

ALBERTO MUA, MASSIMO SANNA, MARCO CASULA, MARIO MELIS,
ARIADNE N.M. FURTADO, ANDREA C. RINALDI

**RUSSULA ROSEOPICTA, A NEW SPECIES OF RUSSULA SUBSECTION MACULATINAE
ASSOCIATED WITH CORK OAK FORESTS OF SARDINIA (ITALY)**

Abstract

Russula roseopicta is described as a new species belonging to *Russula* subsection *Maculatinae*, based on collections from cork oak (*Quercus suber*) forests in Sardinia. Phylogenetic analyses based on ITS and LSU sequences place the species within the *maculata* lineage, where it forms a distinct and well-supported clade separated from other European representatives of the subsection. Morphologically, the new species is characterized by a predominantly pink pileus surface with ochre patches, yellow lamellae and spore print, mild to moderately spicy taste, relatively large basidiospores with partially connected ornamentation, and mostly one-septate dermatocystidia. A detailed description, illustrations, and comparisons with allied taxa are provided.

Riassunto

Russula roseopicta viene descritta come una nuova specie appartenente alla sottosezione *Maculatinae* del genere *Russula*, sulla base di campioni raccolti in foreste di sughere (*Quercus suber*) in Sardegna. Le analisi filogenetiche basate sulle sequenze ITS e LSU collocano la specie all'interno della stirpe *maculata*, dove forma un clade distinto e ben supportato, separato dagli altri rappresentanti europei della sottosezione. Morfologicamente, la nuova specie è caratterizzata da una superficie del cappello prevalentemente rosa con macchie ocre, lamelle e spore gialle, sapore da mite a moderatamente acre, basidiospore relativamente grandi con ornamentazione parzialmente connessa e dermatocistidi per lo più monosettati. Vengono fornite una descrizione dettagliata, illustrazioni e confronti con taxa affini.

Key words Ectomycorrhizal fungi, Mediterranean forests, taxonomy, phylogeny, Russulaceae.

Introduction

Russula Pers. is a monophyletic genus (Buyck *et al.* 2018) belonging to the family Russulaceae, together with *Lactarius* Pers., *Lactifluus* (Pers.) Roussel, *Multifurca* Buyck & V. Hofst, *Boidinia* Stalpers & Hjortstam, *Gloeopeniophorella* Rick and *Pseudoxenasma* K.H. Larss. & Hjortstam. Species of *Russula* are globally distributed ectomycorrhizal fungi associated with a wide range of woody plants, including conifers, broadleaf trees, and shrubs such as members of the *Cistaceae*. Although approximately 800 species are currently recognized, the actual diversity of the genus is considered to be much higher, with estimates exceeding 2,000 species worldwide (Adamčík *et al.* 2019).

At present, nine subgenera are recognized within the genus *Russula* (Hongsanan *et al.* 2015, Das *et al.* 2017; Buyck *et al.* 2018; Buyck *et al.* 2020; Buyck *et al.* 2023). Within *Russula*, subsection *Maculatinae* (Konrad & Joss.) Romagn. belongs to *Russula* subgen. *Russula* and forms part of the so-called “crown clade” recognized in recent phylogenetic studies (Adamčík *et al.* 2019). Species of this subsection constitute a relatively coherent group morphologically and phylogenetically, although species delimitation within the group remains challenging.

The current circumscription of subsection *Maculatinae* largely corresponds to the group traditionally treated as series *maculata* (nom. inval.) by Sarnari (1998). Species of this subsection are typically characterized by reddish to ochraceous basidiomata, often showing rusty discolorations, a mild to spicy taste, non-encrusted dermatocystidia reacting greyish in sulfovanillin, absence of incrustated primordial hyphae, basidiospores with isolated or partially connected ornamentation, and a yellow to yellowish spore print (Adamčík & Jančovičová 2012).

Phylogenetic studies have shown that subsection *Maculatinae* can be divided into two principal lineages: the *maculata* lineage and the *globispora* lineage (ADAMČÍK *et al.* 2016; KIRAN *et al.* 2021; Ji *et al.* 2022). The new species described here belongs to the *maculata* lineage, which includes *R. maculata* Quél., *R. nympharum* F. Hampe & Marxm., *R. mansehraensis* Saba, Caboň & Adamčík, and the sequestrate species *R. candida* (Tul. & C. Tul.) J.M. Vidal.

Species of subsection *Maculatinae* are mainly distributed in Europe and Asia. In Europe, subsection *Maculatinae* includes: *R. maculata*, *R. nympharum*, *R. globispora* (J. Blum) Bon, and *R. dryadicola* R. Fellner & Landa. The sequestrate species *R. mattirolana* (Cavara) T. Lebel, *R. candida* and *R. mediterraneensis* Konstantin., J.M. Vidal, Gelardi, Papadimitriou, Tulli, Angeli & Vizzini are also included; the first two were previously assigned to the genus *Macowanites* Kalchbr. and have recently been recombined within the genus *Russula* (VIDAL *et al.* 2019).

In Asia, the following species have been described: from India, *R. mayawatiana* K. Das, S.L. Mill. & J.R. Sharma (DAS *et al.* 2006); from Pakistan, *R. quercus-floribundae* M. Kiran & Adamčík (CROUS *et al.* 2019), *R. ayubiana* M. Kiran & Khalid, *R. abbotabadensis* Saba & Adamčík (CABOŇ *et al.* 2019), *R. mansehraensis* (CROUS *et al.* 2018), *R. rubricolor* Jabeen, Naseer & Khalid (JABEEN *et al.* 2020), and *R. iqbalii* Naveed, Ijaz, S. Ullah & Jabeen (NAVEED *et al.* 2025); from China, *R. tengii* G.J. Li & H.A. Wen (CABOŇ *et al.* 2019), *R. rubiginosus* R.Q. Ji, M.L. Xie & J.J. Zhou (Ji *et al.* 2022), *R. heilongjiangensis* G.J. Li & R.L. Zhao (LI *et al.* 2018), and *R. puxianensis* L. Fan & H.Y. Fu (FU *et al.* 2026). *R. maculata* has also been reported from Pakistan (SULTANA *et al.* 2011), although these collections lack molecular support.

In North America, *R. subrubescens* Murrill was described (MURRILL 1940).

For Africa, BERTAULT (1978) reported *R. maculata* from Algeria, although these collections may actually represent *R. nympharum*. He also reported *R. maculata* Quél. var. *bresadolana* (Singer) Romagnesi from Morocco, possibly a synonym of *R. globispora*. The taxonomic identity of *R. straminea* Malençon (MALENÇON 1944) remains uncertain and it is probably synonymous with *R. globispora*.

