of clusters of erect terminal cells 23–59(85) × 8–26 µm, with light brown intracellular pigment, subpellis with refringent granules. – Caulocystidia 25–50 × 6–18 µm, cylindrical, subclavate, clavate, in tufts, light brown intracellular pigment. – Clamp connections absent from all tissues.

Habitat. – In small patches with open, low-herb vegetation in calcareous spruce forests, both moist tall-herb types as well as more seasonal hygrophilous ones; also in *Sphagnum*.

Distribution. – Known from Norway in a restricted area in the county of Nordland in Northern Norway; sequence-verified from two localities in the Holmvassdalen area and one locality (with two collections) in the adjacent Geitklauvmyra nature reserve. In addition it has been found in the Netherlands.

Material examined (besides holotype). – NORWAY. Nordland, Grane, Holmvassdalen Nature Reserve, 3 September 2014, *leg.* J. Lorås & S. E. Eidissen, JL128-14 (O-F-76177); Geitklauvmyra Nature Reserve, 11 August 2016, *leg.* J. Lorås, S. P. Stolsmo & S. E. Eidissen, JL35-16 (O-F-257331), JL36-16 (O-F-257332). THE NETHERLANDS. Prov. Overijssel, Weerselo, Lemseler Maten, 8 October 2019, *leg.* M. Jagers, 19032 (L-0607818), GenBank ITS sequence: MW340903.

Comments. – *Entoloma nordlandicum* is characterized by the initially velvety-tomentose-squamulose, dark (bluish-) blackish brown pileus, fibrillose stipe with scaly apex, as well as short, clavate and often septate cheilocystidia, forming turfs/clusters. Furthermore, it seems to be a mainly (but not strictly) northern species. The species is close to *Entoloma holmvassdalenense*, which has recently been described from the same area, and the same kind of habitats (semi-open, calcareous tall-herb spruce forests and margins of rich fens). *Entoloma holmvassdalenense* differs from *E. nordlandicum* by a more polished stipe without caulocystidia and larger spores from two-spored basidia (Weholt et al. 2014). The pileus of *E. holmvassdalenense* seems also on average more squamulose than that of *E. nordlandicum*, but a few young specimens of the former are also observed with a more velvety

