



A review of *Entoloma sensu lato* (Basidiomycota, Entolomataceae) from Yunnan Province, China

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Ediriweera AN, Karunarathna SC, Xu J, Hyde KD, Raspé O, De Silva NI 2020 – A review on the genus *Entoloma* (Basidiomycota, Entolomataceae) in Yunnan Province, China. *Studies in Fungi* 5(1), 526–535, Doi 10.5943/sif/5/1/33

Abstract

This review succinctly discusses data on morphology, systematics, ecology and biochemical properties of all the *Entoloma* species from Yunnan Province, China. We also propose directions for future research on *Entoloma*. Altogether, 8 species of *Entoloma* have been reported in the present study. *Entoloma sinuatum* and *E. mengsongense* showed the most contrasting variation in colour and size of the basidiomes while *E. mengsongense* and *E. yunnanense* were found to display wide variations in spore morphology. Most species are saprotrophic except *E. caeruleoflavum* and *E. sinuatum* which form mycorrhizal associations. Knowledge on biochemical and other chemical attributes of the genus are minimal although such details would help for better utilization of the genus.

Keywords – Checklist – Ecology – macrofungi – morphology – phylogeny

Introduction

Entoloma (Fr.) P. Kumm. (1871), belonging in Entolomataceae, is known from a wide range of geographic domains including the tropics and Arctic regions (Hesler 1967, Largent 1994, Manimohan et al. 1995, 2006, Noordeloos 2004, Gates & Noordeloos 2007, Noordeloos & Hausknecht 2007, Co-David et al. 2009, Karstedt & Capelari 2013). Almost 1500 *Entoloma* species are known worldwide (Gates & Noordeloos 2009, Noordeloos & Morozova 2010, He et al. 2012, He et al. 2019b) the majority of which are saprotrophic, though a few species like *E. caeruleoflavum* (Xiao HL & Li TH) *E. sepium* (Noulet & Dassier) Richon & Roze, *E. aprile* (Britzelm.) Sacc., *E. saundersii* (Fr.) Sacc., *E. sinuatum* (Pers.) P. Kumm. (1871) & *E. clypeatum* (L.) P. Kumm. have been shown to be mycorrhizal (Co-David et al. 2009). *Entoloma* species can be seen in a wide range of habitats such as rainforests, grasslands, temperate to alpine forests and peat-bogs (Zhang & Li 2001b, Co-David et al. 2009, Gates et al. 2009, Kasuya et al. 2010, Gargano et al. 2011, He et al. 2019b).

***Entoloma* in China**

During the past two decades there has been an increased interest in the diversity of *Entoloma* in China, with several new species being described (Zhang & Li 2001a, Li et al. 2009, Li & Li 2009). The first *Entoloma* species described from China was *E. quadratum* (Berk. & M.A. Curtis) E. Horak. Prior to this, about twenty cuboid spored macrofungi species had been reported (Xiao et al. 2015) and later number of *Entoloma* species were reported from a wide range of habitats and ecosystems (Li et al. 2009, Li & Li 2009, He et al. 2010).

Increased research carried out in China on the family Entolomataceae, several new *Entoloma* species have been subsequently described (He et al. 2012, Xiao et al. 2015, Ediriweera et al. 2017). *E. caeruleoflavum* Xiao LH & Li TH, *E. hainanense* Li TH & Xiao LH, and *E. subtenuicystidiatum* Xiao LH (He et al. 2012) from southern China and *E. mengsongense* Ediriweera et al. from Mengsong, Yunnan (Ediriweera et al. 2017) have described recently from Yunnan.

DNA-based identification is on the upsurge in macrofungi with recent development and availability of facilities while the morphology based identification is still followed as the standard methods for identification. Hence both molecular level identification and morphological identification is significant for the precision of macrofungi identification. In *Entoloma* various macromorphological features viz., size, shape, colour, texture, odour, taste etc of basidiomata are crucial for species identification. Habit, habitat and ecological factors are also important in delimiting species in *Entoloma*.

Yunnan Province is a low altitude plateau with multiplex topography and variable climate, which are ideal conditions for a high diversity of macrofungi, including *Entoloma*. The weather of most areas of Yunnan province is reasonably mild in winter and slightly cool in summer. Yunnan province is known as warm region in China where average daily temperature is 24°C and often with several months of warm and humid weather (World Data Lab 2020).

This review intends to update the information on *Entoloma* species described from or reported from Yunnan Province, China. The data will eventually help and pave way for better understanding of the species diversity of *Entoloma* in the region, which in turn will help to formulate conservation measures.

Checklist of *Entoloma* species in Yunnan province, China

The spore quotient is denoted by “Q” in each micro-morphological description of species.

