Russulales-2010
Scripta Botanica Belgica **51**: 64-76 (2013)

Russulaceae (Russulales, Agaricomycotina, fungi) in the thermophilous oak forests of W Slovakia

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Abstract. – The diversity and frequency of Russulaceae basidiomata (*Lactarius*, *Russula*) were studied in the phytocoenologically defined oak forests of three selected localities in the western part of Slovakia in years 2005–2009. Based on the ecological amplitude and the frequency, common and rare, as well as characteristic species were defined for each locality. Taxonomic problems within the species complexes of *Russula decipiens*, *Russula rutila* and *Russula globispora* are discussed.

Résumé. – Résumé. – Russulaceae (Russulales, Agaricomycotina, Fungi) dans les chênaies thermophiles de l'ouest de la Slovaquie. Durant les années 2005–2009, la diversité et la fréquence des carpophores de Russulaceae (*Lactarius*, *Russula*) ont été étudiées dans des forêts de chêne, définies d'un point de vue phytocoenologique, de trois localités sélectionnées de l'ouest de la Slovaquie. Sur base de l'amplitude écologique et de la fréquence, des espèces communes et rares, de même que des espèces caractéristiques, ont été définies pour chaque localité. Les problèmes taxonomiques dans les complexes d'espèces de *Russula decipiens*, *Russula rutila* et *Russula globispora* sont discutés. [Résumé ajouté par l'éditeur]

Key words. – Russula, Lactarius, biodiversity, ecology, taxonomy

INTRODUCTION

Thermophilous oak forests cover approximately 4 130 km^2 (8.3%) of the area of Slovakia according to the map of potential vegetation of Slovakia (Maglocký 2002). Their recent area is strongly reduced because of agricultural management, especially in the areas with suitable soil and terrain characteristics. The most distant natural oak forests occur in the mountains of the south-western part of Slovakia, namely in the Štiavnické vrchy Mts., Pohronský Inovec Mts. and Tríbeč Mts. Thermophilous oak forests occur there with SW, S or SE exposition and altitude from ca. 200 to 750 m. They are dominated by *Quercus* species, but *Carpinus betulus* is another native ectomycorrhiza-forming tree that grows there. The presence of other ectomycorrhizal trees is exceptional and caused by extreme values of some field characteristics, e.g. the occurrence of *Betula* on acid soil, *Populus tremula* on moist places, etc. Some management activities help preserving the natural character of these forests: trees are not cut in large areas; new trees are not planted, but grow from seedlings germinating naturally or from sprouts on stumps.

We have studied the diversity and frequency of two agaricoid genera of family Russulaceae Lotsy – *Lactarius* Pers. and *Russula* Pers. – in the phytocoenologically defined oak forests of nine selected localities in the western part of Slovakia, during the years 2005–2009. The aim of our study was (i) to compare Russulaceae diversity and basidiomata frequency on the selected localities, and (ii) to define selected groups of the genus *Russula* morphologically. Only some of our visits were fully successful with sufficient number of recorded species and collected basidiomata, because we did not foray in the suitable season during some years and/or climatic conditions were unfavorable. As our project is still running, we present the results only from three selected localities, with the most successful visits.

MATERIAL AND METHODS

Brief description of the studied sites

Taxa of *Lactarius* and *Russula* were collected in three selected localities of the W part of Slovakia – Obyce, Horné Majere and Sovia dolina – in the years 2005–2009 (for detailed characteristics of the localities see text below). All localities are situated in the area of Štiavnické vrchy stratovolcano which is mostly formed by andesites and tuffs in underground. The pH of soil depends on its position: Obyce and Sovia dolina are situated on a marginal part of the geological complex at lower altitudes, which is characterized by less acidic soil; Horné Majere situated in its central part has more acidic soil. All sites are managed forests with trees forming tree layer in approximately same age.

Obyce – With W to SW exposition, the locality is situated in the wide valley of Žitava River (ca. 1 km from the river) and has relatively smooth and plane relief.

Sovia dolina – The locality is in the valley of a stream on SE exposition, which has rough terrain with slopes of various angles and is dominated by a small hill in the centre. It is very heteromorphous; close to the stream, there is a flat terrain dominated by *Carpinus betulus*. Up to the hill, there is relatively steep slope, dominated by *Quercus*, disconnected by a small plateau. The locality is crossed by two forest roads without artificially improved surface.