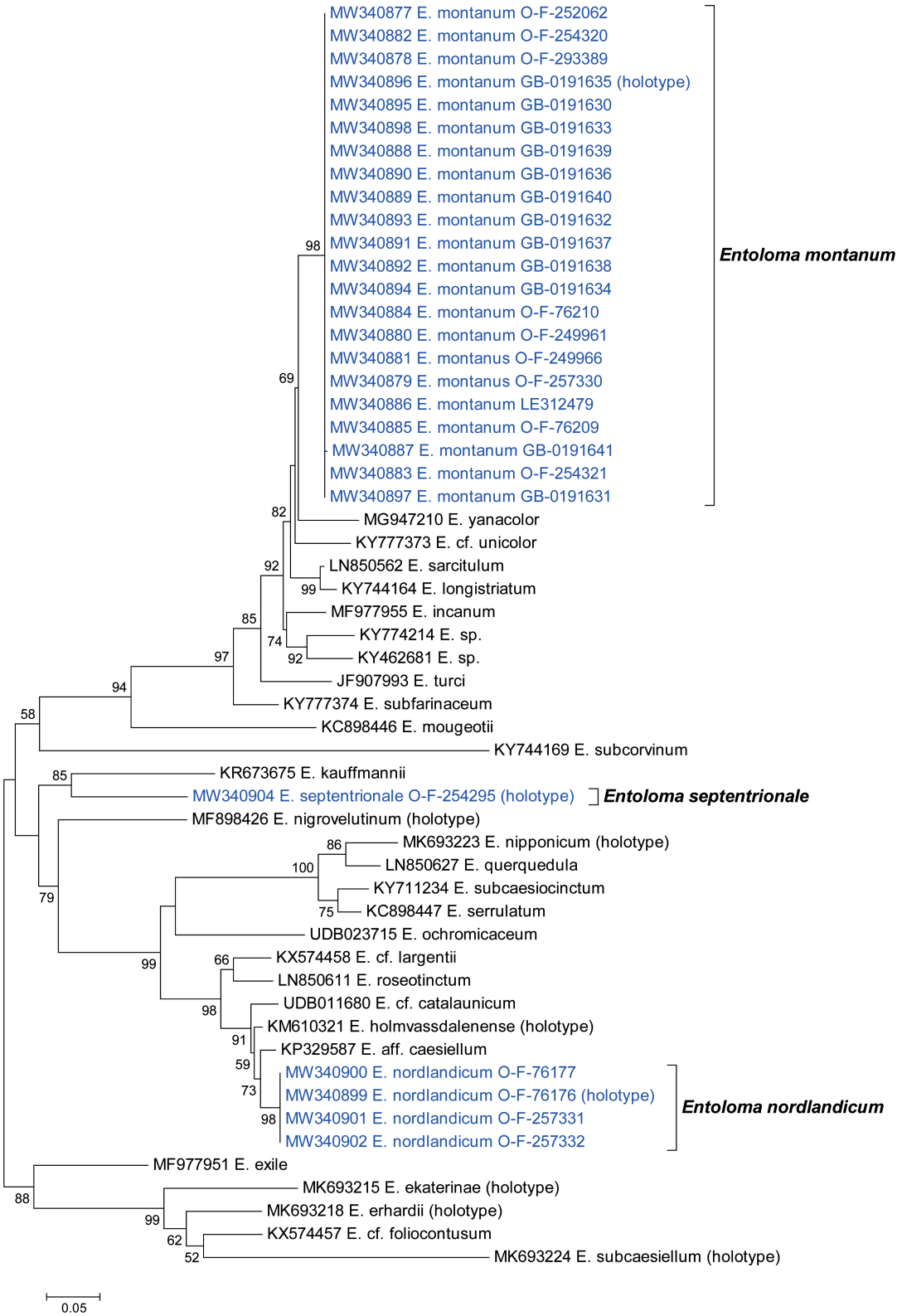

Fig. 1. Phylogenetic relationship of *E. montanum*, *E. nordlandicum* and *E. septentrionale* in the Cyanula clade inferred from nrDNA ITS sequences using PhyML. Newly generated sequences are highlighted in blue. PhyML SH-aLRT support values (>70) are indicated on the branches. Bar indicates 0.05 expected change per site per branch.

tomentose pileus. Both species belong to a rather diverse and well-supported clade together with the European species *E. roseotinctum* Noordel. & Liiv, and a number of taxa with uncertain identity (verified from one sequence each): *E.* cf. *catalaunicum* from Estonia, *E.* aff. *caesiellum* from China and *E.* cf. *largentii* from North America) (Fig. 1). *Entoloma roseotinctum* which also might be co-occurring with *E. nordlandicum* in Holmvassdalen, differs chiefly from the latter on the more umbilicate, radially fibrillose (hardly tomentose-scaly) pileus, and often being paler, including pinkish variants, never seen in *E. nordlandicum*. Microscopically, *E. roseotinctum* differs in having more slender and longer, more fusiform-lageniform cheilocystidia. *Entoloma roseotinctum* appears also to be a somewhat more southern species with a number of collections from *Tilia-Corylus* forests in S Norway, and recorded also from France as *E. glaucodubium* Corriol (Corriol 2016). Little is known about the morphology of the other taxa in the *E. holmvassdalenense-E. roseotinctum* clade, except that *E.* cf. *catalaunicum* (UDB011680) from Estonia is a pink coloured variant of *E. rhynchocystidiatum*.

Fig. 2. *Entoloma nordlandicum*: **A.** Basidiomata from Norway, holotype, drawing Hermod Karlsen; **B–C.** Basidiomata from The Netherlands, L0607818, photo M. Jagers.

