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First record of the rare, northern *Russula xantho* from near Wildacres, North Carolina.

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Abstract – *Russula xantho,* a recently described and rare look-alike of the European *R. aurea,* was only known from the States around the Great Lakes Region in North America. This first official record from the slopes of the Appalachian mountains in North Carolina extends this territory considerably. Microscopic features are described and illustrated and compared with *R. aurea* and some other yellow North American Russulas. Ecology, infrageneric placement and affinities are discussed.

Résumé – *Russula xantho*, un sosie peu commun et récemment décrit de la russule européenne *R. aurea,* était jusqu'à présent uniquement connu des états autour de la Région des Grands Lacs en Amérique du Nord. Cette première découverte officielle provenant des versants de la chaîne de montagnes des Appalaches en Caroline du Nord, étend considérablement sa distribution. Les caractères microscopiques sont décrits, illustrés et comparés avec *R. aurea* ainsi qu'avec un nombre d'autres russules jaunes en Amérique du Nord. Ecologie, placement infragénérique et affinités sont discutés.

INTRODUCTION

Russula xantho was described by Robert Shaffer as late as 1990 as a distinct species from *R. aurea* Pers. (at that time mostly still referred to as *R. aurata* (With.) Fr.). Since then, no other records or notes were published for this taxon which appears to be rare in the US and at least uncommon on the Canadian side. In this paper we describe and comment on a recent collection from near Wildacres, North Carolina, which indicates that the Appalachian Mountains may constitute a possible extension to the Northeastern distribution area around the Great Lakes.

MATERIAL AND METHODS

Microscopic observations and measurements were made in ammoniacal Congo red, after a short aqueous KOH pretreatment to improve tissue dissociation and matrix dissolution. Original drawings for all elements of the hymenium or pellis were made at a 2600 × magnification using a drawing tube. Spore

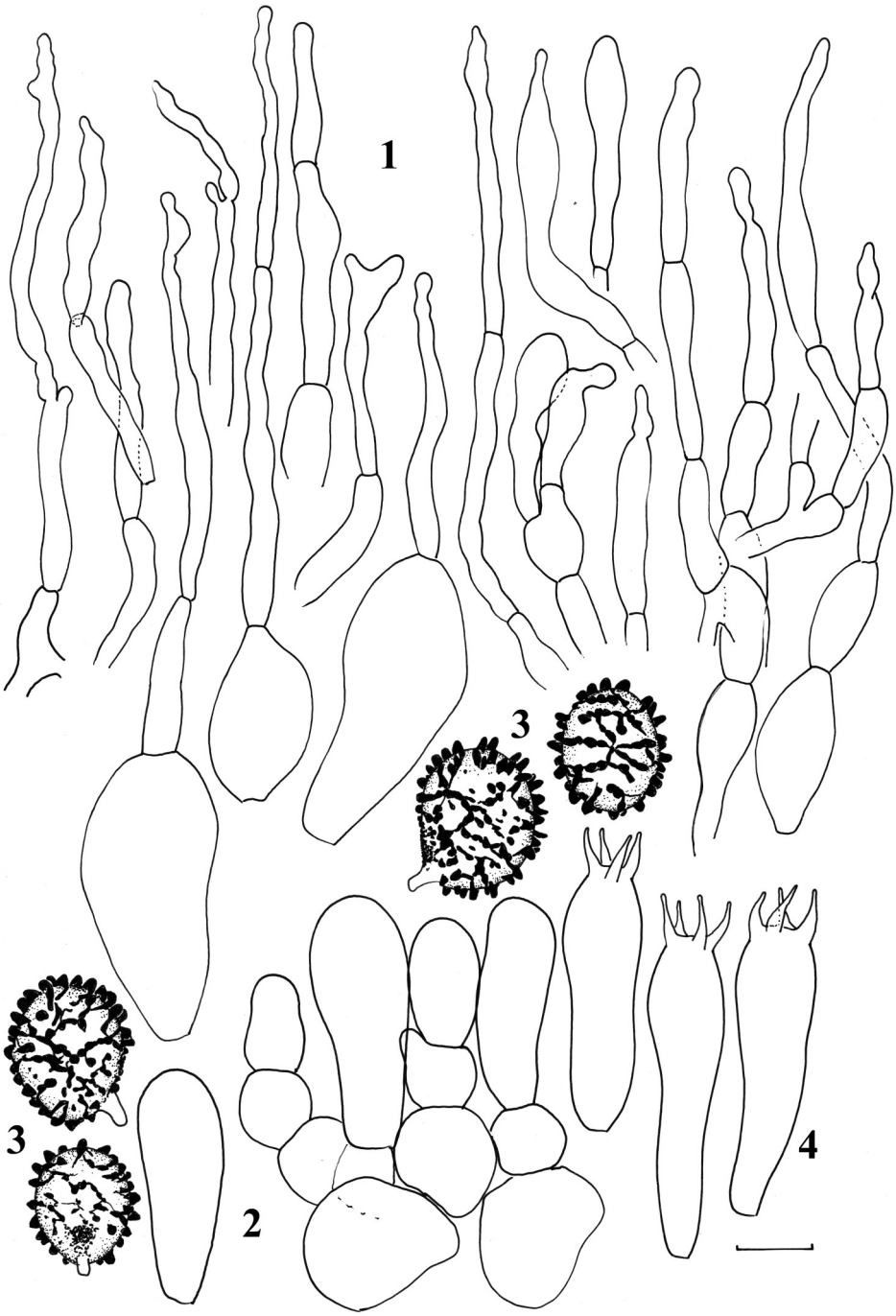
measurements were performed in Melzer's reagent and are based on 20 spores per specimen. Intervals for mean spore length and width among measured collections are indicated in italic with 'n' indicating the total number of spores measured for the taxon. Spore size variation is reflected by substracting, resp. adding, the doubled standard deviation, with extreme measurements between brackets. The mean length/width ratio interval for measured collections (Q) is indicated in italic, and preceded, resp. followed, by the lowest, resp. highest, obtained value for Q. We refer the reader to Buyck (1991) for explanation of cystidial terminology.