Horné Majere – The locality is a terrace above a small stream, lined on one side by an almost vertical slope and on the opposite side by a forest road with natural surface and a meadow. It is located in the central part of the geological complex, at highest altitude. This locality is the smallest and the most homogeneous one.

Phytocoenological observations

Phytocoenological observations are in accordance with Zürich-Montpellier's school Braun-Blanquet 1964, Westhoff and van der Maarel 1978). Geographical coordinates are situated approximately in the middle of the localities. Nomenclature and abbreviations of habitats follow Stanová & Valachovič (2002). The nomenclature of vascular plants follows Marhold & Hindák (1998).

Identifications of fungi

Taxa of the genus *Lactarius* were identified according to monograph by Heilmann-Clausen et al. (1998); *Russula* taxa with several publications, in most cases books by Romagnesi (1967) and Sarnari (1998, 2005). Due to several taxonomic problems, some of our identifications remain still uncertain and limited to the level of a species complex. We labeled them as "cf." and treat them as insufficiently identified morphotypes with expected taxonomical value. Specimens are deposited in the herbarium SAV.

The frequency of basidiomata

The frequency of basidiomata was estimated in accordance with the following scale (cf. Adamčík et al. 2006):

- 1 = infrequent (1 collection with 5 and < basidiomata)
- 2 = moderately frequent (1 collection with 5 and > basidiomata **or** more collections with < than 5 basidiomata)
- 3 = frequent (more collections and at least 1 with > than 5 basidiomata)

RESULTS

Phytocoenological characteristics of the studied localities

Obyce – Thermophilous oak forest (*Quercus cerris* and *Q. petraea* agg.) grows on well de-

Table 1 – Characteristics of localities of research. + = lower, ++ = medium, +++ = higher

Characters / Locality	Obyce	Horné Majere	Sovia dolina
Coordinates (latitude/ longitude)	48°26´25´´N; 18°28´55´´E	48°22´55´´N; 18°54´01´´E	48°19´33´´N; 18°38´59´´E
Slope	W	S	SE
Altitude (m)	320-400	450-460	340-390
	+++	+	++
Acidity of soil	+	+++	++
Depth of soil	+++	+	++
Vegetation type	oak woods on deeper soil	oak woods with *Quercus cerris* on shallow soil	oak woods with *Carpinus betulus*, slightly nitrophilous
β-diversity of vegetation	++	+	+++
Diagnostic vascular plants	*Euonymus europaeus* *Rhamnus cathartica* *Lathyrus tuberosus* *Euphorbia cyparissias*	*Carex montana* *Coronilla vaginalis* *Genista tinctoria* *Lychnis viscaria* *Sorbus torminalis* *Tanacetum corymbosum*	*Ajuga reptans* *Carpinus betulus* *Cruciata glabra* *Galium schultesii* *Hieracium lachenalii* *Veronica officinalis* *Viola reichenbachiana*

veloped soils. Slightly exposed slopes (5-7°) oriented SW-W provide optimal conditions for oak trees. The height of the trees is about 25 m. The herbaceous layer is rich in species and covers around 80% of the surface. The shrub layer is poor; represented by young trees of *Acer campestre*, *Carpinus betulus* and *Prunus avium*, and several shrubs, e.g. *Euonymus europaeus*, *Rhamnus cathartica* and *Rosa canina* agg. Thermophilous species, e.g. *Astragalus glycyphyllos*, *Clinopodium vulgare*, *Fragaria viridis*, *Lychnis viscaria* and *Viola mirabilis* dominate the herb layer, but some mesophilous and nitrophilous taxa also occur, e.g. *Cruciata laevipes*, *Galium aparine* and *Torilis japonica*. The litter layer is thick; mosses rarely occur (table 1). Taxa of Russulaceae are listed in table 2.