In Sardinia, the occurrence of *R. nympharum* and *R. globispora* has been confirmed (CASULA *et al.* 2021), whereas previous reports of *R. maculata* lack molecular support and may correspond to misidentifies collections of *R. nympharum* (BROTZU 1993; MUA & CASULA 2012). During surveys in Sardinian cork oak forests, additional collections attributable to subsection *Maculatinae* were discovered. Morphological and molecular analyses demonstrated that these collections represent a previously undescribed species, here introduced as *Russula roseopicta*.

MATERIALS AND METHODS

Morphological observations

The basidiomata were examined and photographed in situ, and ecological data were recorded in the field.

Macromorphological features were described from fresh basidiomata. Spore print colors were determined according to the code of ROMAGNESI (1967), while morphological terminology follows SARNARI (1998, 2005). Macrochemical reactions were carried out using the following reagents: FeSO₄, phenol (2%), guaiac resin + ethyl alcohol (extemporaneous reaction), and KOH (30%).

Microscopic observations

Micromorphological studies were performed using Optika B-383 PLi trinocular microscopes (Optika Italy, Ponteranica, BG, Italy) and Motic BA 400 (Motic Europe, Barcelona, Spain), both equipped with integrated digital cameras, as well as an Optech B4 binocular microscope (Optech Technology, Taipei City, Taiwan) fitted with a Nikon Coolpix SQ digital camera (Nikon Europe B.V., Campi Bisenzio, FI, Italy).

The exsiccata were rehydrated with NH₄OH (3%). The pileipellis was examined in water, anionic Congo red (2%), sulfovanillin, and basic fuchsin, whereas hymenial cystidia were observed in anionic Congo (2%) red and sulfovanillin. Basidiospores were examined in Melzer's reagent.

Basidiospore measurements were carried out on at least 32 spores obtained from spore deposits, following PARMASO & PARMASO (1987). Basidiospore measurements are presented as (minimum–) mean – SD – mean – mean + SD (–maximum), for both length and width, with the mean value underlined. Q represents the length/width ratio, and Qm the mean quotient. The hilar appendix and spore ornamentation were excluded from measurements, as were sterigmata from basidium measurements. Dimensions of basidia and cystidia can be expressed as minimum–maximum ranges.

Both collections studied (holotype and paratype) were deposited in the Herbarium of the Department of Life and Environmental Sciences, Botanical Section, University of Cagliari (CAG). Duplicate collections (isotype and paratype) are preserved in the private herbarium of Alberto Mua (Quartu Sant'Elena, Italy).

Molecular analysis

The two collections attributable to an undescribed species of *Russula* subsection *Maculatinae* were selected for molecular analysis. The ITS region was sequenced for both collections, whereas the LSU region was obtained for the paratype.

Total DNA extraction, PCR amplification, and sequencing were performed by Alvalab (Oviedo, Spain), following standard protocols. DNA was extracted from dried samples using a cetyltrimethylammonium bromide (CTAB) method (MURRAY & THOMPSON 1980). The ITS region was amplified using the primer pair ITS1F/ITS4 (WHITE *et al.* 1990; GARDES & BRUNS 1993), and the LSU region using LR0R/LR5 (VILGALYS & HESTER 1990). PCR products were checked on 1% agarose gel, and chromatograms were inspected and manually corrected when necessary. Further details on PCR conditions, electrophoresis, and purification are provided in ALVARADO *et al.* (2010, 2012, 2021).

Newly generated sequences were compared with available sequences in GenBank using BLASTn (ALTSCHUL *et al.* 1990) and with sequences available in UNITE through PlutoF (Fungal Records Database). Two datasets were assembled for phylogenetic analyses: an ITS dataset including 52 sequences and an LSU dataset including 26 sequences of *Russula* subsection *Maculatinae* retrieved from GenBank and UNITE, together with the newly generated sequences. The dataset included two sequences of *R. roseopicta* and two sequences of *R. globispora* generated in the present study. *Russula cuprea* Krombh. (GenBank: ITS: MG386711; LSU: MZ358818) was selected as outgroup, as it belongs to subsection *Cupreinae* Bon, which is phylogenetically very close to subsection *Maculatinae*.

All sequences used in the analyses are listed in **Tab. 1**. Sequences were aligned using the MUSCLE (EDGAR 2004), implemented in MEGA 12 (KUMAR *et al.* 2024), and the alignments were manually inspected and adjusted where necessary. Nexus and phylip files were generated using MESQUITE 3.61 (MADDISON & MADDISON 2019).

Maximum likelihood analyses were performed using raxMLGUI 2.0 (STAMATAKIS 2014; EDLER *et al.* 2021), with 1000 bootstrap replicates and the GTR+GAMMA substitution model. Bayesian inference was performed using MrBayes 3.2.7 (RONQUIST *et al.* 2012), with two independent runs of four chains for 10 million generations, sampling every 1000 generations. The first 25% of trees were discarded as burn-in.

Trees were visualized and edited using TreeGraph 2 (STÖVER & MÜLLER 2010). Bayesian posterior probabilities (BPP) were mapped onto the maximum likelihood tree. Branches were considered supported when BPP values were ≥ 0.95 and/or maximum likelihood bootstrap support values (MLBS) were $\geq 70\%$.

RESULTS

Maximum likelihood and Bayesian analyses produced congruent topologies. Bayesian analysis showed satisfactory convergence (avgstddev = 0.003414; PSRF = 1; ESS > 500 for all parameters). Phylogenetic analyses recovered two main clades within *Russula* subsection *Maculatinae*, corresponding to the *maculata* lineage and the *globispora* lineage previously recognized in the literature. The two collections identified as *Russula roseopicta* clustered together with maximal statistical support (MLBS = 100; BPP = 1) and formed a distinct and well-supported lineage within the *maculata* clade (MLBS = 82; BPP = 0.99). The phylogenetic placement of the new species was consistently recovered in both maximum likelihood and Bayesian analyses and remained clearly separated from the morphologically similar European taxa *R. maculata* and *R. nympharum*. The phylogenetic placement of the sequestrate species *R. candida* was recovered within the *maculata* lineage, although with weaker phylogenetic support for some deeper relationships within the clade.

Table 1. List of collections included in the phylogenetic analysis. Sequences in bold were deposited in GenBank directly by the authors.