DESCRIPTION

Russula xantho Shaffer, *Contr. Univ. Mich. Herb.* 17: 303 Fig. 1-8

Pileus 45-80 mm diam., subglobose when young, expanding to deeply pulvinate and eventually plano-convex with a depressed disc, becoming finely tuberculate-striate 3-6 mm from the edge inward; cuticle thin, viscid and shiny when wet, dull when dry, glabrous, separable 1/3 of the pileus radius, when young unevenly deep orange, strong orange yellow, and vivid yellow overall, when mature deep orange centrally and vivid to strong yellow marginally. **Lamellae** 6-8 mm broad, brittle, equal, rounded in front, adnate to adnexed, close, occasionally forked at or near the stipe, intervenose, entire to finely lacerate, with a mild, nondescript taste, pale yellow at first, becoming light yellow, sometimes edged with strong yellow, unchanged or slightly dingy in age. **Stipe** 40-90 × 12-20 mm, equal or enlarging to the base, dry, glabrous, longitudinally rugulose, stuffed, buffy white below and strong yellow above (i.e. on the portion originally in contact with the lamellae edges), or buffy white overall, slightly cinerescent in age or when handled. **Context** 2-3 mm thick at mid-radius, firm-brittle, sometimes strongly yellow to orange just beneath the cuticle, otherwise buffy white to pale yellow, slowly (e.g. overnight) cinerescent where cut, grayish yellow with $FeSO_4$. **Taste** mild, faintly spermatic. **Odor** slight, nondescript. **Spore print** not obtained (light orange yellow in mass according to Shaffer). **Exsiccatum** retaining its colors for a considerable time. (after Shaffer 1990).

Spores quite variable in size, (8,1)8,4-*8,84*-9,3(9,6) × (6,7)7,1-*7,51*-7,9 µm, (Q = 1,13-1,18-1,23); ornamentation subreticulate, composed of strongly amyloid, closely aligned, obtuse warts, rarely slightly exceeding 1 µm, and locally some very short tracts, together forming longer ridges; suprahilar spot distinctly amyloid, variable in size, sometimes distal, at others almost decurrent on the apiculus. **Basidia** rather short, mostly 35-44 × 9-14 µm, four-spored; basidiola voluminous, plump; sterigmata ordinary, 5-6 × 1-2 µm, neither remarkably large nor small. **Cystidia** certainly not abundant (but impossible to count because of poor contents), often remarkably narrow, 55-90 × (6)8-14 µm, subfusiformous with 1 or 2 droplet-like terminal appendices or constricted subapically, thin-walled; contents SV negative, finely crystalline, often poor and mostly concentrated in the upper halve. **Marginal cells** small, e.g. 20-40 × 4-8 µm, rather abundant, mixed in with the other hymenial elements at the gill edge, resembling sometimes deformed basidia (which are also present), pigmented, with irregularly tapering ends reminiscent of the extreme tips in the pileipellis. **Subhymenium** large-celled. **Lamellar trama** composed almost exclusively of thin-walled, very large sphaerocytes, frequently up to 50 µm diam. **Pileipellis** entirely orthochromatic in cresyl blue, without any incrustations on any type of cell, showing a strong yellow pigment that diffuses or dissolves quickly with