Horné Majere – The flat ridge is covered by trees of *Quercus cerris* and partly also by *Q. polycarpa*. The height of the trees is about 20 m. Shrub layer is missing. The soil is stony and shallow, relatively light and sandy. Andesite bedrock influenced the acidic soil reaction. The litter of leaves is 2-3 cm thick; mosses (5%) grow around stones. Acidophilous taxa, e.g. *Hieracium lachenalii*, *H. murorum* and *Veronica officinalis*, occur together with species typical for neutral soils, e.g. *Coronilla vaginalis*, *Tanacetum corymbosum* or *Trifolium alpestre* (table 1). Taxa of Russulaceae are listed in table 2.

Sovia dolina – The light slope (5-7°) at the bottom of the wet valley. The dominance of *Carpinus betulus* indicates the nitrophilous character of the locality while *Quercus cerris* is only additional tree. Several stones (andesite) cover the locality. The cover of herb layer (40%) is evidently less dense than in the localities 1 and 2. In the herb layer, there are numerous taxa characteristic of beech forests, such as *Dentaria bulbifera*, *Galium schultesii*, *Mycelis muralis*, *Symphytum tuberosum* and of course juvenile saplings of *Fagus sylvatica* (table 1). Taxa of Russulaceae are listed in table 2.

Russulaceae diversity

Our data are based on four successful field excursions in the localities Obyce and Sovia dolina, and three successful field excursions in the locality Horné Majere. In total, we collected 80 taxa of Russulaceae (table 2). The highest diversity (50 taxa) was in Sovia dolina, which corresponds to beta diversity of vegetation and heterogeneity of the terrain serving different types of microhabitats (table 1). Relatively large number of taxa (45) was also recorded in

Table 2 – List of species collected in three studied localities. The numbers represent degrees of frequency defined in Material and Methods. **O** = Obyce; **HM** = Horné Majere; **Sd** = Sovia dolina.

	O	HM	Sd
Lactarius acerrimus Britzelm.	-	1	-
L. azonites (Bull.) Fr.	1	-	-
L. bertillonii (Neuhoff ex Z. Schaef.) Bon	2	2	-
L. circellatus Fr.	1	1	1
L. evosmus Kühner & Romagn.	1	2	1
L. fuliginosus (Fr.) Fr.	1	-	-
L. glaucescens Crossl.	-	1	2
L. chrysorrheus Fr.	3	1	2
L. piperatus (L.) Gray	2	-	2
L. quietus (Fr.) Fr.	2	-	1
L. serifluus (DC.) Fr.	-	1	-
L. vellereus (Fr.) Fr.	2	-	2
L. violascens (J. Otto) Fr.	-	1	-
L. volemus (Fr.) Fr.	1	-	1
L. zonarius (Bull.) Fr.	1	-	-
Russula acrifolia Romagn.	2	1	1
R. albonigra (Krombh.) Fr.	1	1	-
R. amoenolens Romagn.	1	-	-
R. anatina Romagn.	-	1	-
R. anthracina Romagn.	1	-	-
R. atropurpurea Krombh.	3	-	2
R. atropurpurea var. *dissidens* Zvára	-	-	1
R. aurea Pers.	1	1	1
R. aurora Krombh.	-	-	1
R. cf. *blumiana* Bon	-	-	1
R. borealis Kauffman	1	-	-
R. carpini Heinem. et R. Girard	1	1	1
R. chloroides (Krombh.) Bres.	-	-	1
R. cf. *convivialis* Sarnari	-	2	-
R. cf. *cremeoavellanea* Singer	1	-	-
R. cuprea Krombh.	1	1	1
R. curtipes F.H. Møller et Jul. Schaeff.	-	1	-
R. cyanoxantha (Schaeff.) Fr.	2	2	2
R. decipiens (Singer) Svrček	1	3	1
R. cf. *decipiens* (Singer) Svrček "small"	1	-	-
R. cf. *decipiens* (Singer) Svrček "spiny"	-	1	2
R. cf. *delica* Fr.	3	1	2
R. densifolia Gillet	-	-	1
R. foetens (Pers.) Fr.	-	2	-
R. cf. *galochroides* Sarnari	1	-	-
R. globispora (J. Blum) Bon	2	1	-
R. graveolens Romell	1	-	1
R. grisea (Pers.) Fr.	-	-	1
R. heterophylla (Fr.) Fr.	1	2	1
R. illota Romagn.	1	-	1
R. cf. *illota* Romagn.	-	1	-
R. cf. *laeta* F.H. Møller & Jul. Schaeff.	2	-	1
R. laurocerasi Melzer	2	1	2
R. lepida Fr.	3	3	3
R. lilacea Quél.	-	-	1
R. cf. *lividopallescens* Sarnari	1	-	1
R. luteotacta Rea	-	1	2
R. melliolens Quél.	-	-	2
R. cf. *melliolens* Quél.	-	1	1
R. minutula Velen.	1	-	-
R. nigricans (Bull.) Fr.	1	-	1
R. odorata Romagn.	1	1	1
R. olivacea (Schaeff.) Pers.	1	-	-
R. parazurea Jul. Schäff.	-	-	1
R. pectinatoides Peck	-	-	1
R. pelargonia Niolle	-	1	1
R. persicina Krombh.	-	2	-
R. cf. *poikilochroa* Sarnari	2	1	1
R. rhodomellanea Sarnari	-	-	2
R. risigalina (Batsch) Sacc.	2	1	1
R. romellii Maire	1	-	-
R. rutila Romagn.	1	-	-
R. cf. *rutila* Romagn.	-	-	1
R. sericulata Romagn.	-	-	2
R. solaris Ferd. et Winge	-	-	1
R. sororia (Fr.) Romagn.	-	-	2
R. cf. *sororia* (Fr.) Romagn.	1	-	1
R. tinctipes Melzer et Zvára	-	-	2
R. cf. *tinctipes* Melzer et Zvára	1	-	-
R. velenovskyi Melzer et Zvára	-	1	-
R. vesca Fr.	3	2	1
R. vinosobrunnea (Bres.) Romagn.	1	1	1
R. cf. *vinosopurpurea* Jul. Schaeff.	1	-	-
R. violeipes Quél.	-	1	-
R. virescens (Schaeff.) Fr.	1	-	1
R. cf. *zonatula* Ebbesen et Jul. Schäff.	-	-	1
∑ 80	45	37	50