Species	Voucher	ITS	LSU	Country	Type	Reference
<i>Russula abbottabadensis</i>	LAH310099	MG386702	—	Pakistan	—	CABOŇ <i>et al.</i> 2019
<i>Russula abbottabadensis</i>	FH00304589	MG386704	MN518356	Pakistan	T	CABOŇ <i>et al.</i> 2019
<i>Russula ayubiana</i>	LAH 35438	MZ358867	MZ358816	Pakistan	—	KIRAN <i>et al.</i> 2021
<i>Russula ayubiana</i>	LAH 35439	NR_174925	MZ358817	Pakistan	T	KIRAN <i>et al.</i> 2021
<i>Russula candida</i>	JC171001N	MK105631	MK105710	Spain	—	VIDAL <i>et al.</i> 2019
<i>Russula candida</i>	JMV799894	MK105630	no	Germany	—	VIDAL <i>et al.</i> 2019
<i>Russula candida</i>	JMV20100724b	MK105632	MK105711	Spain	—	VIDAL <i>et al.</i> 2019
<i>Russula cuprea</i> (outgroup)	GENT (2010 BT168)	MG386711	MZ358818	Germany	—	CABOŇ <i>et al.</i> 2019
<i>Russula dyadicola</i>	TURA 152390	MG386712	MZ358820	Finland	—	CABOŇ <i>et al.</i> 2019
<i>Russula dyadicola</i>	UPS:AT2004140	KU928145	MN518358	Sweden	—	ADAMČÍK <i>et al.</i> 2016
<i>Russula dyadicola</i>	TURA 151632	KU928146	MN518357	Germany	—	ADAMČÍK <i>et al.</i> 2016
<i>Russula globispora</i>	GENT:FH-2007-BT111	KU928144	MG944273	Germany	—	ADAMČÍK <i>et al.</i> 2016
<i>Russula globispora</i>	GENT (2007 BT98)	MG386717	MZ358822	Germany	—	CABOŇ <i>et al.</i> 2019
<i>Russula globispora</i>	SAV:HK12021	KU886595	MN518362	Sweden	—	CABOŇ <i>et al.</i> 2019
<i>Russula globispora</i>	GENT:FH-2007-BT121	KU886594	MG944274	Germany	—	CABOŇ <i>et al.</i> 2019
<i>Russula globispora</i>	GJ03M	PZ559968	—	Italy	—	This study
<i>Russula globispora</i>	FJ16M	PZ559973	—	Italy	—	This study
<i>Russula heilongjiangensis</i>	HMAS:255142	MG719932	—	China	T	LI <i>et al.</i> 2018

Species	Voucher	ITS	LSU	Country	Type	Reference
<i>Russula heilongjiangensis</i>	HMAS:279587	MG719933	—	China	—	LI <i>et al.</i> 2018
<i>Russula iqbalii</i>	UEH-F0026	PQ110531	—	Pakistan	T	NAVEED <i>et al.</i> 2025
<i>Russula iqbalii</i>	UEH-F0027	PQ110532	—	Pakistan	—	NAVEED <i>et al.</i> 2025
<i>Russula maculata</i>	SAV:F-933	KU928150	MG944275	Slovakia	—	ADAMČÍK <i>et al.</i> 2016
<i>Russula maculata</i>	SAV:F-2130	KU928151	MG944277	Estonia	—	ADAMČÍK <i>et al.</i> 2016
<i>Russula maculata</i>	GENT:FH-2010-BT184	KU928154	—	Germany	—	ADAMČÍK <i>et al.</i> 2016
<i>Russula maculata</i>	GENT:FH-2009-BT05	KU928155	MG944279	Germany	—	ADAMČÍK <i>et al.</i> 2016
<i>Russula mansehraensis</i>	HUP-SU33	MG948635	—	Pakistan	—	CROUS <i>et al.</i> 2018
<i>Russula mansehraensis</i>	HUP-SUR180	MG948636	MN518354	Pakistan	T	CROUS <i>et al.</i> 2018
<i>Russula mansehraensis</i>	HUP-SU803	MG948637	—	Pakistan	—	CROUS <i>et al.</i> 2018
<i>Russula mansehraensis</i>	LAH:MAM-0077	KU886598	—	Pakistan	—	CROUS <i>et al.</i> 2018
<i>Russula mattirolloana</i>	JMV800644 (BCN)	MK105653	MK105722	Greece	—	VIDAL <i>et al.</i> 2019
<i>Russula mattirolloana</i>	JMV800713 (BCN)	MK105656	MK105723	Poland	—	VIDAL <i>et al.</i> 2019
<i>Russula mediterraneensis</i>	JMV800641 (BCN)	MK105660	MK105726	Greece	—	VIDAL <i>et al.</i> 2019
<i>Russula mediterraneensis</i>	MG636, 29085 (MCVE)	MK105661	—	Italy	—	VIDAL <i>et al.</i> 2019
<i>Russula mediterraneensis</i>	MG636, 29086 (MCVE)	MK105662	—	Italy	—	VIDAL <i>et al.</i> 2019
<i>Russula nympharum</i>	GENT RUS11121505	NR_153268	—	Spain	T	ADAMČÍK <i>et al.</i> 2016
<i>Russula nympharum</i>	HJB10019	DQ422015	MN518353	Belgium	—	ADAMČÍK <i>et al.</i> 2016
<i>Russula nympharum</i>	CAG P.11.2.32	OM001196	—	Italy	—	CASULA <i>et al.</i> 2021
<i>Russula quercus-floribundae</i>	LAH 36220	MN053391	MN513044	Pakistan	—	CROUS <i>et al.</i> 2019
<i>Russula quercus-floribundae</i>	LAH 36219	MN053395	MN513043	Pakistan	T	CROUS <i>et al.</i> 2019
<i>Russula roseopicta</i>	HE05M	PZ544118	PZ544119	Italy	—	This study
<i>Russula roseopicta</i>	HE15M	PZ544120	—	Italy	T	This study

Species	Voucher	ITS	LSU	Country	Type	Reference
<i>Russula rubiginosus</i>	HMJAU58933	OL828349	—	China	T	J ₁ <i>et al.</i> 2022
<i>Russula rubiginosus</i>	HMAS:267826	KX441111	KX441358	China	—	J ₁ <i>et al.</i> 2022
<i>Russula rubiginosus</i>	HMAS:267741	KX441095	KX441342	China	—	J ₁ <i>et al.</i> 2022
<i>Russula rubiginosus</i>	HMJAU58934	OL828348	—	China	—	J ₁ <i>et al.</i> 2022
<i>Russula rubiginosus</i>	clone QL041	HM105533	—	China	—	WANG <i>et al.</i> 2012
<i>Russula rubricolor</i>	AN-2019a isolate SJ105	MK142796	—	Pakistan	T	JABEEN <i>et al.</i> 2020
<i>Russula rubricolor</i>	AN-2019a isolate SJ106	MK142795	—	Pakistan	—	JABEEN <i>et al.</i> 2020
<i>Russula rubricolor</i>	AN-2019a isolate ASK47	MK142798	—	Pakistan	—	JABEEN <i>et al.</i> 2020
<i>Russula subrubescens</i>	TENN F18339	NR_153232	—	USA	T	—
<i>Russula subrubescens</i>	MQ24-HRL4175	PX308544	—	Canada	—	LANDRY <i>et al.</i> 2025
<i>Russula tengii</i>	HMAS262728	MG386708	—	China	T	CABOÑ <i>et al.</i> 2019

TAXONOMY

Russula roseopicta Mua, Marc. Casula, M. Sanna, M. Melis, A.N.M. Furtado & A.C. Rinaldi
sp. nov.
MycoBank N. 864278

Diagnosis

Russula roseopicta differs from other European members of subsection *Maculatinae* by the combination of predominantly pink pileus cuticle with ochre patches also present on the stipe, yellow lamellae and spore print, mild to moderately spicy taste, relatively large basidiospores with partially connected ornamentation, predominantly one-septate dermatocystidia, and its occurrence in *Quercus suber* forests in Sardinia. Phylogenetically, it forms an independent clade within the *maculata* lineage.