Figs. 1-4. *R. xantho*. 1. Terminal elements of the pileipellis center. 2. Basidiola and subhymenial cells. 3. Spores. 4. Basidia. Scale = 5 µm for spores, 10 µm for the other elements (Buyck 05.128).

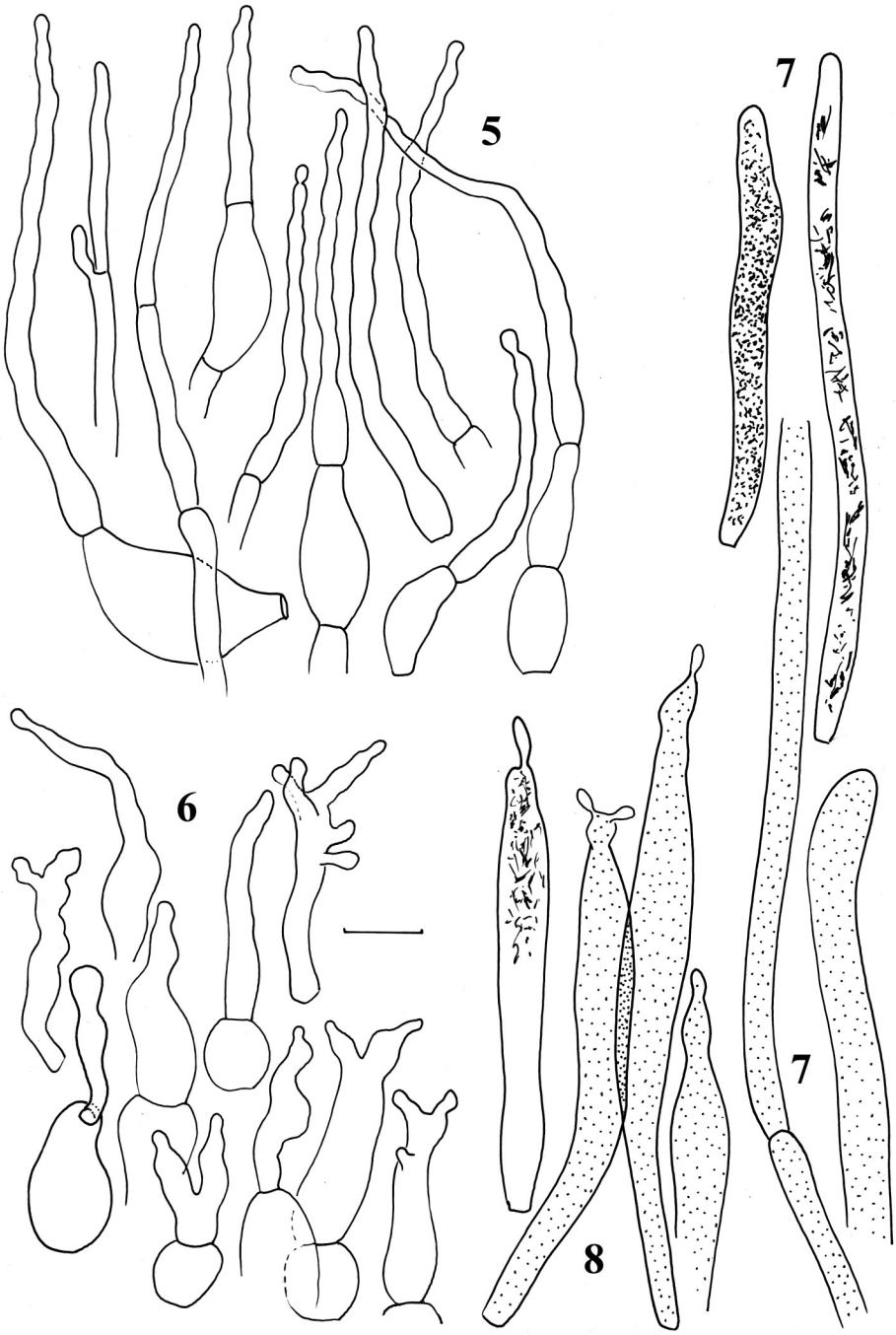


Fig. 5-8. *R. xantho*. 5. Terminal elements near the pileipellis margin. 6. Marginal cells of the gills. 7. Caulocystidia. 8. Hymenial cystidia. Scale = 10 µm (Buyck 05.128).

alkaline reagents; subpellis gelatinized, composed of thin-walled hyphae and some refringent oleiferous hyphal fragments; suprapellis deeper layer containing large ventricose to more irregularly inflated basal cells, up to 17 µm diam. and up to 40 µm long, that do not form a dense pseudoparenchymatous layer but are more or less loosely dispersed, that give rise to mostly long and narrowly cylindrical to aculeate (e.g. 35 × 2-3 µm), or – especially in the center – more variously shaped terminal cells, with the extreme apices often irregularly undulated or subapically constricted and mucronate to appendiculate. Pileocystidia not observed. **Stipitipellis** not very well-developed. Emitting very long, narrow hyphal ends measuring ca. 3 µm diam., both on the surface and in the lower layers also with numerous, cylindrical caulocystidia, mostly 3.5-7 µm diam., some very long, 0-1 septate, with dense finely granular to crystalline contents. **Clamps** absent.

Specimen examined

USA. North Carolina: near Wildacres, in oak-beech forest, 1 Oct. 2005, Buyck 05.128 (PC)

Distribution

Based on the few known collections for this taxon by R. Fatto (NYBG) and Y. Lamoureux (Montreal) as well as on those mentioned in the original description, the distribution of *R. xantho* corresponds roughly to the area surrounding the Great Lakes Region. It comprises the States of Wisconsin (Duna Co-1 coll.), Michigan (Cheboygan Co-2 coll., Emmett Co-2 coll), Maine (Penobscot Co-1 