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CONTRIBUTION TO THE KNOWLEDGE OF CHINESE BOLETES. III: *SUILLUS PHYLOPICTUS*

Abstract

In this third communication the eastern Asian bolete Suillus phylopictus (Suillaceae) i*s reported based on material recently found in Yunnan Province (south-western China) in ectotrophically mycorrhizal association with five-needle* Pinus armandii. *A detailed macro- and micro-morphological description including ecological data is provided and accompanied by a colour image of fresh basidiomes in habitat and line drawings of the main anatomical features. Comparisons with closely related, phenotypically similar taxa are also elucidated and discussed.*

Riassunto

In questo terzo contributo dedicato allo studio dei boleti cinesi viene descritto e illustrato Suillus phylopictus (Suillaceae). *Questo peculiare e interessante boleto asiatico si caratterizza per la taglia media, la superficie pileica formata da squamosità irregolari appressate e appiattite inizialmente di colore rosso-porpora scuro o rosso vinoso tendenti a sbiadire fino al pallido brunastro nei vecchi esemplari, l'imenoforo giallastro da adnato a subdecorrente, i pori angolosi, compositi e allungati radialmente (sub-boletinoidi), il gambo pieno, la presenza di un delicato anello cotonoso-araneoso biancastro derivante da un velo parziale, la superficie del gambo ornata da bande orizzontali rosso-porpora sbiadenti al brunastro pallido in senescenza, il micelio basale biancastro-rosato, la carne crema-rosata virante lentamente a un pallido rosa-brunastro al taglio, le basidiospore da cilindrico-fusiformi a fusiformi, a parete liscia, destrinoidi e fortemente cianofile, la pileipellis costituita da un palisadoderma o tricoderma di ife cilindriche larghe fino a 21 µm, la trama imenoforale del* "tipo-Mariaella" *e la crescita in boschi misti in simbiosi ectomicorrizica elettiva con pini a cinque aghi, endemici dell'Asia orientale, quali* Pinus armandii, P. koraiensis, P. kwangtungensis *e forse* P. parviflora *e* P. pumila, *dubitativamente anche con* P. wallichiana *e* P. cembra. *Questa specie è stata finora segnalata dalla Cina (Province di Heilongjiang, Jilin, Jangsu, Shaanxi, Hubei, Anhui, Zhejiang, Tibet, Sichuan, Yunnan, Guizhou, Hunan, Guangdong, Taiwan e Hainan), Corea e Giappone, ma è molto probabile che abbia una distribuzione coincidente con il range geografico dei suoi partner simbiotici specifici.*

Key words: *Basidiomycota*, *Boletales*, Chinese fungal diversity, ectomycorrhizal fungi, taxonomy, Yunnan Province.

Introduction

The monophyletic genus *Suillus* Gray (including *Boletinus* Kalchbrenner, *Fuscoboletinus* Pomerleau & A.H. Sm. and *Mariaella* Šutara) is the largest natural assemblage of fleshy pored mushrooms (boletes) known worldwide. According to the latest edition of the Dictionary of the Fungi it currently encompasses around fifty species (Kirk *et Al.*, 2008). A more recent and inclusive, large-scale phylogenetic study indicates this genus as comprising approximately one hundred taxa (Nguyen *et Al.*, 2017; Zhang *et Al.*, 2017) but the real number most likely exceeds one hundred and thirty entities (Klofac, 2013; Klofac & Krisai-Greilhuber, 2014; Pers. Obs.). *Suillus* forms a natural assemblage with species characterized by boletoid to occasionally

secotioid habit, medium-small to medium size, viscid to glutinous, rarely dry, glabrous to fibrillose or scaly-squamulose pileus surface, solid or hollow, annulate or exannulate stipe, adnate, adnexed to decurrent, poroid hymenophore, stipe surface frequently typically ornamented by dark colored glandular dots or granules, chocolate brown, olive-brown to purple-brown spore print, ellipsoid-fusiform, short (rarely longer than 11 μm), smooth basidiospores, (ixo)trichoderm pileipellis, presence or absence of clamp connections and an endemic geographic distribution throughout the northern hemisphere in ectomycorrhizal (ECM) association almost exclusively with coniferous trees (family *Pinaceae*) showing a high tendency to host specificity (Singer, 1938a, b, 1986; Smith & Thiers, 1964; Pegler & Young, 1981; Šutara, 1987, 2005; Bruns & Palmer, 1989; Kretzer *et al.*, 1996; Watling, 2008; Nguyen *et al.*, 2017; Klofac, 2013; Klofac & Krisai-Greilhuber, 2014).