Etymology

The epithet refers to the characteristic pink coloration of the pileus cuticle.

Holotype

Italy, Sardinia, Su Berrinu locality, Municipality of Isili (CA), in *Quercus suber* L. forest on calcareous soil, 705 m a.s.l., 07 Oct 2025, *leg.* A. Mua. Deposited in CAG herbarium (C.14.3); isotype in private herbarium Mua (HE15M). GenBank: ITS PZ544120.

Additional specimen examined

Italy, Sardinia, Onitzu locality, Municipality of Belvì (NU), in *Quercus suber* forest on neutral soil, 550 m a.s.l., 28 Sep 2025, *leg.* Alberto Mua, deposited in CAG herbarium (C.14.4) and duplicate in private herbarium Mua (HE05M). GenBank: ITS PZ544118, LSU PZ544119.

Pileus 4–8 cm broad, initially hemispherical with a slightly involute margin, becoming convex, often lobed, and finally shallowly depressed in the centre; surface dry, pink to pink-orange, often fading to whitish, especially towards the centre, frequently with scattered yellow-brown to ochraceous patches. Margin entire, not striate, even at maturity.

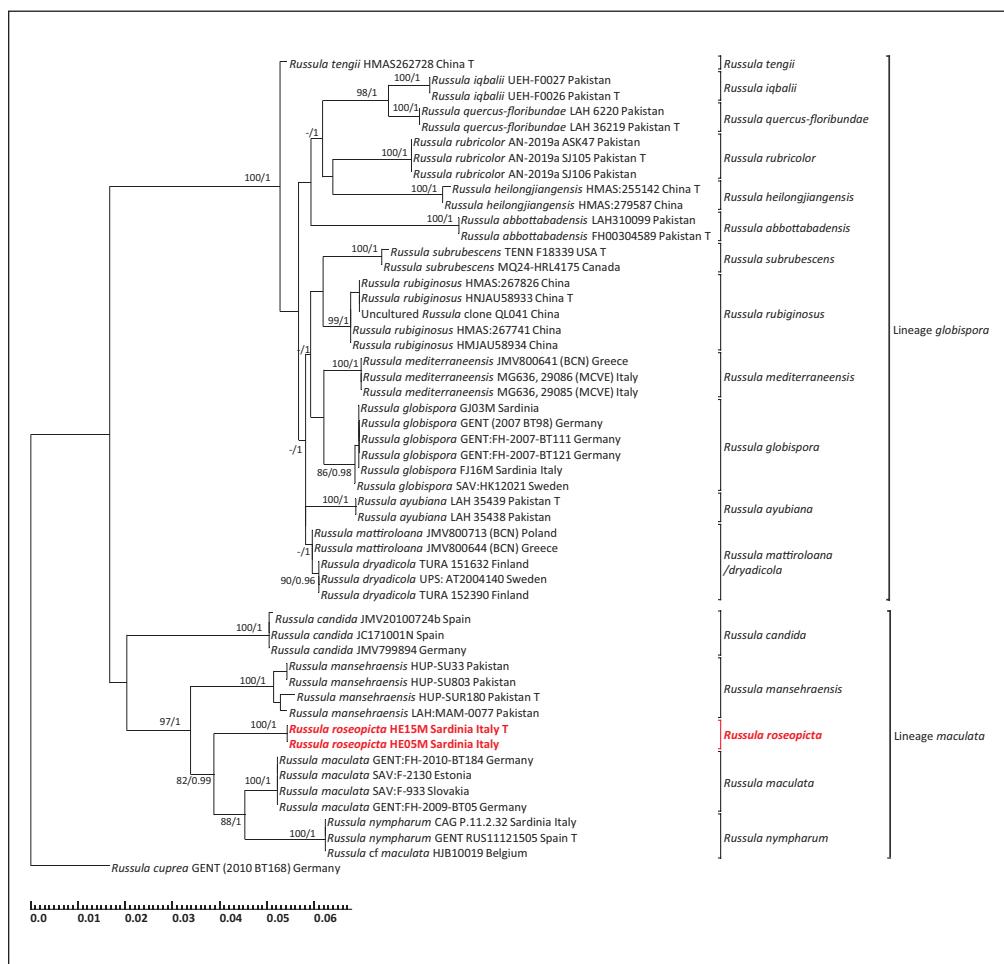


Figure 1. Maximum Likelihood phylogeny of *Russula* subsection *Maculatinæ* inferred with RAxML. Bayesian posterior probabilities obtained from MrBayes are mapped onto the RAxML topology. Branch support values are reported above the branches as Maximum Likelihood bootstrap percentages (MLBS) and Bayesian posterior probabilities (BPP). Only MLBS values $\geq 70\%$ and BPP values ≥ 0.95 are shown. Sequences generated in this study are indicated in red.

Lamellae adnate to slightly decurrent, moderately crowded, with few lamellulae, becoming broader and somewhat ventricose with age; edge blunt; intervenose between the lamellae; initially deep cream, becoming yellow.

Spore print IVd (Romagnesi code).

Stipe central to eccentric, stout, cylindrical to clavate, with a wrinkled surface, white, with ochraceous spots on the lower half; initially stuffed, becoming cavernous, then hollow.

Context white, slightly yellowing over time, firm then soft; taste mild to moderately spicy. Smell pleasant, fungal.

Macrochemical reactions on the stipe surface: FeSO_4 negative or producing a very pale pink-orange reaction; phenol (2%) grey-brown; guaiac weakly and slowly positive; KOH (30%) negative.



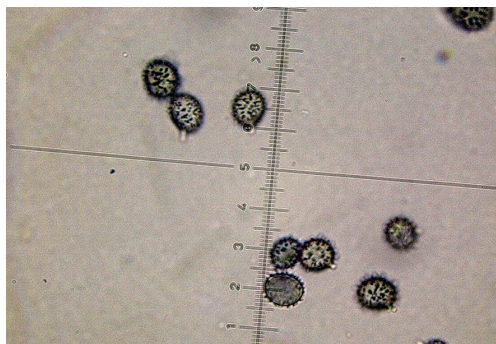
Russula roseopicta. Holotype.