***Entoloma caeruleoflavum* Xiao L. He & T.H. Li, in He et al. Mycol. Progress 11: 4 (2012)**

Following description is based on literature based on research publication of He et al. 2012

Macro-morphology – Basidiomata moderate size. Pileus 30–60 mm in diameter, plano-convex, expanding with maturity, minutely scurfy, blackish blue, outwards paler and mixed with green, dry, not hygrophanous, sulcate from margin to half-center and undulate at margin. Lamellae sinuate, ventricose, up to 8 mm broad, thin, crowded, bright yellow that turns pink to reddish brown when bruised, wavy and edge, three tiers of lamellulae. Stipe central, cylindrical, 50–100 × 4–10 mm, broadening towards base, dark blue, longitudinally fibrillose, hollow, fragile, dry, white tomentum at basal area. Thin Context, whitish. Odor and taste not distinctive.

Micro-morphology – Basidiospores 6.5–7.5 × 6.3–7.3 μm, Q = 1.0–1.1, isodiametric, 5–7 angled in side-view, thin walled. Basidia 30–48 × 9–12 μm, clavate, tapered at base, 4-spored or 2-spored, clamped. Lamellar trama subparallel, composed of inflated and cylindrical elements, 40–90 × 8–22 μm. Fertile Lamellar edge. Cheilocystidia, pleurocystidia absent. Pileipellis a cut is showing a transition to a trichoderm with interwoven hyphae where terminal cells are differentiated, subclavate, bullet-shaped, inflated, 27– 63×11–16 μm, conspicuous brown intracellular pigment. Pileitrama regular, formed with short slightly inflated elements, 23 μm broad, pale pink intracellular pigment or sometimes nearly hyaline. Clamp connections present. Oleiferous hyphae visible in lamellar trama and pileal trama.

Ecology and Distribution – Mycorrhizal, scattered, on soil in mixed forest with Fagaceae, Theaceae and *Pinus yunnanensis*. Recorded from Yunnan, China (He et al. 2012).

Entoloma conchatum Xiao L. He & E. Horak, in He et al. MycoKeys 61:1-26 (2019a)

Following description is based on literature gathered from publication of He et al. 2019a which was the protologue for this species

Macro-morphology – Basidiomata moderate size. Pileus 7–15 mm in diameter, conchate and broadly convex, initially white colour, turns orange-white or yellowish-white and ultimately turns in to pale pinkish with maturity, entirely matted-tomentose, opaque, dry, fibrillose, not hygrophanous, margin is not transparent-striate. Lamellae adnexed, 2 mm wide, subdistant, subventricose, consists of 2–4 tiers of lamellulae, white colour at first, turning pinkish with maturity, margin concolorous. Stipe short, 1–3 × 0.5–1 mm, strongly, lateral, strongly reduced, covered with minute, white fibrils, base with white mycelium. Rhizoids absent. Context white, thin, unchanging. Odour and taste not distinctive.

Micro-morphology – Basidiospores: 8–10 × 6.5–8 µm, Q = 1.2–1.4, 5–6-angled, heterodiametric in profile view. Basidia 28–34 × 9–12 µm, 4-spored or 2-spored, subclavate, fertile lamellar edge. Cheilocystidia, pleurocystidia, caulocystidia absent. Pileipellis a cutis formed of cylindrical hyphae, terminal cells 35–50 × 4–7 µm, cylindrical, poorly gelatinised wall thin, minutely encrusted light yellow pigments. Oleiferous hyphae present in pileipellis. Clamp-connections abundant in all tissues.

Ecology and distribution – saprotrophic, grows on moss of stem basal area of live conifers and fallen branches of conifers, Recorded from Yunnan, China (He et al. 2019a).

Entoloma gregarium Xiao L. He & E. Horak, in He et al. MycoKeys 61: 1–26 (2019a)

Following description is based on literature gathered from publication of He et al. 2019a which was the protologue for this species.

Macro-morphology – Basidiomata small. Pileus 5–10 mm in diameter, broadly convex shape, white colour, no colour change with maturity, entirely matted-tomentose, fibrillose, dry, opaque, not hygrophanous, margin not striate. Lamellae adnexed, sub-distant to distant, sub-ventricose, 2 mm wide, two tiers of lamellulae present, white colour when young later become pale pink, in the presence of moist with small red droplets at edges. Stipe 1–3 × 0.5–1 mm, lateral, strongly reduced, translucent, covered with white fibrils, white basal mycelium. White context, thin. No distinctive Odour and taste.