coll., Hancock Co-3 coll.), and extends further east and north into Canada from Quebec (Montreal area) east to Nova Scotia (Kings Co-1 coll.). When taking into consideration also the specimens labeled as "*R. aurea*" Pers. (collected as '*R. aurata*' Fr. – see under Commentary) in various herbaria, then the States of New York, Vermont, Indiana and Minnesota as well as North Carolina would form a potential addition to this distribution.

The here illustrated collection from Wildacres, North Carolina, is by far the most southern official record for *R. xantho*. A predominantly southern distribution is quite unlikely for this species, since neither William Murrill (when in Florida), nor David Lewis (Texas) have collected it (or *R. aurea*) in the many years they intensively surveyed their area.

R. xantho is rare at higher elevations in its distribution area and at least uncommon in the plains. The collection from near Wildacres, North Carolina, comes from higher elevations, which agrees with the more northern distribution for this species. Among Hesler's collections at TENN, here exist, however, a number of specimens from North Carolina that are labeled as *R. aurata*. Although we did not examine these collections, the descriptions in Hesler's unpubl. notes leave little doubt that these all belong to *R. xantho* (see also under "*Commentary*"). We therefore assume that *R. xantho* may be more widely distributed in the Appalachian mountains.

Ecology

Based on field observations from Canada by Yves Lamoureux (Montreal), *R. xantho* appears to be an exclusive companion for beech and also oak. It was never found in association with other broad-leaved trees in Canada, such as poplar, alder, birch, willow or hornbeam, nor with any of the conifers. *R. xantho* can thus principally be found in beech-oak forests, but occasionally also in beech-hemlock and beech-birch forests.