The first confirmed reports of the genus *Suillus* in China are dated back to the late '30s of the past century (Keissler & Lowag, 1937; Teng, 1939). Chiu (1948) provided extensive descriptions of a number of *Suillus* species collected in Yunnan Province and afterward depicted them in a comprehensive painted atlas (Chiu, 1957). Over the subsequent fifty years the genus has been treated from different regions of China in a broad range of publications varying from research articles, regional mycotas, boletes monographies, checklists, PhD thesis and photographic atlas such as Tai (1979), Zang (1986), Bi & Li (1990), Mao *et al.* (1993, 1997), Bi *et al.* (1994, 1997), Ying & Zang (1994), Chen & Yeh (2000), Li & Song (2000), Mao (2000, 2009), Zhuang (2001, 2005), Chen *et al.* (2002, 2003), Ding (2002), Ding & Wen (2003a,b), Wang (2004), Wang & Yao (2004), Wang *et al.* (2004), Yuan & Sun (2007), Shen *et al.* (2009), Wu *et al.* (2011), although there are many others. In more recent times, the intensive use of molecular tools led to the description of several new Chinese species (Qi *et al.*, 2016; Shi *et al.*, 2016; Zhang *et al.*, 2017; Xue *et al.*, 2018). Among these newly published members of *Suillus* is the widespread *S. phylopictus* Rong Zhang, X.F. Shi, P.G. Liu & G.M. Muell., a species belonging to the *S. spraguei* (Berk. & M.A. Curtis) Kuntze complex that appears to have an obligate ECM association with five-needle pine trees (*Pinus* subgenus *Strobus*) (Zhang *et al.*, 2017). Based on a collection recently yielded in the neighborhood of Kunming, Yunnan, the present author provides a thorough morphological account of this interesting eastern Asian bolete.

Being a continuation of earlier works published in the same mycological journal (Gelardi, 2014, 2018a, b), the reader is referred to the introduction of those papers for further insights.

Materials and methods

Collection sites and sampling

In October 2011 fresh material was collected at a single locality in Yunnan Province, China. Specimens of the collection examined in this study were deposited in the author's private herbarium (MG). Author citations follow the Index Fungorum - Authors of Fungal Names (www.indexfungorum.org/authorsoffungalnames.htm).

Morphological studies

Macroscopic descriptions, macro-chemical reaction (5% KOH) and ecological information, such as habitat notations, time of fruiting and associated plant communities accompanied the detailed field notes of the fresh basidiomes. Colors were recorded under daylight and described in general terms only. Photographs of collections were taken in the natural habitat using a Nikon D3100 camera. Microscopic anatomical features were observed and recorded from revived dried material; sections were rehydrated either in water, 5% potassium hydroxide (KOH) or in anionic solution saturated with Congo Red. All anatomical structures were observed and measured from preparations in anionic Congo Red. Colors and pigments were

described after examination in water and 5% KOH. Measurements were made at 1000× using a calibrated ocular micrometer (Nikon Eclipse E200 optical light microscope). Basidiospores were measured directly from the hymenophore of mature basidiomes, dimensions are given as (minimum) average ± standard deviation (maximum), Q = length/width ratio with the extreme values in parentheses, Qm = average quotient (length/width ratio) ± standard deviation and average spore volume was approximated as a rotation ellipsoid [$V = (\pi.L.W^2)/6$ ± standard deviation]. The notation [n/m/p] indicates that measurements were made on "n" randomly selected basidiospores from "m" basidiomes of "p" collections. The width of each basidium was measured at the widest part, and the length was measured from the apex (sterigmata excluded) to the basal septum. Metachromatic, cyanophilic and iodine reactions were tested by staining the basidiospores in Brilliant Cresyl blue, Cotton blue and Melzer's reagent, respectively. Line drawings of microstructures were traced free hand based on digital photomicrographs of rehydrated material.

TAXONOMY

Suillus phylopictus Rong Zhang, X.F. Shi, P.G. Liu & G.M. Muell., *Mycologia* 109 (2): 301 (2017)

Macroscopic description (Fig. 1)

Basidiomes medium.