Micro-morphology – Basidiospores 7–9 × 5.5–7 µm, Q = 1.16–1.47, 5–6 angled, heterodiametric in profile view. Basidia 4-spored, 30–34 × 7–10 µm, subclavate, clampless. Pleurocystidia, Cheilocystidia and caulocystidia absent. Pileipellis a cutis of cylindrical hyphae, terminal cells 35–60 × 5–10 µm, subclavate or cylindrical, repent or slightly uplifted, non-gelatinised thin wall, smooth, with inconspicuous plasmatic pigment, subpellis formed with short-celled cylindrical hyphae, Oleiferous hyphae of 6–14 µm present in pileipellis. Clamp-connections present in all tissues.

Ecology and Distribution – Saprotrophic, grow on moss on stem base of *Castanopsis* in fagalean forest. Recorded from Yunnan, China.

Entoloma mengsongense Ediriweera, Karun., J.C. Xu, K.D. Hyde & P.E. Mortimer, Turkish Journal of Botany 41 (5): 509 (2017)

Following description is based on literature gathered from publication of Ediriweera et al. 2017 which was the protologue for this species.

Macro-morphology – Basidiomata large. Pileus 3.5–5 cm in diameter, conical when young, plano-concave when mature, umbo in center, dry surface, fibrillose, more fibrillose near center, yellowish brown surface due to the fibrillose pileipellis. Lamellae adnexed, moderately crowded with lamellulae of 4 lengths. Stipe 65–90 × 6–7 mm, cylindrical, brittle, solid, surface fibrillose, concolorous when young and turns sky blue at maturity. Context white, thin, greenish blue or yellowish green when bruised. Mycelium cottony appearance at the base. Odor peculiar and distinct (Ediriweera et al. 2017).

Micro-morphology – Spores 4–8 × 4–6 μm, cuboid–quadrate, regular or irregular. Basidia 40–60 × 9–14 μm, clavate/obclavate, 1–4 spored, sterigmata 5 μm long. Cheilocystidia 35–40 × 9–12 μm, thin-walled, clavate and hyaline. Hymenophoral trama is subregular, hyphae 3–15 μm diameter, thin-walled, hyaline. Subhymenium poorly developed. Pileal trama parallel and interwoven. Pileipellis a cutis, hyphae 2–10 μm diameter, thin-walled, pale yellowish. Stipitipellis a disrupted cutis, hyphae 1–8 μm wide, hyaline, thin-walled. They form either ascending or erect bundles, clavate or cylindrical hyphae, 7–8.5 μm diam. Clamp connections present in all tissues (Ediriweera et al. 2017).

Ecology and Distribution – Saprotrophic. In small groups on soil, known only from the type locality in Yunnan, China (Ediriweera et al. 2017).

Entoloma pleurotoides Xiao L. He & E. Horak in He et al. MycoKeys 61: 1-26 (2019a)

Following description is based on literature gathered from publication of He et al. 2019a which was the protologue for this species.

Macro-morphology – Basidiomata small. Pileus 5–15 mm, conchate, broadly convex when young and become appanate when mature, entirely matted- tomentose, membranous, fibrillose, white at first, turns orange, yellowish-white and pale pinkish at maturity, hygrophanous, margin not transparent-striate. Lamellae adnexed, lamellulae with 1–2 tiers, narrow, distant, 1.5 mm wide, subventricose, white, pinkish with maturity, entire edges are concolorous. Stipe 1–2.5 × 0.5–1 mm, lateral, reduced, light grey brownish, slightly covered with pale greyish fibrils, white mycelium present at base. Thin Context. Odour absent. Indistinctive taste.

Micro-morphology – Basidiospores 8–10 × 7.5–9.5 μm, Q = 1.0–1.25, 5–6 angled, isodiametric to subisodiametric. Basidia 4-spored, 32–40 × 12–14 μm, clavate, clampless. Fertile Lamellar edge. Cheilocystidia, pleurocystidia, caulocystidia absent. Pileipellis a cutis formed with cylindrical hyphae, terminal cells 30–40 × 3–8 μm, either subclavate or cylindrical, slightly uplifted, thin, non-gelatinised wall, smooth, plasmatic pigment present, subpellis formed with short-celled cylindrical hyphae, 5–10 μm of diameter. Oleiferous hyphae present. Clamp-connections present.

Ecology and Distribution – Saprotrophic, grow on moss at base of living *Castanopsis* sp. and sometimes on debris of *Castanopsis* sp. Recorded from Yunnan, China (He et al.2019a).

Entoloma reductum Xiao L. He & E. Horak in He et al. MycoKeys 61: 1-26 (2019a)

Following description is based on literature gathered from publication of He et al. 2019a which was the protologue for this species.