Obyce, which is the locality with rather large area, deep soil and lowest acidity of soil. The lowest diversity (37 taxa) was in Horné Majere – the locality with the smallest area; the lowest beta diversity corresponds to its most homogeneous character and nutrient poor acidic soil.

In spite of similar underground and soil type of localities, 42 taxa were scored only in a single locality, which is more than half of all collected taxa (52.5%). This suggests that many of the taxa have relatively narrow ecological amplitude and are specific for certain

type of habitat. Among those taxa, 18 were collected only in Sovia dolina, 14 in Obyce and 10 in Horné Majere. Twenty two taxa were collected in two localities together and only 16 taxa in the three localities.

There are 15 species of *Lactarius* collected in all three localities. This small number is probably caused by the fact that we have not forayed in autumn, which is the most suitable period for *Lactarius* fructification. Accordingly, some common *Russula* species were not recorded because of their later phenology, e.g. we did not find *R. atropurpurea* in Horné Majere, that we did not investigate later in the season, when the species mostly grow.

Several collections were identified only to a species range ("cf."), due to taxonomic problems or because they did not correspond well to the descriptions of the literature. Such species are discussed bellow.

DISCUSSION

Ecological groups and frequency of collected taxa – In the text below, there are collected taxa grouped according to their distribution, frequency and host preferences. For evaluating the taxa, we used our experiences during this study in Štiavnické vrchy Mts., also published information from larger area of Slovakia (Adamčík et al. 2006, Kuthan et al. 1999) as well as literature data on distribution and occurrence of species in some areas of Europe (Romagnesi 1967, Sarnari 1998, 2005, Einhellinger 1994, Knudsen et al. 2008).

The terms "common" or "rare" usually refer to the literature or our experience at the larger scale of Europe. The terms "frequent = 3", "moderately frequent = 2" or "infrequent = 1" are defined above in the chapter "Material and Methods".

Frequent and common taxa – *Lactarius chrysorrheus*, *Russula atropurpurea* and *R. decipiens* – taxa known as preferably associated with oak trees – were frequent at least in one of the studied localities. Frequent taxa known from a wide range of habitats were *R. lepida*, *R.* cf. *delica* and *R. vesca*.