Photo by Alberto Mua

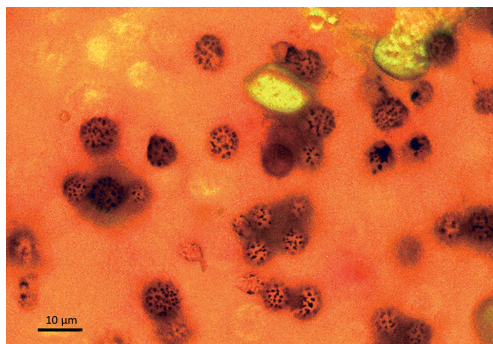


Russula roseopicta. Paratype.

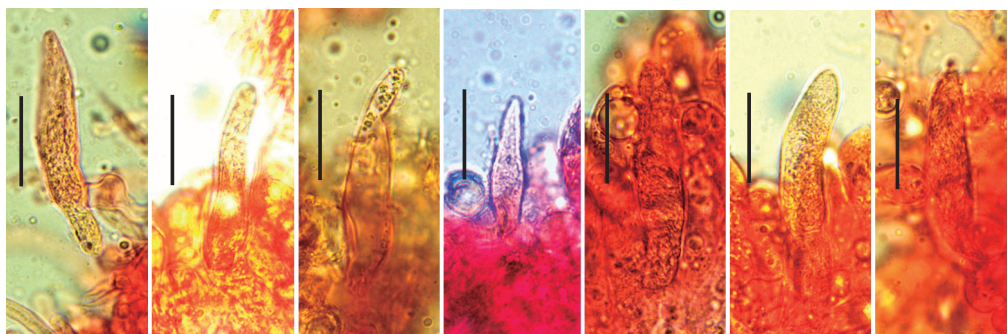
Photo by Alberto Mua



R. roseopicta. Spores in Melzer reagent. Holotype (1000×). Scale bar = 10 μm. Photo by Marco Casula

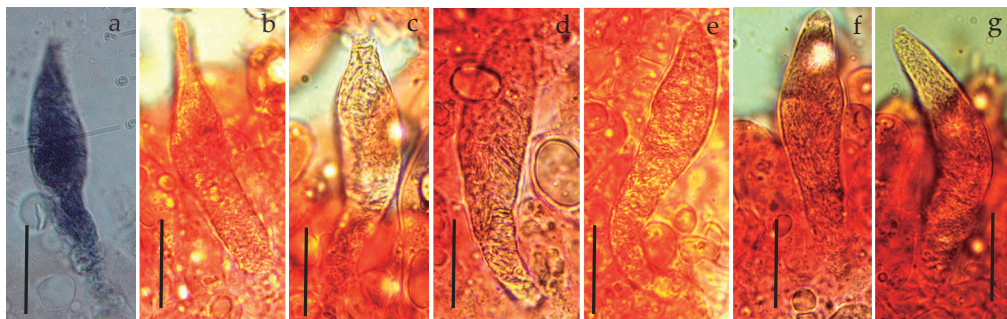


R. roseopicta. Spores in Melzer reagent. Holotype (1000×). Scale bar = 10 μm. Photo by Marco Casula



R. roseopicta. Cheilocystidia in Congo red. Holotype. Scale bar = 20 μm.

Photo by Alberto Mua



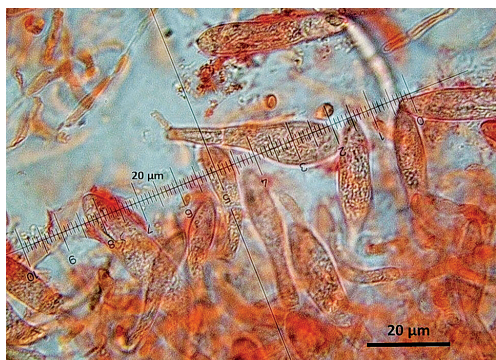
R. roseopicta. Pleurocystidia. Holotype. **a**. In sulfovanillin; **b-g**. In Congo red. Scale bar = 20 μm.

Photo by Marco Casula (**a**); Photo by Alberto Mua (**b-g**)

Basidiospores (8.00) 8.44-9.39-10.34 (11.38) × (6.11) 7.14-7.95-8.75 (9.90) μm, Q = 1.10-1.18-1.26, subglobose to ellipsoid, ornamented with amyloid spines 0.6-1.2 μm high, mostly isolated, occasionally connected by short ridges; suprahilar plage amyloid, very conspicuous, with irregular, sometimes stellate margins.

Basidia 35-50 × 11-14 μm, clavate, predominantly 4-spored, with a few 2-spored; sterigmata 3-4 μm long.

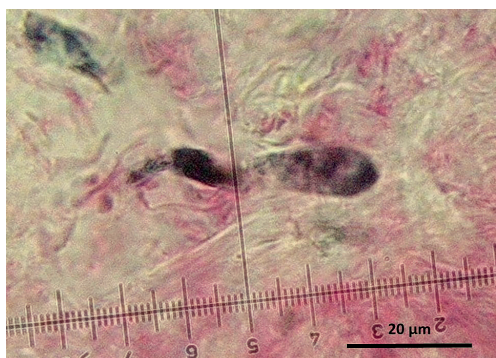
Cheilocystidia 33-58 × 5.2-11.5 μm, fusiform to clavate, elongate, turning black in sulfovanillin.



R. roseopicta. Dermatocystidia in Congo red. Holotype (1000×). Scale bar = 20 μm. Photo by Marco Casula



R. roseopicta. Dermatocystidia in basic fuchsin. Holotype (1000×). Scale bar = 20 μm. Photo by Marco Casula



R. roseopicta. Dermatocystidia in sulfovanillin. Holotype (1000×). Scale bar = 20 μm. Photo by Marco Casula

Pleurocystidia 54-74 × 11-14 μm, fusiform to clavate, turning black in sulfovanillin, rarely appendiculate.

Pileipellis a non-gelatinized trichoderm, approximately 150 μm thick, not clearly differentiated into suprapellis, mediopellis, and subpellis. At the pileus margin, it is composed of broad hairs, (1.49) 1.75-2.19-2.64 (3.09) μm wide, and numerous dermatocystidia, (3.55) 4.54-5.83-7.13 (8.31) μm wide and up to 150 μm long. The dermatocystidia are partly clavate and unicellular, but predominantly septate with a single septum, only rarely possessing two

septa. The center of the pileus is composed of cylindrical terminal hyphae (hairs), (1.2) 1.9-2.5-3.2 (3.9) μm wide, mostly with rounded apices, rarely attenuate or appendiculate, occasionally diverticulate. Dermatocystidia very abundant, partly unicellular but more commonly one-septate and only rarely two-septate, clavate, (4.90) 5.86-8.41-10.96 (14.80) μm wide, containing granular contents in Congo red, turning black in sulfovanillin, lacking incrustations after treatment with basic fuchsin, rarely diverticulate; terminal element usually clavate, rarely cylindrical. Primordial hyphae absent.