Macro-morphology – Basidiomata small. Pileus 8–25 mm diameter, convex to appanate, conchate, greyish when young, turns greyish-brown with maturity, surface entirely matted-tomentose, slightly hygrophanous, margin slightly transparent-striate. Lamellae moderately close, two tiers of lamellulae present, adnate, ventricose, 4 mm wide, pale greyish colour at first, become pink with age, all edges concolorous. Stipe 1–2.5 × 0.5–1 mm, reduced, lateral, greyish brown, slightly covered with fibrils, basal area covered with white mycelium. Thin Context, greyish. Odour absent. No distinctive taste.

Micro-morphology – Basidiospores 8–10.5 × 6–7.5 μm, Q = 1.25–1.61, 5–6 angled, heterodiametric. Basidia 4-spored, 20–34 × 8–11 μm, clavate, clampless. Fertile Lamellar edge. Cheilocystidia, pleurocystidia and caulocystidia absent. Pileipellis a cutis formed with cylindrical hyphae, terminal cells 40–65 × 5–7 μm, slightly uplifted, cylindrical, non-gelatinised thin wall, minutely encrusted with pale brown pigments. In pileipellis Oleiferous hyphae and clamp connections present.

Ecology and Distribution – Saprotrophic, grow on decaying stumps of *Castanopsis* sp., on soil, rock, moss in forest dominated by *Quercus* sp. Recorded from Yunnan, China (He et al.2019a).

Entoloma sinuatum (Bull. ex Pers: Fr.) Kummer. Führ. Pilzk. (Zerbst): 97 (1871)

Following description is based on literature gathered from protologue (Fries & Elias 1821)

and Horak (1987).

Macro-morphology – Basidiomata medium-sized. Pileus 30–250 mm in diameter, conico-convex first but expands to either convex or applanate, with or without broad low umbo, when become mature margin become irregularly concave, pale grey-livid or cream color, glabrous and smooth, fluffy or rugulose at centre. Lamellae moderately crowded, 1 – 3 tiers of lamellulae, adnate or emarginate, narrowly segmentiform, appears in distinct yellow when young, turns into salmon-yellow or to pink, the yellow colour retains for a long time towards margin of pileus, serrulate and concolorous edge. Stipe 40 – 150 × 5–35 mm, cylindrical, sometimes compressed, distinctly swollen base, white or grey, subconcolorous with pileus, pruinose apex, smooth downwards, fibrillose. Context firm, white. Smell strong, Taste unpleasant.

Micro-morphology – Basidiospores 8–11 × 7–9.5 μm, Q = 1.0–1.3, 6-angled. Basidia 4-spored, clamped. Fertile Lamella edge. Cystidia absent. Pileipellis an ixo-cutis, narrow, cylindrical hyphae present, yellow-brown, 2–5 μm wide, intracellular pigment present, Clamps abundant.

Ecology and Distribution – Ectomycorrhizal. Grow solitary or in groups forming fairy rings. Fairly common in North America, Europe and the British Isles including Ireland. Except that *E. sinuatum* is recorded from Black Sea region, Turkey, Iran, and Yunnan in China (Li et al.2009, Xiao et al. 2012)

Chemical properties and special features – Pileipellis hyphae contain blue intracellular pigment in suprapellis and with brown cytoplasmic pigment in hypodermal hyphae. Stipitipellis hyphae present with blue intracellular pigment (Li et al. 2009, Xiao et al. 2012).

***Entoloma yunnanense* J.Z.Ying, Mycotaxon 54: 309 (1995)**

Following description is based on the protologue in Ying (1995)

Macro-morphology – Basidiomata small. Pileus 9–15 mm in diameter. Hemispherical to sub-campanulate, brown colour, fibrils present, squamulose. Lamellae emarginated, sub-decurrent. Stipe 55 –80 × 2 mm, cylindrical, concolorous with pileus.

Micro – morphology – Basidiospores 12.6–16.2 × 7.2–10 μm, sub-hyaline, 5–8 angled. Basidia 4-spored, 34–54 × 12.6–16 μm. Pleurocystidia absent. Cheilocystidia 19.8–23.4 × 14.4–18 μm, clavate.

Ecology and Distribution – Saprotrophic, Gregarious, grow on grounds. Recorded from Yunnan, China.