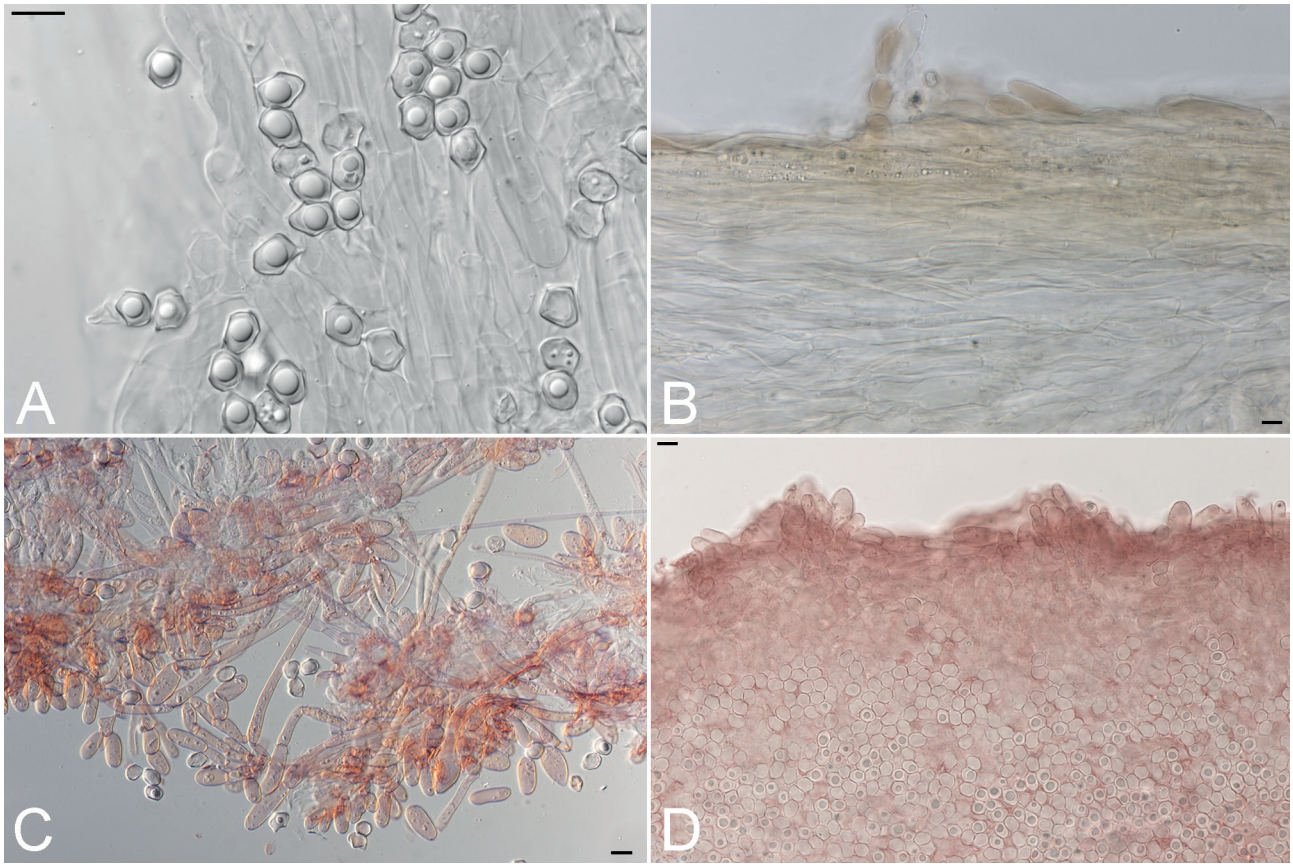

Fig. 3. *Entoloma nordlandicum*, holotype. **A.** Spores; **B.** Pileipellis; **C–D.** Lamella edge. Bar = 10 µm.

***Entoloma septentrionale* Noordel., Lorås, Eidissen & Dima, spec. nov.** – Fig. 4.
MycoBank no.: MB 838102

Etymology. – The epithet refers to the northern distribution of this species.

Holotype. – NORWAY. Nordland, Grane, Holmvassdalen Nature Reserve, 13 August 2014, *leg.* J. Lorås & S. E. Eidissen, JL77-14 (holotype, O-F-254295). GenBank ITS: MW340904.

Pileus about 20 mm in diameter, convex or expanded campanulate with low, broad umbo, with distinct umbilicus on umbo, with straight margin, probably hygrophanous, blackish-brown at centre (umbilicus), rest deeply translucently striate with dark reddish brown lines alternating with paler pinkish brown stripes, granulose-minutely squamulose at centre only, rest innately radially fibrous. – Lamellae moderately distant, L = about 40, l = 3–5, deeply emarginate with decurrent tooth, ventricose, white to pale pink with very finely crenulate, darker coloured edge. – Stipe about 60–70 × 2–3 mm, not equal but slightly and gradually broadened towards base, deep blue-grey, finely pruinose in upper part, downwards polished, dull, not shiny, base with white tomentum. – Smell and taste not noted. – Basidiospores 10.0–13.5 × 7.0–9.0 µm, average 10.5–12.0 × 7.8–8.4 µm, Q = 1.2–1.6, Qav = 1.35–1.45, heterodiametrical, 5–7-angled to almost nodulose in side-view. – Basidia 22–40 × 8.5–13 µm, 4, rarely also 2-spored, cylindrical to subclavate. – Lamella edge sterile of serrulatum type. – Cheilocystidia 25–75 × 7.5–18 µm, clavate to almost vesiculose, with brown, intracellular pigment. – Hymenophoral and pileitrama regular, made up of inflated elements, 120–200 × 7.0–19 µm. – Pileipellis a cutis with transitions to a trichoderm, made up of clavate terminal elements, 45–125 × 5–15(25) µm. – Pigment brownish-grey, intracellular in pileipellis. – Caulocystidia in dense clusters, 14–27 (43) × 5–11 µm, cylindrical to clavate, with brown, intracellular pigment. Brilliant granules present, particularly in pileitrama. – Clamp connections absent from all tissues.