Commentary

In contrast to the European *R. aurea*, for which *R. xantho* had been taken before it was described as a separate taxon by Shaffer, the North-American species appears to be much less variable and flexible, both in appearance and ecology. The available notes and illustrations (unpubl.) for *R. xantho* show always a warm, often uniformely, deep orange to apricot yellow or even bright yellow cap, without any of the bright red to much darker, purplish, reddish or brownish tones so typical for the European species. Furthermore, its flesh has a tendency to turn slowly but distinctly grayish when ageing or injured. *R. xantho* seems finally also much more specific in its host choice. Indeed, the European *R. aurea* is distributed all over Europe, and associates with a wide range of conifers and deciduous trees in an area that extends from the arctic circle in Scandinavia to the Mediterranean evergreen oak forests (Sarnari, 2005). Whether *R. aurea* is actually present in North America is not clear for the moment, but I am not aware of any collections that match its description. The only exception is Kauffman's monograph on Michigan *Russula* (1909) but the description of *R.aurea* is possibly based on European material. And even though he cites a few North American collections reported to him by colleagues, he interestingly admits that he never found it himself in Michigan.

Hesler's notes for the specimens at TENN fit the macroscopic description of *R. xantho* much better than they do that of *R. aurea*. Hesler's notes (unpubl.) report *R. aurea* as rare in the area around Asheville, North Carolina (close to Wildacres), and as doubtful elsewhere. Hesler's collections were mostly made "in lawns under oaks" in June and July, which corresponds to the European situation, where *R. aurea* is also an early species. A single Hesler collection was reported from hemlock woods, but according to Y. Lamoureux from Canada, where *R. xantho* also occurs in hemlock forests, it is never found in pure stands, but only when there is some beech nearby. Also Beardslee has collected "*R. aurata"* near Asheville as testified by a single collection at F.

As far as the systematic position of *Russula xantho* is concerned, there is little doubt that it is very close to *R. aurea* in Europe, from which it is certainly distinct because of

– the slowly cinerescent flesh, and in our collection also the less firm stipe

– the less variable cap colours that are constantly yellow-orange, (instead of mostly bright red to purple sometimes mixed with yellow-orange as in *R. aurea*),

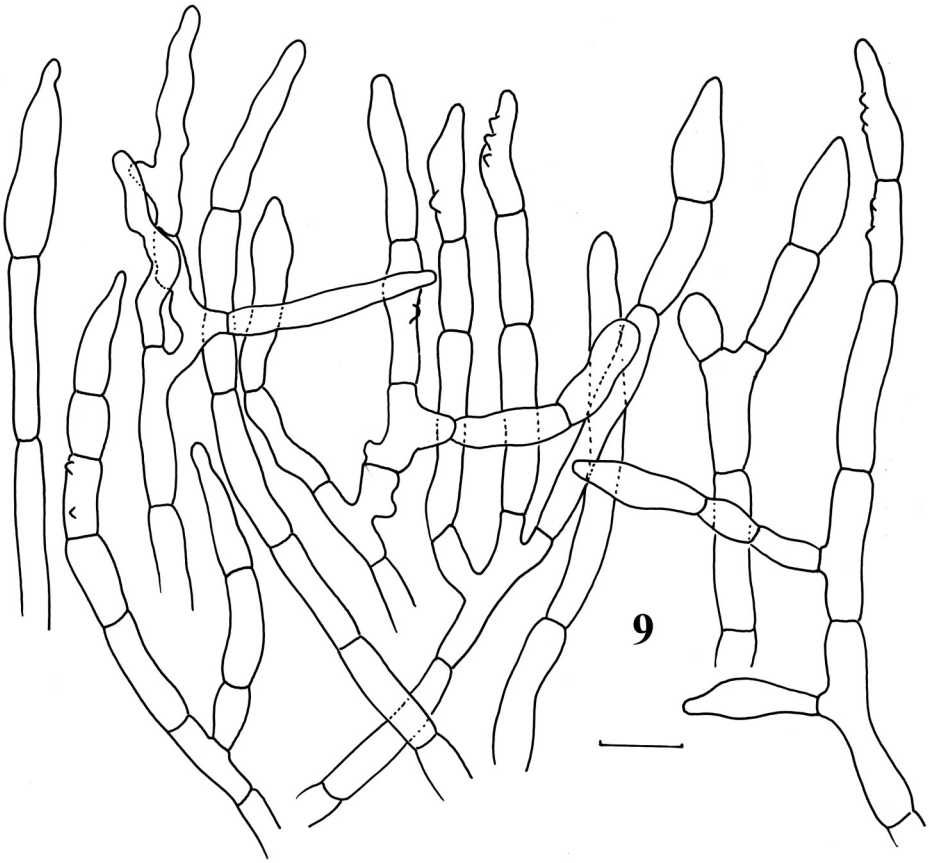
– the terminal cells in the pileipellis which are very narrowly cylindrical to aculeate whereas, in *R. aurea*, the terminal cells are often the more inflated ones and ampullaceous or lageniformous (see our Fig. 9 from specimens collected in Uppsala, Sweden).