Table 1 Information on taxa and GenBank accession numbers of ITS based sequences of *Entoloma* specimens used for phylogenetic analysis

Name of the species	Voucher	Locality	Gen Bank accession number (ITS, 5.8S)
<i>E. azureosquamulosum</i>	HKAS53408	China	JQ410334
<i>E. stylophorum</i>	GDGM25736	China	JQ281480
<i>E. subtenuicystidium</i>	GDGM 29246	China	JQ320114
<i>E. praegracile</i>	GDGM 29256	China	JQ320107
<i>E. caespitosum</i>	GDGM24025	China	JQ281490
<i>E. mastoideum</i>	GDGM28820	China	JQ281476
<i>E. coelestinum</i>	HMLD1659	China	KC257434
<i>E. holmvassdalenense</i> (Type)	O-F75311	Norway	KM610321
<i>E. caeruleopolitum</i>	RBG Kew K M 102319	England	EU784210
<i>E. chalybaeum</i> var. <i>lazulinum</i>	RBG Kew K M 90810	England	EU784215
<i>E. insidiosum</i>	L376	Russia	KC898443
<i>E. virescens</i>	-	Japan	AB509863
<i>E. hochstetteri</i>	TL2573	New Zealand	KP191941
<i>E. mengsongense</i> (holotype)	HKAS90774	China	KU131556
<i>E. petchii</i>	HKAS56716	China	JQ281485
<i>E. omiense</i>	GDGM27563	China	JQ281487
<i>E. inocephalum</i>	LE262922	Viet Nam	KC898449
<i>E. griseocyaneum</i>	LE254351	Russia	KC898444

Table 1 Continued.

Name of the species	Voucher	Locality	Gen Bank accession number (ITS, 5.8S)
<i>E. turci</i>	3882	USA	JF907993
<i>E. incanum</i>	HKAS54614	China	JQ281488
<i>E. asprellum</i>	RBG Kew K M 91347	England	EU784206
<i>E. anatinum</i>	RBG Kew K M 58618	England	EU784202
<i>E. mougeotii</i>	LE254352	Russia	KC898446
<i>E. serrulatum</i>	HKAS 52713	Iran	KC898446
<i>Entoloma sp.</i>	HKAS 52713	China	KT833862
<i>E. aff. kjuense</i>	-	Japan	JQ410336
<i>E. nitidum</i>	-	Canada	AB509866
<i>E. bloxamii</i>	-	Canada	AY228340
<i>E. flavidum</i>	GDGM24473	China	EF530938
<i>E. chalybaeum</i>	LE254353	Russia	JQ281481
<i>E. abortivum</i>	GDGM27313	China	KC898445
<i>E. shandongense</i>	CUH AM109	India	KP241852
<i>E. conferendum</i>	HKAS48953	China	KP241852
<i>E. lampropus</i>	LE9121	Russia	JQ281484
<i>E. subaraneosum</i>	GDGM 28823	China	KC898378
<i>E. pallidocarpum</i>	GDGM 28828	China	JQ320113
<i>E. sinuatum</i>	AFTOL-ID 524	USA	JQ3201
<i>Lyophyllum decastes</i>	Lc42 T5P	Switzerland	AF357060
<i>L. decastes</i>	901016	Sweden	HM572546
<i>E. ravinense</i>	PSC3331	Australia	KX387622
<i>E. atricolor</i>	LE 295001	Vietnam	KY777496
<i>E. atricolor</i>	LE295002	Vietnam	KY777497
<i>E. bulakhae</i>	LE 253787	Russia	NR_158425
<i>E. bidupense</i>	LE 262935	Vietnam	MF476906

Phylogram formed from ML analysis based on combined ITS sequence data of *Entoloma* species available in Yunnan, China. Related sequences were acquired from GenBank. Forty-four taxa are included in the sequence analyses, which comprise 1032 number of characters with gaps. *Lyophyllum decastes* (901016) and *Lyophyllum decastes* (Lc42T5P) were used as the out group taxa. The best scoring RAxML tree with a final likelihood value of -13967.009706 is presented. The matrix had 795 distinct alignment patterns, with 37.61% of undetermined characters or gaps. Estimated base frequencies were as follows; A = 0.281044, C = 0.188343, G= 0.193093, T = 0.337520; substitution rates AC = 1.527188, AG = 3.374662, AT = 2.188792, CG = 0.731264, CT = 4.565623, GT = 1.000000; gamma distribution shape parameter $\alpha = 0.817722$.

The maximum parsimonious dataset consisted of 353 constant, 542 parsimony-informative and 137 parsimony-uninformative characters. The parsimony analysis of the data matrix resulted in the maximum of two equally most parsimonious trees with a length of 3210 steps (CI= 0.393, RI= 0.482, RC= 0.189, HI = 0.607) in the tree. RAxML & maximum parsimony bootstrap support values $\geq 50\%$ (BT) are shown respectively near the nodes. The type species are in bold.

Discussion

The morphological characteristics of reported *Entoloma* species share similar features with few exceptions. Cap size is one of the major morphological features with appreciable variation among species studied. It ranges from 3.5 mm in *E. mengsongense* to 250 mm in *E. sinuatum*.