Distribution and ecology it has been collected in Sardinia in Mediterranean forests dominated by *Quercus suber*. The species appears to be associated with thermophilous ectomycorrhizal habitats in insular Mediterranean ecosystems.

Discussion

The combination of morphological characters and phylogenetic evidence supports the recognition of *Russula roseopicta* as a distinct species within subsection *Maculatinae*. The most diagnostic features include the predominantly pink basidiomata with ochre discolorations, yellow lamellae and spore print, relatively large basidiospores with partially connected ornamentation, and predominantly one-septate dermatocystidia. In addition, the species appears to be ecologically associated with Mediterranean *Quercus suber* forests in Sardinia.

Below is a description of the characteristics that distinguish *R. roseopicta* from other European members of the subsection *Maculatinae*.

Russula maculata is distinguished from *R. roseopicta* by the presence of small purplish to rust-colored spots on the basidiomata, a stem often tinged with reddish hues, larger hymenial cystidia, spores with lower and generally more interconnected warts, and, on average, thinner dermatocystidia (ADAMČÍK & JANČOVIČOVÁ 2013).

Russula nympharum differs in having rusty patches on the cuticle, slightly smaller spores with lower warts, pleurocystidia and cheilocystidia that are on average longer, and thinner dermatocystidia, predominantly unicellular and only occasionally septate (ADAMČÍK *et al.* 2016).

Russula mansehraensis, an Asian species that is nevertheless closely related phylogenetically to the European species *Russula roseopicta*, *Russula maculata* and *Russula nympharum*, differs in being associated with conifers (*Pinus roxburghii* Sarg.), having smaller spores with lower and more interconnected warts, a gelatinized suprapellis, and narrower dermatocystidia (ADAMČÍK *et al.* 2016, CROUS *et al.* 2018).

Russula globispora differs by its predominantly ochraceous basidiomata, only occasionally showing reddish tones, more extensive rust-coloured patches on the pileus surface, paler lamellae, and larger subglobose basidiospores bearing isolated spines [1-1.5 (2) μm high] that are only exceptionally connected by short ridges. In addition, pileipellis hairs in *R. globispora* usually possess attenuated terminal elements (BLUM 1962; SARNARI 1998, (ADAMČÍK & JANČOVIČOVÁ 2013).

Russula dryadicola differs ecologically by its alpine habitat associated with *Dryas octopetala* L. and *Salix reticulata* L., and probably also with *Betula* spp. and *Picea abies* as well as morphologically by its viscid pileus cuticle with rust-coloured patches, and slightly smaller basidiospores (BINCOLETTO & OSTELLARI 2005).

Additional European taxa showing partial morphological similarities include *Russula cuprea*, which can be distinguished by its different pileus coloration, the yellow–orange lamellae at maturity, and by its markedly diverticulate pileipellis hairs and dermatocystidia, the latter being additionally multiseptate and, on average, narrower.

Russula decipiens (Singer) Svrček differs by its yellow–orange lamellae, absence of ochraceous patches on the pileus and stipe, evident greying of the context, and large, abundant, and consistently unicellular dermatocystidia (SARNARI 1998).

Russula quercilicis Sarnari appears to be associated mainly with holm oak forests and shows initially very pale lamellae and pileus colours resembling those of *Russula vesca* Fr., later becoming more similar to *Russula decipiens*. It further differs by possessing unicellular and encrusted dermatocystidia (SARNARI 1998).

Russula rutila Romagn. is characterized by a predominantly red pileus usually lacking ochraceous discolorations and by strongly encrusted dermatocystidia (SARNARI 1998).

The discovery of *Russula roseopicta* further highlights the still incompletely known diversity of Mediterranean representatives of subsection *Maculatinae*. Mediterranean ectomycorrhizal ecosystems, particularly insular systems such as Sardinia, likely harbour a greater diversity of *Russula* species than currently recognized. Mediterranean cork oak ecosystems represent important reservoirs of ectomycorrhizal fungal diversity and may support locally specialized fungal communities. The insular isolation of Sardinian ectomycorrhizal communities may also have contributed to diversification processes within Mediterranean lineages of *Russula*. The apparent association of the new species with *Quercus suber* forests suggests a potentially specialized ecological niche within thermophilous Mediterranean habitats. Additional sampling and multilocus phylogenetic studies will likely reveal further undescribed diversity and help clarify phylogenetic relationships within the *maculata* lineage.

Authors' addresses

ALBERTO MUA

Via Spano 8 - 09045 Quartu S. Elena (CA-IT).

E-mail: albermua@gmail.com

<https://orcid.org/0000-0002-9586-0403>

Associazione Micologica Bresadola Gruppo di Cagliari Sette Fratelli

MASSIMO SANNA

Via Galileo Galilei 18 - 09047 Selargius (CA-IT).

E-mail: massanfungo@gmail.com

<https://orcid.org/0000-0002-3427-702X>

Associazione Micologica Bresadola Gruppo di Cagliari Sette Fratelli

MARIO MELIS

Via Sardegna 78, 09045 Quartu S. Elena (CA-IT).

E-mail: mariomelis02@gmail.com

<https://orcid.org/0009-0003-3961-6013>

Associazione Micologica Bresadola Gruppo di Cagliari Sette Fratelli

MARCO CASULA

Via Piave 21, 09048-Sinnai (CA-IT).

E-mail: casula.mek@gmail.com

<https://orcid.org/0009-0008-8898-5778>

Associazione Micologica Bresadola Gruppo di Cagliari Sette Fratelli

ARIADNE N.M. FURTADO

Dipartimento di Scienze Biomediche- Università di Cagliari- 09042 Monserrato (CA-IT).

E-mail: ariadnemf@gmail.com

<https://orcid.org/0000-0001-9596-7553>

ANDREA C. RINALDI

Dipartimento di Scienze Biomediche- Università di Cagliari- 09042 Monserrato (CA), Italia,

Associazione Micologica Bresadola Gruppo di Cagliari Sette Fratelli.