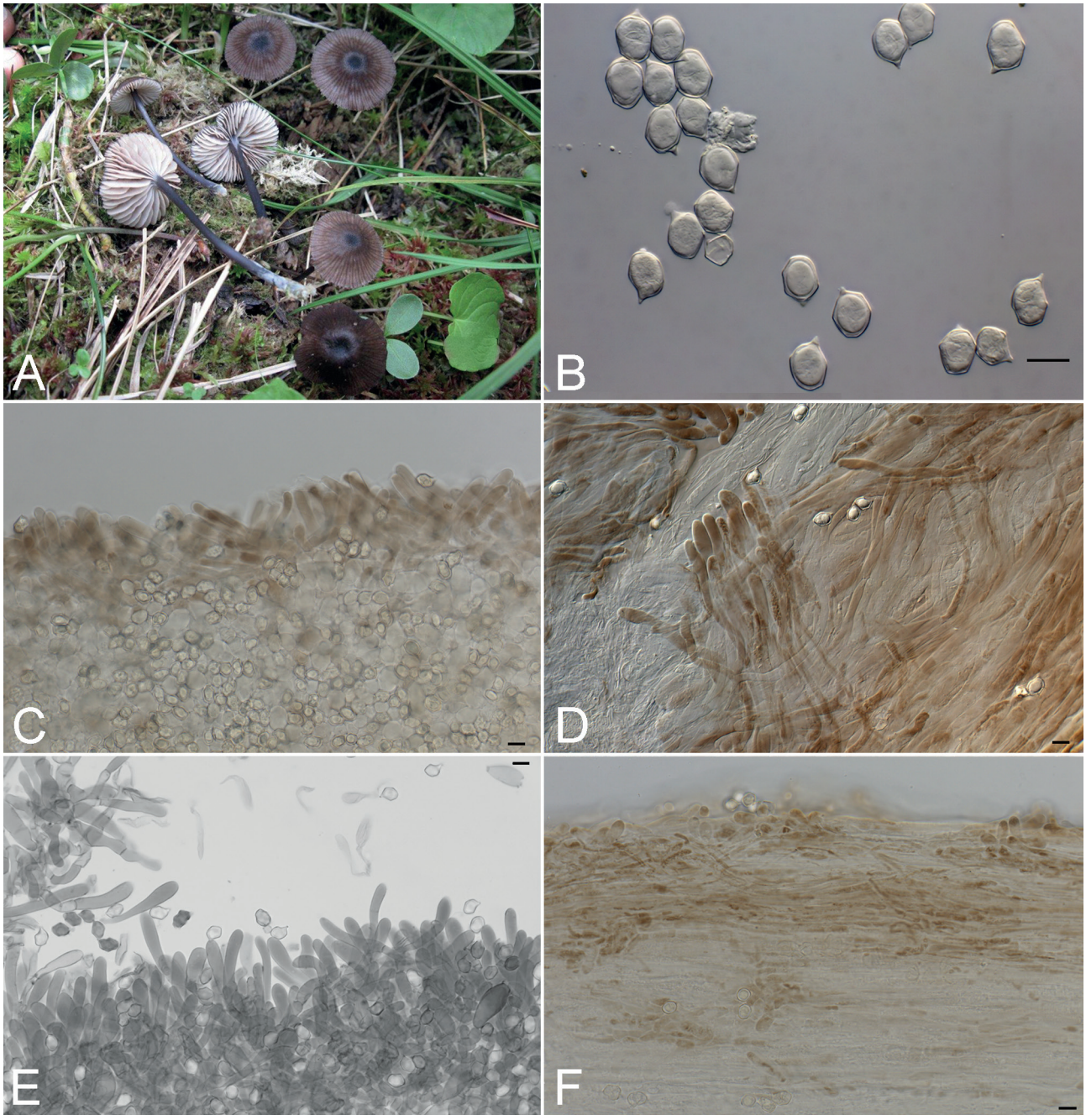

Fig. 4. *Entoloma septentrionale*, holotype. **A.** Basidiomata; **B.** Spores; **C.** Lamella edge; **D.** Pileipellis; **E.** Details lamella edge; **F.** Stipitipellis with caulocystidia. Bar = 10 µm.

Habitat. – In a damp, moss-covered groove with *Sphagnum*, adjacent to calcareous *Picea abies* forest.

Distribution. – Norway, so far only found in one location in North Norway; Holmvassdalen Nature Reserve.

Material examined. – Holotype.

Comments. – *Entoloma septentrionale* is characterized by small basidiomata with a combination of a porphyry brown, translucently striate, finely fibrillose-glabrous pileus, brownish lamellae edge, glossy, distinctly bluish stipe and abundant, broadly clavate cheilocystidia. This tiny Cyanula has some resemblance to species in the *E. cyanulum*

complex, having similar blue, translucently striate pilei and blue stipes, but these clearly have larger spores and two-spored basidia, as well as a polished stipe without caulocystidia, and a distant phylogenetic position. The serrulate, brown pigmented lamella edge reminds of some species in the *E. querquedula/E. serrulatum* group, which has a blue-black instead of brown lamella edge, and belong to another clade (Fig. 1).

So far, we only know one, rich collection of this species, but since being morphologically clearly different from close taxa, and since isolated and well-supported phylogenetically (see Fig. 1), we have decided to describe this as a new species.

Entoloma montanum **Noordel., J.B. Jordal, Lorås, Eidissen, E. Larss. & Dima, spec. nov.** – Fig. 5.
MycoBank no.: MB 838103

Etymology. – The epithet refers to the preference for mountainous habitats.

Holotype. SWEDEN. Pite Lappmark, Arjeplog, Ahkaris, 14 August 2018, *leg.* J.B. Jordal, E. Larsson, J. Vauras & H. Croneborg, EL143-18 (GB-0191635, isotype, L 0607987). GenBank ITS: MW340896.