Shaffer does mention some ill-defined pileocystidia, but in our collection these were not present, or it was at least impossible to distinguish with certainty from the granular contents from pigment origin in most of the other, often very versiform cells in the pielipellis. The caulocystidia on the other hand are very distinct and abundant.

DISCUSSION

Possible confusions with other bright orange to yellow-capped Russulas include:

– *R. flavida* Frost (in Peck 1880) differs by the presence of strong incrustations on the pileipellis elements that mostly turn reddish brown in alkaline



Figs. 9. *R. aurea*. Terminal elements of the pileipellis center. Scale = 10 µm (Sweden, Uppsala, Castle parc, 4 July 1998, Buyck s.n.).

solutions (also as a macrocharacter when applying KOH to the cap!) and by the distinct refringent contents in the terminal cells of the multicellular encrusted hyphal chains in the suprapellis, similar to those in dermatocystidia. No clear caulocystidia.

– *R. claroflava* Grove has much more strongly graying to blackening context, always white stipe and no dermatocystidia but primordial hyphae.

– *R. ochroleucoides* has a very dense pileipellis of tortuous extremities mixed with pileocystidia.

The systematic position of both species, *R. xantho* and *R. aurea*, within the classification of the genus *Russula* is much more controversial. The absence of pileocystidia has been given most importance in the more "practical" classification of Bon (1988) who placed *R. aurea* in his group of "cuticules sans rien" where he attributes *R.aurea* a subsection of its own together with some enigmatic or very rare other European Russulas. Certainly easy to use as a character in an identification key, one might argue that this argument may perhaps be only secondary in establishing relationships, when not linked with presence of absence of

dermatocystidia elsewhere on the fruiting body (in this case the stipe). Since *Auratinae* do have typical caulocystidia, in contrast to for ex. *Amoeninae* or *Olivaceinae*, the position of Sarnari (2005) and several other authors placing *R. aurea* in the vicinity of *R. romellii* and/or *R. rubroalba* (Singer 1986, Romagnesi 1985) is quite defendable. This seems not contradicted by the analysis of ITS sequences, although without good support and an insufficient number of taxa (Miller & Buyck 2002). In the European context, this is probably the best solution in our opinion. Also, when trying to key *R. xantho* (original description!) to subsectional level using the European keys of Bon (1988) or Sarnari (2005), one arrives at *Integriforminae* Bon *ss* Sarnari, which puts *R. xantho* in the vicinity of both *R. aurea* and *R. romellii* as most authors have done.

The strong resemblance between the pileipellis elements of *R. olivacea* and *R. aurea* opposes itself to the absence of caulocystidia and a different chemistry of the former. When looking for affinities among exotic infrageneric taxa without pileocystidia, a number of African subsections immediately come to mind. Some of these are characterized by strongly pigment-incrusted cap-elements and not only the caps but also the stipes lack dermatocystidia. This makes these species extremely similar to *R. flavida,* even microscopically: ex. *Brunneofloccosinae* Buyck, *Testaceoaurantiacinae* Buyck or *Concolorinae* Buyck. Other candidates among African subsections without dermatocystidia lack these incrustating pigments (ex. *Echinospermatinae* Buyck) and have similar hyphal endings as *R. xantho* in the pellis. Preliminary molecular data (Miller *et al.,* 2001) have shown that *R. discopus* Heim (*Concolorinae*) does not belong to Sect. *Fistulosae* (Heim) Buyck where it was originally placed, but should be placed in one of the larger clades, that comprises most of the dark-spored *Russula*, and which comprises also *Auratinae* and *Integriforminae*. Therefore, a close relationship between *R. aurea, R. xantho* and these exotic groups remains a very valid option, certainly if also *R. flavida* would be closely related to *R. aurea*. A molecular analysis to test this hypothesis is in preparation.

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