E-mail: rinaldi@unica.it

<https://orcid.org/0000-0002-9352-1037>

References

- ADAMČÍK S., CABOŇ M., EBERHARDT U., SABA M., HAMPE F., SLOVAK M., KLEINE J., MARXMUELLER H., JANČOVIČOVÁ S. & PEISTER D.H. – 2016: A molecular analysis reveals hidden species diversity within the current concept of *Russula maculata* (Russulaceae, Basidiomycota). *Phytotaxa* 270 (2): 71-88. (<https://doi.org/10.11646/phytotaxa.270.2.1>)
- ADAMČÍK S. & JANČOVIČOVÁ S. – 2012: Type studies in *Russula* subsection *Maculatinae*: *R. decipiens* and related taxa as interpreted by H. Romagnesi. *Cryptogamie Mycologie* 33: 411-420. (<https://doi.org/10.7872/crym.v33.iss4.2012.411>)
- ADAMČÍK S. & JANČOVIČOVÁ S. – 2013: Type studies in *Russula* subsection *Maculatinae* and affiliated taxa: four species as interpreted by Henri Romagnesi. *Sydowia* 65(2): 201-222.
- ADAMČÍK S., LOONEY B., CABOŇ M., JANČOVIČOVÁ S., ADAMČÍKOVÁ K. *et al.* – 2019: The quest for a globally comprehensible *Russula* language. *Fungal Diversity*, 99 (1): 369-449. (<https://doi.org/10.1007/s13225-019-00437-2>)
- ALTSCHUL S.F., GISH W., MILLER W., MYERS E.W. & LIPMAN D.J. – 1990: Basic local alignment search tool. *Journal of Molecular Biology* 215: 403-410. ([https://doi.org/10.1016/S0022-2836\(05\)80360-2](https://doi.org/10.1016/S0022-2836(05)80360-2))
- ALVARADO P., MANJÓN J.L., MATHENY P.B. & ESTEVE-RAVENTÓS F. – 2010: *Tubariomyces*, a new genus of *Inocybaceae* from the Mediterranean region. *Mycologia* 102 (6): 1389-1397.

- ALVARADO P., MORENO G. & MANJÓN J.L. – 2012: Comparison between *Tuber gennadii* and *T. oligospermum* lineages reveals the existence of the new species *T. cistophilum* (Tuberaceae, Pezizales). *Mycologia* 104 (4): 894–910. (<https://doi.org/10.3852/11-254>)
- ALVARADO P., CABERO J., MORENO-MATEOS D., VIZZINI A., ALONSO J., LEBEUF R., SIQUIER J.L. & VIDAL J.M. – 2021: Phylogenetic relationships among false truffle genera of *Paxillaceae* – *Alpova*, *Melanogaster*, *Neopalpova*, and *Paralpova*, gen. nov. *Mycologia* 113: 828–841. (<https://doi.org/10.1080/00275514.2021.1911552>)
- BERTAULT R. – 1978: Russules du Maroc. *Bulletin de la Société Mycologique de France* 94 (1): 5–31.
- BINCOLETTA A. & OSTELLARI C. – 2005: *Russula dryadicola* (Singer) Fellner & Landa, primo ritrovamento in Italia. *Rivista di Micologia* 48 (4): 301–307.
- BLUM J. – 1952: Quelques espèces collectives de Russules. II. *Bulletin de la Société Mycologique de France* 68: 224–257.
- BROTZU R. – 1993: *Guida ai funghi della Sardegna*, vol. 2. Archivio fotografico sardo.
- BUYCK B., HORAK E., COOPER J.A. & WANG X.H. – 2023: *Russula* subgen. *Cremeochochraceae* subgen. nov.: a very small and ancient lineage sharing with *Multifurca* (Russulaceae) an identical, largely circum-Pacific distribution pattern. *BioRxiv*: 2023-07. (<https://doi.org/10.1101/2023.07.26.550279>)
- BUYCK B., WANG X.-H., ADAMČÍKOVÁ K., CABOŇ M., JANČOVIČOVÁ S., HOFSTETTER V. & ADAMČÍK S. – 2020: One step closer to unravelling the origin of *Russula*: subgenus *Glutinosae* subg. nov. *Mycosphere* 11 (1): 285–304. (<https://doi.org/10.5943/mycosphere/11/1/6>)
- Buyck B., Zoller S. & Hofstetter V. – 2018: Walking the thin line... ten years later: the dilemma of above versus below-ground features to support phylogenies in the Russulaceae (Basidiomycota). *Fungal Diversity* 89(1): 267–292. (<https://doi.org/10.1007/s13225-018-0397-5>)
- CABOŇ M., LI G.J., SABA M., KOLAŘÍK M., JANČOVIČOVÁ S., KHALID A.N., MOREAU P.A., WEN H.A., PFISTER D.H. & ADAMČÍK S. – 2019: Phylogenetic study documents different speciation mechanisms within the *Russula globispora* lineage in boreal and arctic environments of the Northern Hemisphere. *IMA Fungus* 10: 1–16. (<https://doi.org/10.1186/s43008-019-0003-9>)
- CASULA M., MUA A. & SANNA M. – 2021: *Russula* rare o interessanti della Sardegna (Italia) 7. *Rivista Micologica Romana, Bollettino dell'Associazione Micologica Ecologica Romana* 113: 87–101.
- CROUS P.W., WINGFIELD M.J., BURGESS T.I., HARDY G., GENÉ J. *et al.* – 2018: Fungal Planet description sheets: 716–784. *Persoonia: Molecular Phylogeny and Evolution of Fungi* 40: 240–393. (<https://doi.org/10.3767/persoonia.2018.40.10>)
- CROUS P.W., WINGFIELD M.J., LOMBARD L., ROETS F., SWART W.J. *et al.* – 2019: Fungal Planet description sheets: 951–1041. *Persoonia: Molecular Phylogeny and Evolution of Fungi* 43: 223. (<https://doi.org/10.3767/persoonia.2019.43.06>)
- DAS K., MILLER S.L. & SHARMA J.R. – 2006: *Russula* in Himalaya 2: Four new taxa. *Mycotaxon* 95: 205–215.
- DAS K., GHOSH A., BHATT R.P., CHAKRABORTY D., HOFSTETTER V. & BUYCK B. – 2017: Fungal biodiversity profiles: 41–50. *Cryptogamie Mycologie* 38 (4): 527–547. (<https://doi.org/10.7872/crym/v38.iss4.2017.527>)
- EDLER D., KLEIN J., ANTONELLI A. & SILVESTRO D. – 2021: raxml GUI 2.0: a graphical interface and toolkit for phylogenetic analyses using raxML. *Methods in Ecology and Evolution* 12 (2): 373–377. (<https://doi.org/10.1111/2041-210X.13512>)
- EDGAR R.C. – 2004: MUSCLE: multiple sequence alignment with high accuracy and high throughput. *Nucleic Acids Research* 32 (5): 1792–1797. (<https://doi.org/10.1093/nar/gkh340>)
- FU H.Y., LI J.H., JI H.M., MAO N., LI T. & FAN L. – 2026: Morphological and phylogenetic evidence reveal nine new species of *Russula* (Russulaceae, Russulales) from Shanxi Province, North China. *Journal of Fungi* 12 (1): 78. (<https://doi.org/10.3390/jof12010078>)
- 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. (<https://doi.org/10.1111/j.1365-294X.1993.tb00005.x>)
- HONGSANAN S., HYDE K.D., BAHKALI A.H., CAMPORESI E., CHOMNUNTI P., EKANAYAKA H., GOMES A.M., HOFSTETTER V., JONES E.B.G., PINHO D.B., PEREIRA O.L., TIAN Q., WANASINGHE D.N., XU J.-C. & BUYCK B. – 2015: Fungal biodiversity profiles 11–20. *Cryptogamie, Mycologie* 36 (3): 355–380. (<https://doi.org/10.7872/crym/v36.iss3.2015.355>)