A myriad of cap colors were observed among the species we studied vary from pale to shades of deep blue and brown color. Cap shape is another feature noticed with appreciable variation among different species and range from conical, convex, plano-convex, campanulate, hemispherical to broadly convex. Margin of the cap may in rolled when young, then involute and later deflexed. Lamella attachment in *Entoloma* species vary from adnexed, narrowly adnate to

emarginate and color may vary from white, greyish white to pink. Stipe of *Entoloma* sporocarps can be solid, stuffed or fibrillose and size also varies greatly among various species of *Entoloma*.

Of the various micro-morphological features, the spore size and spore shape of *Entoloma* species vary greatly and those characteristics have particular importance in species segregation. In the present study the smallest spores were observed in *E. mengsongense* (4–8 × 4–6 μm) and the largest were in *E. yunnanense*. The color of the spores is usually pink and varies from reddish pink to brownish pink. Spore shape is also important and found varying from cuboid, heterodiametric, pentagonal, heptagonal or even with irregular edges. Spores of most species are hyaline and thin-walled.

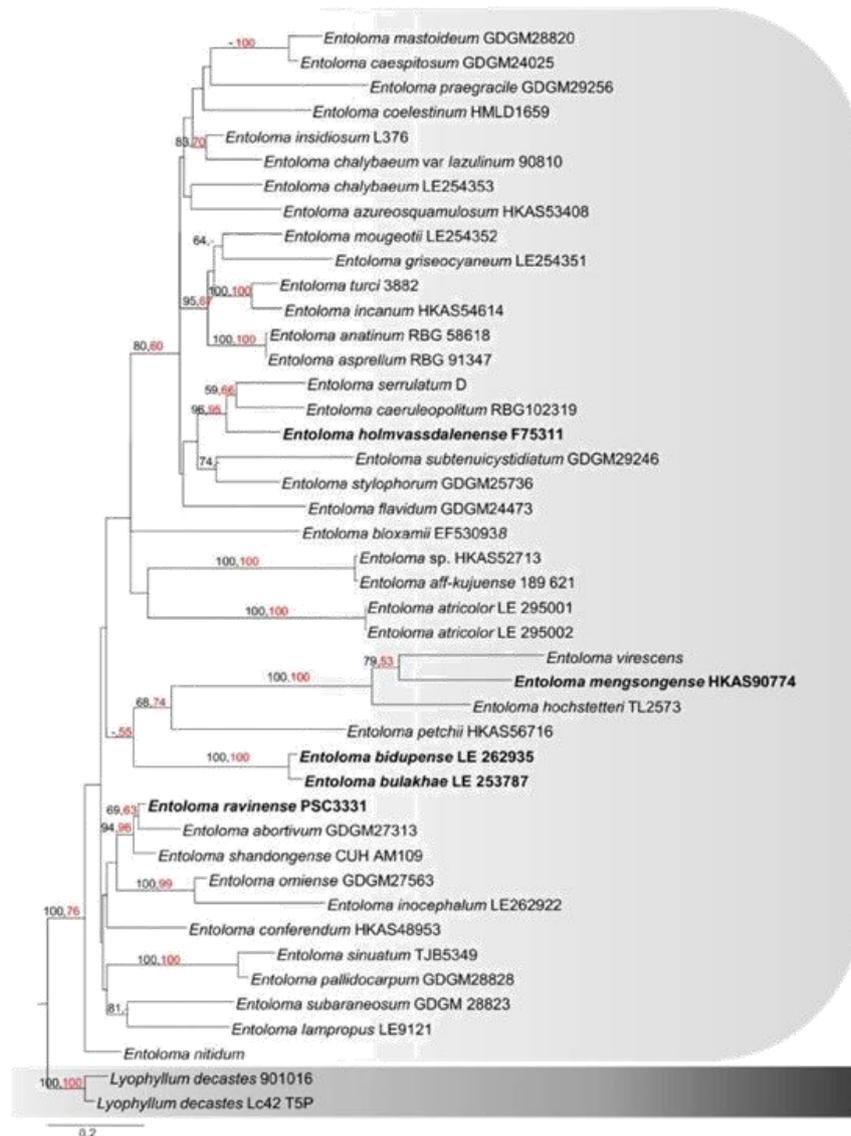


Fig. 1 – Phylogenetic tree obtained from RAxML analyses that shows the phylogenetic positioning of different *Entoloma* species based on the sequences of ITS data. Bootstrap support values for maximum parsimony (MP, left) and maximum likelihood (ML, right) greater than 50% and are given at the nodes. The tree is rooted with *Lyophyllum decastes* and the type species are indicated in black bold.