Pileus 4.3-9.3(10.5) cm broad, persistenly convex since the early developmental stage then broadly pulvinate-flattened and finally slightly depressed at centre, regularly to somewhat unevenly shaped, moderately fleshy, firm at the beginning but progressively softer with age, flabby in old basidiomes; margin steady to faintly wavy, initially involute then curved downwards and finally completely plane, extending beyond the tubes up to 2 mm and often appendiculate with persistent, cottony velar remnants hanging at the edge; surface matt, dry, evenly ornamented by fine patchy, adpressed, flattened scales forming tufts, at first densely arranged tending to loose with age showing the context beneath; cuticle hardly detachable from the pileal context, dark reddish-brown, dark purple-red to wine red throughout in young specimens due to the densely adpressed scales, then pale cream colored backgroud gradually appears among the scales as soon as they start to separate from each other and red tones progressively fade with age until they completely disappear leaving the squamules of a pale brown color in senescence; slowly becoming sordid brown on handling or when injured; subcuticular layer pale pinkish-cream.

Tubes somewhat broad since the beginning and tending to become broader with age, always shorter than the thickness of the pileus context (up to 0.5 cm long), adnate to subdecurrent, pale yellow at first to ochraceous or ochraceous-orange then light olive-brown, unchangeable to slightly darkening when cut.

Pores forming a flat to convex surface, broad then gradually wider (up to 2.5 mm in diam.), compound, angular and radially arranged, initially hidden by a thin, cottony, whitish partial veil easily disrupting and forming an adhering white annulus around the stipe; concolorous with the tubes and very slowly and faintly darkening on bruising or when injured.

Stipe 7.4-9.3 × 0.8-2.0(2.4) cm, as long as the pileus diameter at maturity or slightly longer, central, solid, firm, dry, straight or faintly curved particularly towards the base, cylindrical or more frequently swollen towards the base to decidedly clavate, rarely attenuate downwards, rounded or ending with a short taproot at the very base, not to moderately rooting; surface finely reticulate at apex, laking glandular dots and with a soft, cottony, whitish annulus becoming dark brown with age due to spore discharge; pale yellow to ochraceous-yellow above the annulus,