Other taxa known as common – Although some taxa were moderately frequent or infrequent in the localities, they are common, based on our experience from other localities of the studied area and literature data. Such taxa associated with oak were: *L. azonites*, *L. quietus*, *L. serifluus* and *R. atropurpurea* var. *dissidens*; associated with *Carpinus betulus* and *L. circellatus* was infrequent. Common but moderately frequent taxa, with wide range of host trees, were: *L. piperatus, L. vellereus, R. cyanoxantha*, *R. foetens*, *R. heterophylla*, *R. laurocerasi* and *R. risigallina*; infrequent were: *R. aurea*, *R. pectinatoides, R. velenovskyi* and *R. virescens*. Taxa associated preferably with beech and known as common in the literature were infrequent in the studied localities: *R. aurora, R. chloroides*, *R. nigricans*, *R. olivacea*, *R. romellii* and *R. solaris*.

Uncommon taxa – Several species are known in the literature as well distributed but uncommon or only locally common. Such uncommon taxa – known as associated preferably with oak – were moderately frequent or infrequent also in the studied localities. Moderately frequent taxa collected in all three localities were *R. poikilochroa* and *R. odorata*; in two localities *L. evosmus*, *R.* cf. *decipiens* with spiny spores, *R. graveolens*, *R. pelargonia* and *R. vinosobrunnea*; only in one locality *R. persicina* and *R. rhodomellanea*. Infrequent species recorded only in one locality were *R. amoenolens*, *R. anatina* and *R. parazurea*. *R. carpini* – the species associated with *Carpinus betulus* – was collected in all studied localities, but it was infrequent. *R. sericatula* is another species restricted to *Carpinus betulus* according to our field observations; it was collected in two localities and it was moderately frequent in Sovia dolina. According to our experience from other localities, *R. sericatula* is also frequent as *R. carpini*, but in the literature it is considered as rare. *Russula acrifolia* was the only uncommon species with a wide host preference that was collected in all three localities. Uncommon species with wide host preference collected in two studied localities were: *L. bertillonii*, *L. glaucescens*, *L. volemus*, *R. albonigra*, *R. globispora* and *R. illota*. *R. melliolens* is an uncommon species that was collected in Sovia dolina only and was moderately frequent. Infrequent species with wide host preference collected only in one locality were: *L. fuliginosus*, *R. curtipes*, *R. densifolia*, *R. grisea*, *R. lilacea* and *R. violeipes*.

Rare taxa – Several taxa are known in literature as rare and they were also infrequent in the

studied localities. *R.* cf. *lividopallescens* and *R. cuprea* – species associated with oak – were collected in two of the studied localities. All other oak associated rare taxa were collected only in one locality: *L. violascens*, *L. zonarius, R. rutila* and *R. zonatula*. Rare taxa known from various types of habitats were collected only in one locality: *R. anthracina*, *R. borealis* and *R. minutula*.

Insufficiently identified taxa – As discussed below, we have not identified several taxa sufficiently. Most of such not identified taxa are infrequent in the localities: *R.* cf. *blumiana*, *R.* cf. *convivialis*, *R.* cf. *decipiens* with small basidiomata, *R.* cf. *galochroides, R.* cf. *illota*, *R.* cf. *melliolens, R.* cf. *rutila, R.* cf. *tinctipes* and *R.* cf. *vinosopurpurea*.

We have also collected, in two of the studied localities, several specimens of *R. borealis* and *R.* cf. *laeta*, species which seem to be moderately frequent; however the interpretation of frequency is little precise because of uncertain taxonomical concept and taxa delimitation in this group.

Taxa associated with forest roads – A few species were collected only on disturbed soil near forest roads. Especially the locality Sovia dolina is typical with forest road crossings, where *R. luteotacta*, *R. sororia* and *R. tinctipes* were moderately frequent. *R. luteotacta* was collected together with *L. acerrimus* on forest road in Horné Majere.

CONCLUSION

Which species are typical?

All three studied localities have several common features. The most important are: similar altitude, exposition, volcanic underground and forests dominated by oak trees. Despite of this, only a few taxa, among the total number of 81, wwere collected in all three localities.

The most frequent species present in the three localities were: *Lactarius chrysorrheus*, *Russula atropurpurea*, *R. decipiens*, *R.* cf. *delica*, *R. lepida* and *R. vesca*. There are also several taxa which were collected in all three localities but were not so abundant: *R. acrifolia*, *R. aurea*, *R. carpini*, *R. cyanoxantha*, *R. heterophylla*, *R. laurocerasi*, *R. odorata*, *R.* cf. *poikilochroa* and *R. risigallina*.