The size and shape of basidia in *Entoloma* species studied were almost uniform and clavate. But this characteristic does not value much at the species level recognition. The number of sterigmata is found to vary with species, though majority were 4-sterigmate while 1, 2, 3-were also

observed. Presence or absence of cheilocystidia is important and observed only in *E. yunnanense*. Oleiferous hyphae, pileipellis and stiptipellis is discussed with relevance to *E. mengsongense* and Oleiferous hyphae was found in *E. caeruleoflavum*, *E. gregarium*, *E. pleurotoides* and *E. reductum*. Cheilocystidia and Pleurocystidia had been only recorded from *E. yunnanense* among species recorded from Yunnan. Specific odor and taste has been recorded from *E. mengsongense* whilst rest of the *Entoloma* species discussed in the study has no distinctive odor and taste.

Distribution and ecology of *Entoloma* species found in Yunnan province, China, are mostly saprotrophic and found to occur in decomposing matter of leaf litter and other debris. *E. sinuatum* and *E. caeruleoflavum* are found only species found to form ectomycorrhizal association. Though many *Entoloma* species were reported from China, many of them are misidentified and lack of voucher specimens (Xiao et al. 2012).

Economically this genus is of little value and *E. abortivum* is the only species coming under the edible category while none were found to have medicinal value among species recorded from Yunnan. But, many species of *Entoloma* were reported as edible and medicinal worldwide. *Entoloma aprile*, *E. argyropus*, *E. crassipes*, *E. madidum* and *E. microcarpum* are valued as edible mushrooms in many regions of world (Hall 2016) while *E. nitidum* is well known for its antitumor properties that inhibits the growth of Sarcoma 180 and Ehrlich solid carcinoma in mice by 60 to 70%, respectively (Ohtsuka et al. 1973, Isiloglu et al. 2010, Ainsworth et al. 2018). *Entoloma stritictius* and *E. murrayi* are highly toxic. Knowledge on biochemical properties of the species are important to utilize them properly for food, medicine and in industry.

Conclusion

A comprehensive review of species of *Entoloma* in Yunnan, China is provided. It details the preference and variations of individual species on habit, habitat, distribution, macro and micro-morphological and molecular features. Data on ecology and morphology of genus *Entoloma* though well known, little is known about its chemical attribute. Extended chemical studies are necessary to know the chemical attributes of the species which in turn will pave way for better utilization as food and medicine.

Acknowledgement

Kevin D. Hyde thanks the Chinese Academy of Sciences, project number 2013T2S0030, for the award of Visiting Professorship for Senior International Scientists at Kunming Institute of Botany. This study was funded by the Chinese Ministry of Science and Technology, under the 12th five-year National Key Technology Support Program (NKTSP) 2013BAB07B06 for integration and comprehensive demonstration of key technologies on Green Phosphate-Mountain Construction; the CGIAR Research Program 6: Forest, Trees and Agroforestry; Thailand Research Fund grant - Taxonomy, Phylogeny and Biochemistry of Thai Basidiomycetes (BRG 5580009); the National Research Council of Thailand NRCT) projects – Taxonomy, Phylogeny and Cultivation of *Lentinus* species in northern Thailand (NRCT/55201020007); and Mae Fah Luang University, project – Taxonomy, Phylogeny and Cultivation of *Lentinus* species in Northern Thailand (MFU/54 1 01 02 00 48).

We would like to acknowledge Dr. C.K. Pradeep, Senior Scientist and Head, Microbiology Division, Jawaharlal Nehru Tropical Botanic Garden and Research Institute for his suggestions and comments during the preparation of the article.

Reference

- Ainsworth AM, Douglas B, Suz LM. 2018 – Big Blue Pinkgills formerly known as *Entoloma bloxamii* in Britain: *E. bloxamii* s. str., *E. madidum*, *E. ochreoprunuloides* forma *hyacinthinum* and *E. atromadidum* sp. nov. *Field Mycology* 19, 5–14.
- Co-David D, Langeveld D, Noordeloos ME. 2009 – Molecular phylogeny and spore evolution of Entolomataceae. *Persoonia* 23,147–176.