Fig. 1. *Suillus phylopictus* in habitat (MG442). Photo by Matteo Gelardi

Fig. 2. *Pinus armandii* in habitat. Photo by Matteo Gelardi

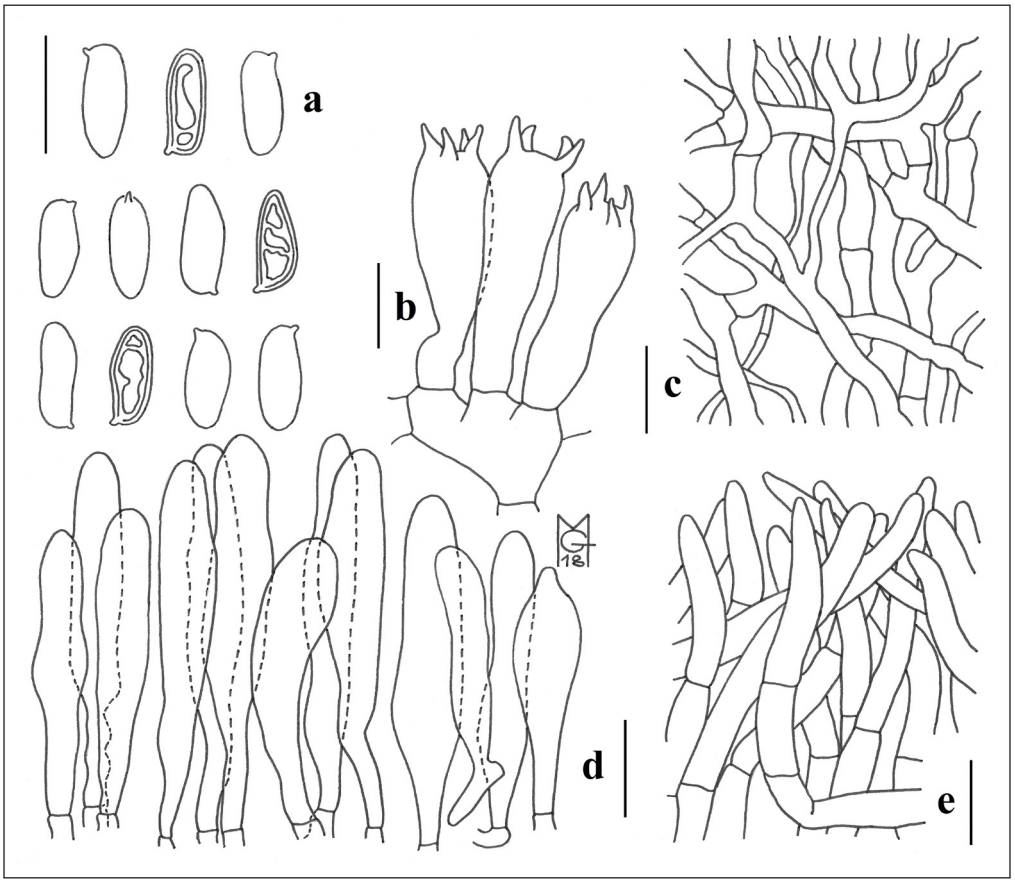

Plate 1. *Suillus phylopictus*. Microscopic characters (MG442). **a**. Spores. **b**. Basidia. **c**. Partial veil. **d**. Cheilo- and pleurocystidia. **e**. Pileipellis. Scale bars: ***a-b*** = 10 μm; **c-d** = 20 μm; **e** = 30 μm. Drawings by Matteo Gelardi

concolorous with the pileus below with transversely arranged, wine red to purplish-red then pale brown bands progressively reducing in thickness and turning into separate tufts downwards on a pale cream-whitish background, pinkish-white at the very base, slowly and faintly turning sordid brown when pressed; basal mycelium whitish-pink.

Context firm and tough when young, later soft textured and eventually flabby in the pileus (up to 2.0 cm thick in the central zone), a little more fibrous in the stipe, cream-pinkish throughout or a little darker in the stipe base; more or less evenly turning pinkish-flesh to pinkish-brown at the base when exposed to air, oxydation phenomenon more obvious in young specimens; subhymenophoral layer cream-pinkish.

Odor vaguely fruity, agreable.

Taste mild.

Spore print not obtained.

Macrochemical reaction 5% KOH: staining dark red then blackish on pileus cuticle and hymenophore, light blue-lilac on pileus context, sordid lilac on stipe context and progressively darker downwards up to blackish at the base.

Edibility edible and traded in local mushroom markets (Li & Song, 2002; Wang *et Al.*, 2004; Dai *et Al.*, 2010, either as "*Suillus spraguei*" or "*Suillus pictus*").

Microscopic description (Plate 1)

Basidiospores [34/3/1] (7.9)9.3 ± 0.88(11.3) × (3.4)3.8 ± 0.21(4.3) μm, Q = (2.04)2.15-2.86(3.02), Qm = 2.43 ± 0.10, V = 157 ± 14 μm³, inequilateral, cylindrical-fusiform to fusiform in side view, fusiform in face view, smooth, apex rounded, with a short apiculus and without or at most with a very shallow suprahilar depression, moderately thin-walled (0.3-0.5 μm), straw yellow colored in water and 5% KOH, having one or two large oil droplets when mature, rarely pluriguttulate, dextrinoid, strongly cyanophilic and with an ortochromatic reaction.

Basidia 24-34(37) × (6)8-10 μm (n = 10), cylindrical-clavate to clavate, moderately thick-walled (0.5-0.9 μm), predominantly 4-spored but also 2-spored, usually bearing relatively short sterigmata (2-4 μm), hyaline to pale yellowish and sometimes containing straw-yellow oil guttules in water and 5% KOH, bright yellow (inamyloid) in Melzer's, without basal clamps; basidioles subcylindrical to faintly clavate, similar in size to basidia.

Cheilocystidia (38)40-62(68) × 7-10 μm (n = 12), very common, not fasciculate, decidedly slender, projecting straight to sometimes flexuous, irregularly cylindrical or cylindrical-fusiform to subclavate, rarely short mucronate, with rounded tip, smooth, moderately thick-walled (0.5-1.0 μm), hyaline to pale yellowish or occasionally with a golden yellow plasmatic pigment in water and 5% KOH, bright yellow (inamyloid) in Melzer's, without epiparietal encrustations.

Pleurocystidia (54)57-85(93) × 9-13 μm (n = 12), scattered, shape, color and chemical reactions similar to but longer and slightly broader than cheilocystidia.

Pseudocystidia not recorded.