Taxa relatively frequent only in one locality can be specific for this locality. In Horné Majere, *L. evosmus*, *R. foetens* and *R. persicina* were relatively frequent. Despite of larger species diversity in Obyce, only two taxa were relatively frequent: *R. globispora* and *R.* cf. *laeta*. The highest number of species which can be considered as specific for one locality, was recorded in Sovia dolina: *L. glaucescens*, *R.* cf. *decipiens* with spiny spores, *R. melliolens*, *R. rhodomelanea* and *R. sericatula*.

Interesting is also the absence of relatively frequent species only in one of the studied localities. *L. piperatus* and *L. vellereus* were not collected in Horné Majere, but were relatively frequent in both other localities. *L. bertillonii* was not collected in Sovia dolina, but was relatively frequent in two other localities.

In our opinion, the presence or absence of taxa scored as rare and infrequent is not useful for specification of certain type of habitat in our case, because of limited number of successful visits and limited number of localities included in this study. More distinct differences in species diversity among the localities are presented by absence, in one locality, of taxa which are frequent and common in other of the compared localities.

Table 3 – Frequency of the taxa of *Russula* sect. *Ingratae* collected in three studied localities of Štiavnické vrchy Mts. The numbers represent degrees of frequency as defined in Material and Methods.

Obyce		**Horné Majere**		**Sovia dolina**	
Russula amoenolens	1	*Russula foetens*	2	*Russula* cf. *sororia*	1
Russula illota	1	*Russula* cf. *illota*	1	*Russula sororia*	2
Russula laurocerasi	2	*Russula laurocerasi*	1	*Russula laurocerasi*	2
				Russula pectinatoides	1

Differences in *Russula* diversity among studied localities – example of *Russula* sect. *Ingratae* (Quél.) Maire

In the text above, we mention the numbers of taxa occurring i) in one single locality; ii) in two localities; iii) in all three localities. These numbers do not show differences between diversity of *Russula* and *Lactarius* in details. Taxa of some infrageneric groups are more ubiquitous, while some groups of related species may be more sensitive to the ecological conditions. A good example of group showing high differences in diversity is *Russula* subsect. *Foetentinae* (Melzer & Zvára) Romagn. (table 3). Only one species *R. laurocerasi* was collected in all three localities. Each locality has at least two taxa that were not collected in any other. It is also interesting that *R. subfoetens*, the common species in Slovakia (Adamčík et al. 2006, Kuthan et al. 1999), was collected in none of the studied localities; even if it was observed in several other localities in the studied area.

Taxonomic notes on some species complexes

When we used the recent keys for *Russula* identification (Romagnesi 1985; Sarnari 1998, 2005, Bon 2002, 2003; Knudsen et al. 2008) we encountered several taxonomic problems. We present such discrepancies between our observations and the literature on example of the collections in range of *R. decipiens* and *R. rutila*. All included taxa share some common

Figure 1 – Basidiomata of typical form of *Russula decipiens* (SAV F-1359, Obyce, Pohronský Inovec Mts., Slovakia). Photo Per Marstad.

Figure 2 – Basidiomata of *Russula* cf. *decipiens* with spiny spores (SAV F-1512, Prenčov, Štiavnické vrchy Mts., Slovakia). Photo Per Marstad.

Table 4 – Comparison of three morphotypes recognized in range of *R. decipiens*.

Characters compared	***R. decipiens* typical**	***R.* cf. *decipiens* with spiny spores**	***R.* cf. *decipiens* with small basidiomata**
Cap color	discolored in centre	bright red all over	discolored on spots near centre
Cap size	moderately large to large	moderately large to large	small
Spore ornamentation	moderately prominent	prominent	low
Width of pileocystidia	wide	wide	narrow
Ecology	grassy exposed places	grassy exposed places	shadowy places, humus rich soil

characters: they have predominantly red pileus, yellow spore print, acrid taste, firm flesh and sulfovanilline positive pileocystidia.