Description. – Pileus 10–50 mm broad, initially conico-campanulate long staying so, then expanding to conico-convex, convex, finally flattened, with rounded, subumbonate, or slightly truncate centre, rarely with slight central depression, but never really umbilicate, with deflexed margin, with undulating marginal zone, rather variably coloured from fairly dark sepia with blackish brown central part, to rather bright yellowish-sepia or reddish yellow, centre often considerably darker, when young and fresh tomentose all over, breaking up quickly in small, appressed squamules of most of the surface, when mature often somewhat glabrescent, when young and fresh not translucently striate but gradually becoming transparent at margin, rarely up to half the radius. – Lamellae fairly crowded to moderately distant, L = 20–40, l = 3–7, not purely white when young but with a fairly distinct yellowish-cream colour, later on yellowish pink, mostly with entire, brown or partly brown pigmented edge. – Stipe 25–60 × 2–4 mm, cylin-

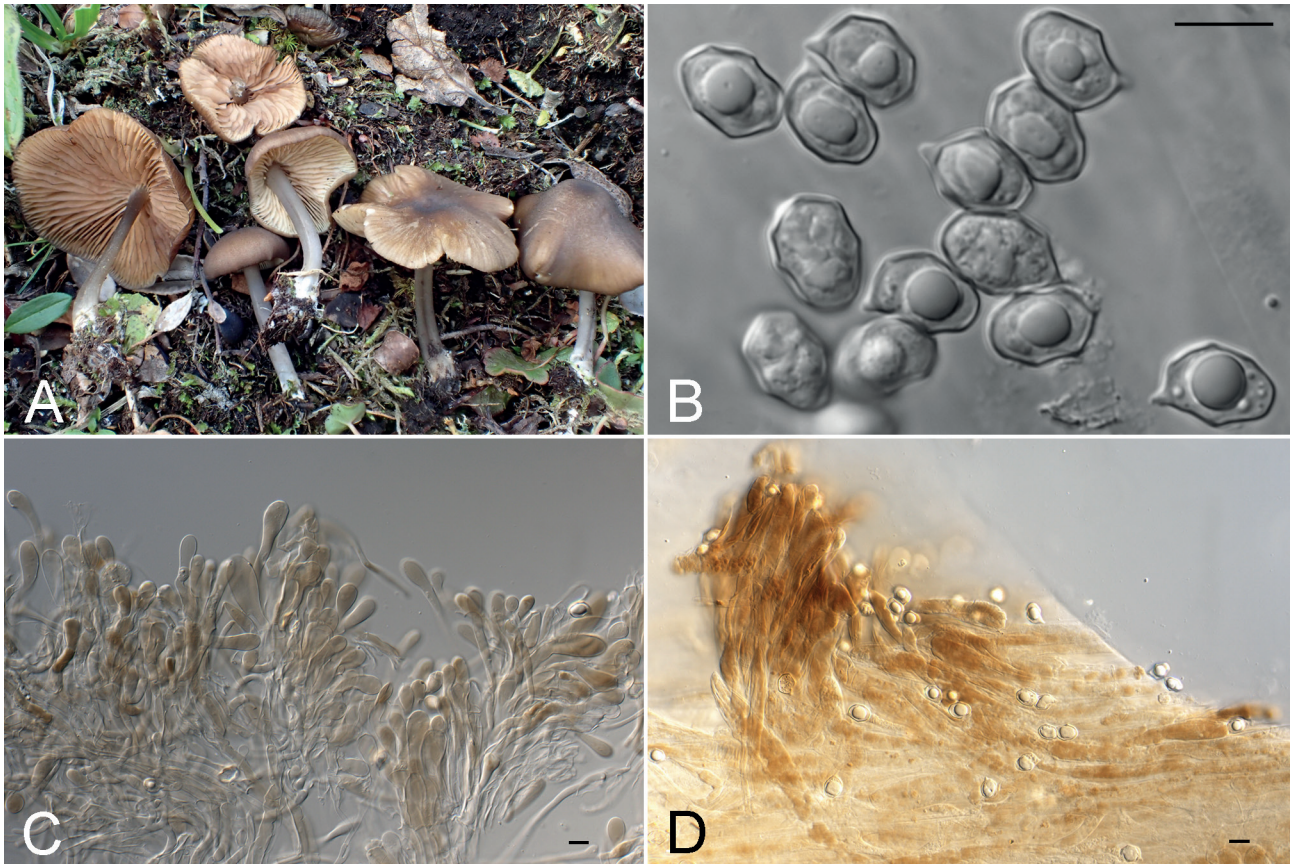

Fig. 5. *Entoloma montanum*, holotype. **A.** Habit; **B.** Spores; **C.** Cheilocystidia; **D.** Pileipellis. Bar = 10 µm.

drical or compressed, grey with more and less blue tinge when fresh, less frequently distinctly and deeper blue, soon fading to grey or pale grey, finally brownish grey, polished, white tomentose at base.