Velar remnants consisting of strongly interwoven, elongated, filamentous, frequently branched, moderately thick-walled (up to 0.8 μm), smooth, non-gelatinous hyphae, 13-190 × (2)3-8 μm, hyaline to pale yellowish in water and 5% KOH.

Pileipellis a palisadoderm to trichoderm consisting of subparallel to moderately interwoven, elongated, cylindrical, seldom branched hyphae tending to be repent in the outermost layer and thus turning into a cutis not embedded in gelatinous matter; terminal elements 35-116 × (4)6-21 μm, long and slender, cylindrical, apex rounded-obtuse to pointed, moderately thick-walled (up to 1 μm), very pale yellowish to straw yellow or ochraceous-yellow in water and 5% KOH, weakly dextrinoid in Melzer's, smooth to occasionally ornamented by a very subtle zebra-like epiparietal encrustation; subterminal elements similar in shape, size and color to terminal elements.

Stipitipellis a layer of slender, parallel to loosely intermingled and longitudinally running, smooth walled, adpressed hyphae, 3-13 μm wide, hyaline to yellowish in water and 5% KOH; the stipe apex covered by a well-developed caulohymenial layer consisting of sterile caulobasidioles, very sparse, predominantly 2-spored, diminutive fertile caulobasidia, 19-21 × 5-6 μm (sterigmata up to 5 μm long) (n = 2) and interspersed projecting **caulocystidia** similar in shape and color to hymenial cystidia but distinctly shorter, 40-49(53) × 6-12 μm (n = 5), having a wall up to 1 μm thick.

Lateral stipe stratum under the caulohymenium present although not well differentiated from the stipe trama, of the "boletoid type", at the stipe apex a 30-50(60) μm thick layer consisting of divergent, inclined and running towards the external surface, loosely intermingled and branched hyphae remaining separate and embedded in a gelatinous substance.

Stipe trama composed of confusedly and densely arranged, strongly interwoven, filamentous, smooth, barely dextrinoid hyphae, 3-22 μm broad.

Hymenophoral trama of the "*Mariaella*-type", (15)20-50(60) μm broad, consisting of very slightly divergent or almost parallel to subparallel, loosely arranged, gelatinized hyphae with nearly no differentiation between mediostratum and lateral strata [hyphae in transverse section remaining separate and (1)2-6(7) μm apart, 2-12 μm broad], hyaline to very pale yellowish in water and 5% KOH, inamyloid in Melzer's.

Oleipherous hyphae unfrequent, golden yellow to brown in 5% KOH.

Clamp connections absent in all tissues.

Hyphal system monomitic.

Ontogenetic development presumably mixangiocarpic.

Ecology: solitary to gregarious or subcaespitose, in temperate to subtropical and tropical regions in montane to lowland environment, growing in mixed woods in obligate ECM association with multiple five-needle pine trees (*Pinus* subgenus *Strobus*) such as *Pinus armandii* Franch., *P. koraiensis* Siebold & Zucc., *P. kwangtungensis* Chun & Tsiang and possibly *P. parviflora* Siebold & Zucc. and *P. pumila* (Pall.) Regel, dubitatively with *P. wallichiana* A. B. Jacks. and *P. cembra* L., fairly common, summer to autumn.

Examined material: China, Yunnan Province, Kunming City, Qiongzhu Temple, N 25° 03′ 55″, E 102° 37′ 33″, 2180 m, on a north-facing slope, several specimens in all developmental stages growing in litter in a conifer mixed forest under *Pinus armandii*, *P. yunnanensis* Franch. and *Keteleeria evelyniana* Mast.; legit. M. Gelardi, B. Feng, G. Wu and Y.-J. Hao; 05 October 2011, MG442.

Other species found in the same habitat: *Cystodermella* cf. *cinnabarina* (Alb. & Schwein.) Harmaja, *Strobilurus orientalis* Zhu L. Yang & J. Qin, *Xerocomellus communis* Xue T. Zhu & Zhu L. Yang, etc.