- Ediriweera AN, Karunarathna SC, Xu J, Mortimer PE. 2017 – *Entoloma mengsongense* sp. nov. (Entolomataceae, Agaricales), a remarkable blue mushroom from Yunnan Province, China. Turkish Journal of Botany 41, 505–515.
- Fries, Elias M. 1821 – Systema Mycologicum, Lund, Officina Berlingiana 1,197
- Gates GM, Noordeloos M. 2007 – Preliminary studies in the genus *Entoloma* in Tasmania-I. Persoonia 19, 157–226.
- Gates GM, Noordeloos M. 2009 – Preliminary studies in the genus *Entoloma* in Tasmania-II. Cryptogamie Mycologie 30, 07–140.
- Gates GM, Hortan BM, Noordeloos M. 2009 – A new *Entoloma* (Basidiomycetes, Agaricales) from Tasmania. Mycotaxon 107, 175–179.
- Gargano ML, Mandracchia G, Saitta A, Venturella G. 2011 – Two rare Northern *Entoloma* species observed in Sicily under exceptionally cold weather conditions. The Scientific World 2012: 95722.
- Hall LR. 2016 – A list of putative edible and medicinal ectomycorrhizal mushrooms. Technical Report.
- He X, Jiang Z, Li T. 2010 – Three species of white *Entoloma* new to China. Mycosystema 29, 920–923.
- He XL, Horak E, Wang D, Li TH et al. 2019a – Descriptions of five new species in *Entoloma* subgenus *Claudopus* from China, with molecular phylogeny of *Entoloma* s.l. MycoKeys 61, 1–26.
- He M, Zhao R, Kirk PM. 2019b – Notes, outline and divergence times of Basidiomycota. Fungal Diversity 99, 105–367.
- Hesler LR. 1967 – *Entoloma* (Rhodophyllus) in Southeastern North America. Beihefte zur Nova Hedwigia 23, 1–220.
- Horak E. 1987 – “Agaricales from Yunnan China I”. Nippon Kingakukai Kaiho. 28, 171–88.
- Isiloglu M, Sermenli HB, Senol A, Isler M. 2010 – *Entoloma* mushroom poisonings in Mediterranean Turkey. Turkish Journal of Botany 35, 247–249.
- Karstedt F, Capelari M. 2013 – *Inocephalus* (Entolomataceae, Agaricales) from Sao Paulo State, Brazil. Nova Hedwigia 96, 279–308.
- Kasuya T, Takehashi S, Hoshino T, Noordeloos ME. 2010 – *Entoloma aprile* (Agaricales, Entolomataceae) new to Japan, with notes on its mycorrhiza associated with *Populus maximowiczii* in cool-temperate deciduous forests of Hokkaido. Sydowia 62, 205–223.
- Largent DL. 1994 – Entolomatoid Fungi of the Pacific Northwest and Alaska. Eureka, CA, USA: Mad River Press.
- Li CH, Li TH. 2009 – A new *Entoloma* species (Entolomataceae, Agaricales) from Hainan Island. Mycosystema 28, 641–643.
- Li TH, Li CH, Shen YH. 2009 – Two new blue species of *Entoloma* (Basidiomycetes, Agaricales) from South China. Mycotaxon. 107, 405–412.
- Manimohan P, Joseph AV, Leelavathy KM. 1995 – The genus *Entoloma* in Kerala State, India. Mycological Research 99, 1083–1097.
- Manimohan P, Noordeloos ME, Dhanya AM. 2006 – Studies on the genus *Entoloma* (Basidiomycetes, Agaricales) in Kerala state, India. Persoonia 19, 45–93.
- Noordeloos ME, Morozova OV. 2010 – New and noteworthy *Entoloma* species from the Primorsky Territory, Russian Far East. Mycotaxon 112, 231–255.
- Noordeloos ME. 2004 – *Entoloma* s.l. Fungi Europaei, vol. 5a. Edizione Candusso, Italy.
- Noordeloos ME, Hausknecht A. 2007 – The genus *Entoloma* (Basidiomycetes, Agaricales) of the Mascarenes and Seychelles. Fungal Diversity 27, 111–144.
- Ohtsuka S, Ueno S, Yoshikumi C, Hirose F et al. 1973 – Polysaccharides having an anti-carcinogenic effect and a method of producing them from species of Basidiomycetes. UK Patent 1331513.
- World Data Lab. 2020 – Available from World data info
<https://www.worlddata.info/asia/china/climate-yunnan.php> (Accessed September 2020)

- Xiao LH, Li TH, Zi DJ, Shen YH. 2012 – Four new species of *Entoloma* s.l. (Agaricales) from southern China. *Mycological progress* 11, 915–952.
- Xiao LH, Horak E, Li TH, Peng WH, Gan BC. 2015 – Two new cuboid-spored species of *Entoloma* s.l. (Agaricales, Entolomataceae) from southern China. *Cryptogamie, Mycologie* 36, 237–249
- Ying JZ. 1995 – New and noteworthy Agarics from China II. New species of *Entoloma*. *Mycotaxon* 54, 309–313.
- Zhang W, Li TH. 2001a – A new species of *Entoloma* from Nanling National nature reserve. *Mycosystema* 21, 483–484.
- Zhang W, Li TH. 2001b – A new subgenus and a new species of *Entoloma*. *Mycosystema* 21, 153–155.