Basidiospores (9.0)9.5–13 × 7.0–9.5 µm, average 10–11.5 × 7.8–8.5 µm, Q = (1.1)1.2–1.5(1.6), Qav = 1.35–1.4, heterodiametrical, 5–7-angled, sometimes almost nodulose-angled in side view. – Basidia 19–34 × 7.5–12 µm, 4-spored, clamp connections absent. – Lamella edge sterile, made up of dense clusters of septate cheilocystidia, terminal elements broadly clavate to subvesiculose, 15–32 × 10–16(20) µm, in part with brown, intracellular pigment. – Hymenophoral trama regular, made up of cylindrical to inflated elements, 75–250 × 5.0–10 µm. – Pileipellis a cutis with transitions to a trichoderm at margin, a trichoderm at centre, terminal elements, clavate, 22–60 × 5.0–21 µm. – Pileitrama regular, made up of cylindrical to inflated elements, 70–250 × 5.0–19 µm, without or with few brilliant granules. Vascular hyphae abundant to sparse, in subpellis and trama. Pigment brown, intracellular in pileipellis and in cheilocystidia. Clamp connections absent.

Habitat. – In Norway recorded in rich to calcareous *Picea abies* forests, in low-herb sites, tall-herb sites and transitions to rich swamp forests, in northern and upper part of middle boreal zone. In Sweden found several times in calcareous mountain heaths and early snowbeds, above the forest limit. The type was found in moist calcareous mountain heath with e.g. *Dryas octopetala*, *Salix reticulata*, *Thalictrum alpinum* and scattered shrubs of *Salix glauca* in the northeastern slope of the Ahkaris Mt. In Caucasus recorded in alpine, steep, stony, richer but not calcareous sites.

Distribution. – Widespread in Northern Scandinavia (Norway, Sweden), also recorded from the mountains of the W Caucasus (Russia).

Material examined (besides type). – NORWAY. Trøndelag. Steinkjer, Limbuåsen, September 2010, *leg.* H. Holien et al., HH111-10 (O-F-293389); Grong, Skiftesbekken, 6 September 2009, *leg.* E. Bendiksen, EB80/09 (O-F-252062). Nordland. Grane, Holmvassdalen Nature Reserve, 7 September 2011, *leg.* J. Lorås & S. E. Eidissen, JL40-11 (O-F-257330); 21 September 2011, *leg.* J. Lorås & S. E. Eidissen, JL192-11 (O-F-249961); 24 August 2013, *leg.* J. Lorås & S. E. Eidissen JL110-13 (O-F 249966); 13 August 2014, *leg.* J. Lorås & S. E. Eidissen, JL75-14 (O-F-254321); 20 August 2016, *leg.* J. Lorås & S. E. Eidissen, JL129-16 (O-F-76209); 2 September 2016, *leg.* J. Lorås, JL108-16 (O-F-76210); Salomonbergan Nature Reserve, 4 September 2014, *leg.* J. Lorås & S. E. Eidissen, JL53-14 (O-F-254320). SWEDEN. Pite Lappmark. Arjeplog, Ahkaris, 14 August 2018, *leg.* J.B. Jordal, GB-0191630, GB-0191633, GB-0191631). Lule Lappmark. Jokkmokk, Padjelanta NP, Arralåbbdå, 10 August 2016, *leg.* G. Gulden, GB-0191640; Arranoajvve, 11 August 2016, *leg.* J. Olsson, GB-0191639; Vielggisbakte, 12 August 2016, *leg.* J. Olsson, GB-0191638, GB-0191637, GB-0191636; Ajajaure, 16 August 2016, *leg.* S. Jacobsson, GB-0191632; Njoemmeljaure, 18 August 2016, *leg.* H. Croneborg, GB-0191634. Torne Lappmark. Jukkasjärvi, Abisko, Latjavagge, 19 August 2013, leg. P.-A. Moreau, PAM13-52, GB-0191641. RUSSIA. Karachaevo-Cherkesia Republic, Teberda Biosphere Reserve, Malaya Khatipara Mt, ca. 2500 m asl, 16 August 2009, *leg.* O. Morozova, LE312479.

Comments. – *Entoloma montanum* is a fairly distinct species with a sordid to rather brightly coloured yellow-brown to sepia, often persistently campanulate pileus; yellowish-cream tinged lamella with a brown or partly brown edge, and grey, polished stipe with blue tinge when young. Particularly the grey stipe with faint blue tinge when young is distinctive. It belongs to the /Sarcitulum clade, but fairly distant from *E. sarcitulum* and related species (Fig. 1). The faint blue tinge in the stipe is rather uncommon in this clade of mostly brown-coloured species. *Entoloma sarcitulum* var. *majusculum* sometimes has a similar faint blue-grey tinge in the stipe, but has generally duller colours, and usually lacks a brownish, distinctly sterile lamella edge.