Notes

Suillus phylopictus is a remarkable eastern Asian bolete that is promptly characterized by the following set of diagnostic morphological and ecological features: medium-sized basidiomes, pileus surface covered by patchy, adpressed, flattened scales initially dark purple-red to wine red then fading pale brown in aged specimens, adnate to subdecurrent, yellowish hymenophore, compound, angular and radially arranged (sub-boletinoid) pores, solid stipe, presence of a soft, cottony, web-like whitish ring on the stipe deriving from a partial veil, stipe surface ornamented by radially arranged, purplish-red bands discoloring pale brown with age, whitish-pink basal mycelium, context cream-pinkish slowly turning pale pinkish-brown on exposure, cylindrical-fusiform to fusiform, smooth, dextrinoid and strongly cyanophilic basidiospores, palisadoderm to trichoderm pileipellis consisting of cylindrical hyphae up to 21 μm broad, hymenophoral trama of the "*Mariaella*-type" and occurrence in mixed forests in obligate ECM association with five-needle pine trees. This species has till now been reported from China (including Heilongjiang, Jilin, Jangsu, Shaanxi, Hubei, Anhui, Zhejiang, Tibet, Sichuan, Yunnan, Guizhou, Hunan, Guangdong, Taiwan and Hainan Provinces), Korea and Japan (Li & Song, 2000, as "*Boletinus pictus*" (Peck) Peck and "*S. pictus*" (Peck) Kuntze; Zhang *et al.*, 2017), however, it is most likely to have a distribution coinciding with the geographic range of its specific host trees.

Up to very recent times, the American species *Suillus spraguei* [= *Suillus pictus* (Peck) Kuntze nom. illegit. Art. 53.1, non *Boletus pictus* Schultz] was assumed to have an endemic disjunct geographical distribution in eastern North American (Berkeley, 1872; Snell, 1945; Singer, 1946; Smith & Thiers, 1964, 1971; Both, 1993; Bessette *et al.*, 2000, 2016; Wu *et al.*, 2000; Mueller *et al.*, 2001; Nguyen *et al.*, 2017) and East Asia (Chiu, 1948, 1957; Hongo & Yokoyama, 1978; Vasiljeva, 1978; Tai, 1979; Imazeki & Hongo, 1989; Bi *et al.*, 1990, 1994, 1997; Zang & Chen, 1990;

Wang, 1999; Li & Song, 2000; Mao, 2000; Wu *et Al.*, 2000; Mueller *et Al.*, 2001; Ding, 2002; Ding & Wen, 2003; Kikuchi & Futai, 2003; Hirose *et Al.*, 2004; Wang *et Al.*, 2004; Min *et Al.*, 2014). Prior to the study of Zhang *et Al.* (2017), chinese/american (Wu *et Al.*, 2000; Burchhardt *et Al.*, 2011) and Japanese researchers (Hirose *et Al.*, 2004; Hirose & Tokumasu, 2007) had already suggested that different species in the *S. spraguei* complex may be present in eastern North America and East Asia based on preliminary phylogenetic outcomes. Zhang *et Al.* (2017) definitely rejected the hypothesis of *S. spraguei* as a single disjunct species with an intercontinental distribution and uncovered three putative distinct Asian species, two of which were formally described and named, viz. *S. phylopictus* and *S. kwangtungensis* R. Zhang, X.F. Shi, P.G. Liu & G.M. Mueller. *S. spraguei* s. str., *S. phylopictus* and *S. kwangtungensis* all are associated with members of *Pinus* subgenus *Strobus* (Zhang *et Al.*, 2017).

Suillus spraguei s. str. is practically indistinguishable from *S. phylopictus* from the morphological viewpoint and in East Asia the latter entity has long been misidentified with the American counterpart as highlighted above. In agreement with Zhang *et Al.* (2017), the only reliable distinguishing feature, aside from molecular phylogenetic analysis and different geographic range, appears to be the host tree since *S. spraguei* s. str. specifically associates with *Pinus strobus* Linn., whereas *S. phylopictus* forms symbiosis with a number of East Asian indigenous five-needle pine trees such as *P. armandii*, *P. kwangtungensis*, *P. korayensis* and possibly additional species. Interestingly, given the association with introduced plantations of *P. strobus* in Germany and the Netherlands, the few records of *S. spraguei* in Europe as an exotic species [Bas, 1973; Dieker, 2007; Arnolds & Chrispijn, 2011; Schreiner, 2012, all as "*Boletinus pictus*" or "*S. pictus*"] are almost certainly to be referred to the American taxon.

The far less widespread *S. kwangtungensis* is another lookalike of *S. phylopictus* and their symbiotic partners and geographic distribution partially overlap. However, *S. kwangtungensis* is recognized by red fibrillose scales not fading with age on both pileus and stipe surface, shorter stipe (3-4.5 cm long), context turning light blue on exposure, inamyloid spores and is exclusively associated with *P. kwangtungensis* at high elevation (above 1400 m) in southern China (Guangdong), where it presently seems to be restricted in an isolated ecological niche (Zhang *et Al.*, 2017).