- JABEEN S., NASEER A. & KHALID A.N. – 2020: *Russula rubricolor* sp. nov. from Himalayan forests of Pakistan. *Mycotaxon* 135: 765-776. (<https://doi.org/10.5248/135.765>)
- Ji R.Q., XIE M.L., ZHOU J.J., MENG L.P., LI Y., ZHANG Z.H. & LI G.J. – 2022: *Russula rubiginosus* sp. nov. in *Russula* subsect. *Maculatinae* from Heilongjiang Province, Northeast China. *Phytotaxa* 575 (2):140-148. (<https://doi.org/10.11646/phytotaxa.575.2.3>)
- KIRAN M., MIROSLAV C., SENKO D., ABDUL N.K. & SLAVOMÍR A. – 2021: Description of the fifth new species of *Russula* subsect. *Maculatinae* from Pakistan indicates local diversity hotspot of ectomycorrhizal fungi in southwestern Himalayas. *Life* 11 (7): 662. (<https://doi.org/10.3390/life11070662>)
- KUMAR S., STECHER G., SULESKI M., SANDERFORD M., SHARMA S. & TAMURA K. – 2024: MEGA12: Molecular Evolutionary Genetic Analysis version 12 for adaptive and green computing. *Molecular Biology and Evolution* 41(12), msae 263. (<https://doi.org/10.1093/molbev/mbae263>)
- LI G.J., ZHANG C.L., ZHAO R.L. & LIN F.C. – 2018: Two new species of *Russula* from Northeast China. *Mycosphere* 9 (3): 431-443. (<https://doi.org/10.5943/mycosphere/9/3/1>)
- MADDISON W.P. & MADDISON D.R. – 2019: Mesquite: a modular system for evolutionary analysis. Version 3.61. (<https://www.mesquiteproject.org>)
- MALENÇON M.G. – 1944: Notes critiques sur quelques *Hymenomyces* d'Europe et d'Afrique du Nord. *Bulletin Trimestriel de la Société Mycologique de France*. 58 :14-56.
- MUA A. & CASULA M. – 2012: *Atlante dei funghi della Sardegna*. Grafica del Parteolla.
- MURRILL W.A. – 1940: Additions to Florida Fungi: 3. *Bulletin of the Torrey Botanical Club* 67: 145-154.
- MURRAY M.G. & THOMPSON W. – 1980: Rapid isolation of high molecular weight plant DNA. *Nucleic acids research* 8 (19): 4321-4326.
- Naveed M., Jabeen S., Ijaz H., Azeem M., Kha, M. & Ullah S. – 2025: *Russula iqbalii* sp. nov., Identified in *R.* subsect. *Maculatinae* from Pakistan, based on morphology, microscopy, and phylogeny. *Microscopy Research and Technique* 88 (4): 986-998. (<https://doi.org/10.1002/jemt.24761>)
- PARMASTO E. & PARMASTO I. – 1987: Variation of basidiospores in the *Hymenomyces* and its significance to their taxonomy. *Bibliotheca Mycologica* 115: 1-168. J. Cramer, Berlin & Stuttgart.
- ROMAGNESI H. – 1967: *Les Russules d'Europe et d'Afrique du Nord*. Bordas, Paris: 998 pp.
- RONQUIST F., TESLENKO M., VAN DER MARK P., AYRES D.L., DARLING A., HÖHNA S., LARGET B., LIU L., SUCHARD M.A. & HUELSENBECK J.P. – 2012: MrBayes 3.2: efficient Bayesian phylogenetic inference and model choice across a large model space. *Systematic Biology* 61: 539-542. (<https://doi.org/10.1093/sysbio/sys029>)
- SARNARI M. – 1998: *Monografia illustrata de genere Russula in Europa*. Tomo Primo. Vol. 1. A.M.B. Fondazione centro studi micologici, Vicenza.
- SARNARI M. – 2005: *Monografia illustrata del genere Russula in Europa*. Tomo secondo. A.M.B. Fondazione centro studi micologici, Vicenza.
- STAMATAKIS A. – 2014: raxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics* 30 (9): 1312-1313. (<https://doi.org/10.1093/bioinformatics/btu033>)
- STÖVER B.C. & MÜLLER K.F. – 2010: TreeGraph2: Combining and visualizing evidence from different phylogenetic analyses. *BMC Bioinformatics* 11: 7. (<https://doi.org/10.1186/1471-2105-11-7>)
- SULTANA K., RAUF C.A., RIAZ A., NAZ F., IRSHAD G. & UL HAQUE M.I. – 2011: Check list of agarics of Kaghan valley–1. *Pakistan Journal of Botany* 43 (3): 1777-1787.
- VIDAL J., ALVARADO P., LOIZIDES M., KONSTANTINIDIS G., CHACHUELA P., MLECZKO P., MORENO G., VIZZINI A., KRAKHMALNYI M. & PAZ A. – 2019: A phylogenetic and taxonomic revision of sequestrate *Russulaceae* in mediterranean and temperate Europe. *Persoonia, Molecular Phylogeny and Evolution of Fungi* 42: 127-185. (<https://doi.org/10.3767/persoonia.2019.42.06>)
- VILGALYS R. & HESTER M. – 1990: Rapid genetic identification and mapping of enzymatically amplified ribosomal DNA from several *Cryptococcus* species. *Journal of Bacteriology* 172 (8): 4238-4246. (<https://doi.org/10.1128/JB.172.8.4238-4246.1990>)
- WHITE T.J., BRUNS, T., LEE S. & TAYLOR J. – 1990: Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In *PCR Protocols: A Guide to Methods and Applications*; INNIS M.A., GELFAND D.H., SNINSKY, J.J., WHITE T.J., Eds.; Academic Press: New York, NY, USA: 315-322.