Entoloma montanum also reminds of the general, wide concept of *E. poliopus* (Romagn.) Noordel., particularly when the basidiomes have a relatively dark brown pileus and pronounced blue tinges in the stipe. For that reason, it was thought to be conspecific with *E. poliopus* var. *alpigenum* (J. Favre) Bon, described from the Alps (Favre 1955), with similar morphology. However, the lectotype of *E. poliopus* var. *alpigenum* is phylogenetically distant and represents another species (unpublished results of the type specimen at G).

Entoloma montanum was first recorded from Caucasus, Russia, and Grong in Nord-Trøndelag, Central Norway, in 2009, and then a number of sites in Holmvassdalen nature reserve and adjacent areas in Nordland, Norway, a renowned hotspot for *Entoloma*. Later it was found in abundance also in different locations in Northern Sweden, so it may well appear to be widespread in northern boreal, calcareous taiga forests and adjacent alpine-arctic habitats. In the alpine study sites at Padjelanta, Northern Sweden, *E. montanum* was one of the most frequent members of the Cyanula clade. Due to its presence in the Caucasus, it seems probable that this one occurs also in more southern alpine-subalpine regions in Europe, such as the Carpathians, the Alps and the Pyrenees, but this remains to be documented. That the species has a northern distribution pattern is reinforced by the fact that it has

never been found in well investigated regions in South Norway.

Acknowledgements

Hermod Karlsen (Fredrikstad) prepared the beautiful painting of *Entoloma nordlandicum* reproduced in this paper, for which we are very grateful. The director and Philippe Clerc (Conservatoire et Jardin botaniques de la Ville de Genève) are thanked for facilitating a visit of MEN to study original material of Favre and Kühner. The Rijksherbariumfonds Dr. E. Kits van Waveren (Leiden) provided funding for type studies and sequencing for the Dutch barcoding of *Entoloma*, and travel expenses for MEN, which is greatly acknowledged. Naturvårdsverket, The Swedish Taxonomy Initiative, ArtDatabanken, SLU, Uppsala, and Göran Gustafssons Stiftelse for provided funding for inventory of the alpine mountain regions in Sweden. The study of Olga V. Morozova was carried out within the framework of a research project of the Komarov Botanical Institute RAS (AAAA-A19-119020890079-6). The work of Bálint Dima was supported by the ÚNKP-20-4 New National Excellence Program of the Ministry for Innovation and Technology from the source of the National Research, Development and Innovation Fund, and by the ELTE Institutional Excellence Program supported by the National Research, Development and Innovation Office of Hungary (NKFIH-1157-8/2019-DT). We thank to Pablo Alvarado (ALVALAB, Santander) to generate some sequence data to this work.

References

Alvarado P., Moreno G., Vizzini A., Consiglio G., Manjón J.L., Setti L. (2015) *Atractosporocybe*, *Leucocybe* and *Rhizocybe*: three new clitocyboid genera in the Tricholomatoid clade (Agaricales) with notes on *Clitocybe* and *Lepista*. *Mycologia* **107**(1): 123–136.

Carriconde F., Gardes M., Bellanger J.-M., Letellier K., Gigante S., Gourmelon V., Ibanez T., McCoy S., Goxe J., Read J., Maggia L. (2019) Host effects in high ectomycorrhizal diversity tropical rainforests on ultramafic soils in New Caledonia. *Fungal Ecology* **39**: 201–212.

Corriol G. (2016) Algunos *Entoloma* inéditos del subgénero *Leptonia*. *Errotari* **13**: 33–50.

Crous P.W., Wingfield M.J., Burgess T.I., Carnegie A.J., Hardy G.E.St.J., Smith D. et al. (2017) Fungal planet description sheets: 625–715. *Persoonia* **39**: 270–467. https://doi.org/10.3767/persoonia.2017.39.11

Crous P.W., Carnegie A.J., Wingfield M.J., Sharma R., Mughini G., Noordeloos M.E. et al. (2019): Fungal planet description sheets: 868–950. – *Persoonia* **42**: 291–473. https://doi.org/10.3767/persoonia.2019.42.11

Crous P.W., Wingfield M.J., Burgess T.I., Hardy G.E.St.J., Gené J., Guarro J. et al. (2018): Fungal planet description sheets: 716–784. – *Persoonia* **40**: 240–393. https://doi.org/10.3767/persoonia.2018.40.10.

Favre J. (1955) Les champignons supérieurs de la zone alpine du parc national Suisse. *Ergebnisse der wissenschaftlichen Untersuchungen im Schweizerischen Nationalpark* **33**: 1–212.

Gardes M., Bruns T.D. (1993) ITS primers with enhanced specificity for basidiomycetes—application to the identification of mycorrhizae and rusts. *Molecular Ecology* **2**(2): 113–118.

Gouy M., Guindon S., Gascuel O. (2010) SeaView version 4: a multiplatform graphical user interface for sequence alignment and phylogenetic tree building. *Molecular Biology and Evolution* **27**: 221–224. https://doi.org/10.1093/molbev/msp259

Guindon S., Gascuel O. (2003) A simple, fast and accurate algorithm to estimate large phylogenies by maximum likelihood. *Systematic Biology* **52**(5): 696–704.