Phylogenetically, *Suillus decipiens* (Peck) Kuntze was recovered as sister to *S. phylopictus* (Zhang *et Al.*, 2017). It can be readily separated from the latter species by the apricot orange, pinkish-orange to dull yellow pileus and stipe surface, brighter yellow-orange context, slightly longer basidiospores [(8.7)9.0-10.5(12.0) × 3.5-4.0(4.2) μm] and the occurrence under three-needle *Pinus palustris* Mill., *P. taeda* L. and *P. caribea* Morelet (*Pinus* subgenus *Pinus*) in eastern and south-eastern North America down to the gulf coastal plain into Central America and the Caribbean (Singer, 1946; Smith & Thiers, 1964; Singer *et Al.*, 1983; Both, 1993; Bessette *et Al.*, 2000, 2016; Kropp, 2001; Ortiz-Santana *et Al.*, 2007; Klofac, 2013; Angelini, pers. comm.).

Suillus cavipes (Klotzsch) A.H. Smith & Thiers and *S. asiaticus* (Singer) Kretzer & T.D. Bruns are two morphologically similar Eurasian larch-associated species, however, they differ from *S. phylopictus* in the conspicuously squamulose pileus surface, strongly decurrent hymenophore, more radially stretched, truly boletinoid pores, hollow stipe, unchangeable tissues, presence of clamp connections and host specific association with *Larix* spp. in cool temperate regions; moreover, the dark brown to brownish-red pileus [bright yellow in the xanthoid phenotype *S. cavipes* var. *aureus* (Rolland) Bellù] and broader pileipellis hyphae (up to 33 μm wide) further separate *S. cavipes* from *S. phylopictus* (Pilát & Dermek, 1974; Alessio, 1985; Breitembach & Kränzlin, 1991; Lannoy & Estadès, 2001; Muñoz, 2005; Watling & Hills, 2005; Klofac, 2007; Knudsen & Taylor, 2012; Klofac & Krisai-Greilhuber, 2014; Pers. Obs.), whereas *S. asiaticus* exhibits slightly larger spores [(7.5)10-11.6(12.2) × (3.3)4.0-4.7(5.0) μm], longer caulocystidia (50-100 × 8-15 μm), context tending to become bright yellow on drying and is found in the

northernmost boreal zones up to the subarctic regions of East Asia (Russia, Siberia, China, Japan) and at high altitudes in the Himalayan range, introduced as an exotic species in Scandinavian countries (Finland) and recently France (Singer, 1938, 1965; Tuomikoski, 1953; Pilát & Dermek, 1974; Vasiljeva, 1978; Moron, 1987; Alpago-Novello & Moron, 2004; Nagasawa, 2004; Muñoz, 2005; Knudsen & Taylor, 2012; Robin, 2012; Shi *et Al.*, 2013; Klofac & Krisai-Greilhuber, 2014; Das *et Al.*, 2015). It is worth noting that all American collections named *S. cavipes* are indeed *S. ampliporus* (Peck) Kuntze (Nguyen *et Al.*, 2017).

The western North American *Suillus lakei* (Murrill) A.H. Sm. & Thiers is delimited by the tawny-brown to rusty-brown or reddish-brown squamulae on a concolorous to yellowish (var. *calabrus* Lavorato) background, prominent and thick, cottony annulus forming a sheathing band around the stipe, context in the stipe base often staining pale greenish-blue on exposure and emerald green then reddish-brown reaction on pileus and stipe surface with KOH; furthermore, this species occurs in the Rocky Mountains and all along the Pacific Northwest in obligate association with Douglas Fir [*Pseudotsuga menziesii* (Mirb.) Franco] (Smith & Thiers, 1964; Arora, 1986; Both, 1993; Bessette *et Al.*, 2000; Siegel & Schwarz, 2016) although it has also been recorded from introduced plantations in eastern North America (Bessette *et AL.*, 2000), southern South America (Barroetaveña *et Al.*, 2007; Niveiro & Albertó, 2013), Europe (Pietras *et Al.*, 2018 and references therein; Pers. Obs.), Australia and New Zealand (Mcnabb, 1968; Chu-Chou & Grace, 1986; Watling & Li, 1999).

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