He X.-L., Wang D., Peng W.-H., Gan B.-C. (2017) Two new *Entoloma* s.l. species with serrulatum-type lamellar edge from Changbai Mountains, Northeast China. *Mycological Progress* **16**(8): 761–768.

Katoh K., Standley D.M. (2013) MAFFT Multiple sequence alignment software version 7: improvements in performance and usability. *Molecular Biology and Evolution* **30**: 772–780. http://dx.doi.org/10.1093/molbev/mst010

Kim C.S., Jo J.W., Kwag Y.N., Sung G.H., Lee S.G., Kim S.Y., Shin C.H., Han S.K. (2015) Mushroom flora of Ulleunggun and a newly recorded *Bovista* species in the Republic of Korea. *Mycobiology* **43**(3): 239–257.

Kokkonen K. (2015) A survey of boreal *Entoloma* with emphasis on the subgenus *Rhodopolia*. *Mycological Progress* **14**: 1–116.

Kumar S., Stecher G., Tamura K. (2016) MEGA7: Molecular Evolutionary Genetics Analysis version 7.0 for bigger datasets. *Molecular Biology and Evolution* **33**(7): 1870–1874.

Larsson E., Jacobsson S. (2004) The controversy over *Hygrophorus cossus* settled using ITS sequence data from 200-year-old type material. *Mycological Research* **108**: 781–786. https://doi.org/10.1017/S0953756204000310.

Larsson E., Vauras J., Cripps C. (2018) *Inocybe praetervisa* group: A clade of four closely related species with partly different geographical distribution ranges in Europe. *Mycoscience* **59**: 277–287. DOI: 10.1016/j.myc.2017.11.002

Lorås J., Eidissen S.E. (2011) Rødlistede beitemarkssopp i kalkgranskog - arter, økologi og habitatpåvirkning i Holmvassdalen naturreservat. *Agarica* **31**: 45–56.

Lorås J., Weholt Ø., Eidissen S.E. (2014) *Entoloma gomerense* Wölfel & Noordel. - a new species to Northern Europe. *Agarica* **35**: 19–24.

Morozova O.V., Noordeloos M.E., Vila J. (2014) *Entoloma* subgenus *Leptonia* in boreal-temperate Eurasia: towards a phylogenetic species concept. *Persoonia* **32**: 141–169.

Noordeloos M.E., Dima B., Weholt Ø., Eidissen S.E., Lorås J., Brandrud T.E. (2017) *Entoloma chamaemori* (Entolomataceae, Basidiomycota) – a new boreal species, with isolated phylogenetic position. *Phytotaxa* **298**(3): 289–295.

Noordeloos M.E., Morozova O.V. (2010) New and noteworthy *Entoloma* species from the Primorsky Territory, Russian Far East. *Mycotaxon* **112**: 231–255.

Noordeloos M.E., Weholt Ø., Bendiksen E., Brandrud T.E., Eidissen S.E., Lorås J., Morozova O. & Dima B. (2018) *Entoloma aurorae-borealis* sp. nov. and three rare *Entoloma*

species in the Sinuatum clade (subg. *Entoloma*) from northern Europe. *Sydowia* **70**: 199–210.

Osmundson T.W., Robert V.A., Schoch C.L., Baker L.J., Smith A., Robich G., Mizzan L., Garbelotto M.M. (2013) Filling gaps in biodiversity knowledge for macrofungi: contributions and assessment of an herbarium collection DNA barcode sequencing project. *PLoS ONE* **8**: e62419.

Truong C., Mujic A.B., Healy R., Kuhar F., Furci G., Torres D., Niskanen T., Sandoval-Leiva P.A., Fernandez N., Escobar J.M., Moretto A., Palfner G., Pfister D., Nouhra E., Swenie R., Sanchez-García M., Matheny P.B., Smith M.E. (2017) How to know the fungi: combining field inventories and DNA-barcoding to document fungal diversity. *New Phytologist* **214**(3): 913–919.

Weholt Ø., Lorås J., Eidissen S.E. (2014) One new and one rare species of *Entoloma* from the Norwegian nature reserve Holmvassdalen. *Österreichische Zeitschrift für Pilzkunde* **23**: 55–60.

Weholt Ø., Eidissen S.E., Lorås J. (2015) *Entoloma fulvoviolaceum* Noordel. & Vauras – not previously reported from Norway. *Agarica* **36**: 117–123.

Weholt Ø., Eidissen S.E., Lorås J., Alvarado P. (2016) *Entoloma graphitipes*, a new species to Northern Europe. *Karstenia* **55**: 19–24.

White T.J., Bruns T., Lee S., Taylor J. (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis M.A., Gelfand D.H., Sninsky J.J., White T.J. (eds.). PCR protocols: a guide to methods and applications, New York: Academic Press, pp. 315–322.

(Manuscript accepted 8 December 2020; Corresponding Editor: I. Krisai-Greilhuber)