***Russula decipiens* (Singer) Svrček –** The species is defined by red cap, yellow spore print, acrid taste, unchanging flesh, uni-celled clavate pileocystidia with strong sulfovanillin reaction, absence of incrustation in pileipellis and subglobose spores with moderately prominent warts connected to form chains. It is one of the most common species in thermophilous oak forests of Slovakia. Although our collections exhibit all the typical characters of *R. decipiens*, we observed a large variability in the characters which is not sufficiently described in the literature. Accordingly, we recognized three morphotypes; the differences among these morphotypes are presented in table 4 and on figures 1-6.

Figure 3 – Basidiomata of *Russula* cf. *decipiens* with small basidiomata (SAV F-1503, Bohnický Roháč, Štiavnické vrchy Mts., Slovakia). Photo Per Marstad.

Table 5 – Comparison of two morphotypes recognized in range of *R. rutila*.

Microscopical characters	***R. globispora* typical**	***R.* cf. *rutila***
Height of spore ornamentation	up to 1 µm	1.2-1.4 µm
Connections on spores ornamentation	chained warts	spines connected by lines
Hyphal endings in pileipellis	blunt	acute

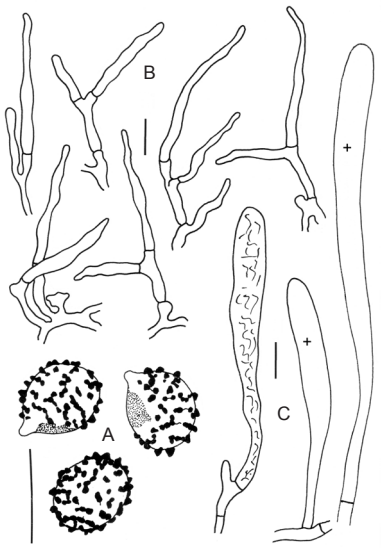

Figure 4 – Microscopical structure of typical form of *Russula decipiens* (SAV F-1346, Obyce, Pohronský Inovec Mts., Slovakia). A: spores, B: hyphal endings in pileipellis near the cap margin, C: pileocystidia with content indicated in one element as seen in Congo red, content of other pileocystidia is indicated by a plus sign (+). Scale bar = 10 μm.

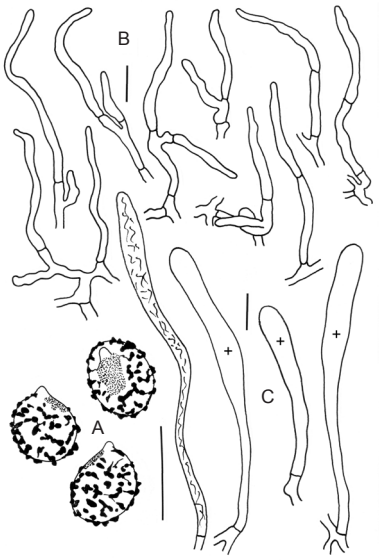

Figure 6 – Microscopical structure of *Russula* cf. *decipiens* with small basidiomata (SAV F-991, Betlehem, Tríbeč Mts., Slovakia). A: spores, B: hyphal endings in pileipellis near the cap margin, C: pileocystidia with content indicated in one element as seen in Congo red, content of other pileocystidia is indicated by a plus sign (+). Scale bar = 10 μm.

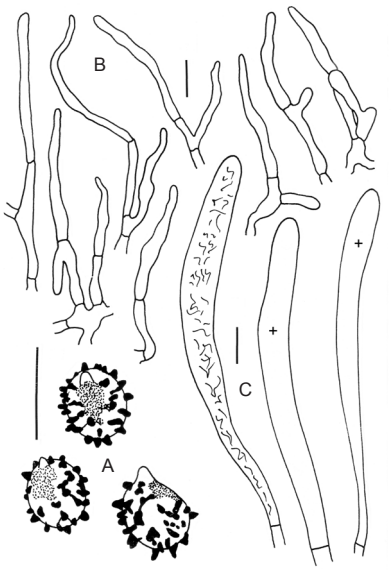

Figure 5 – Microscopical structure of *Russula* cf. *decipiens* with spiny spores (SAV F-1022, Sovia dolina, Štiavnické vrchy Mts., Slovakia). A: spores, B: hyphal endings in pileipellis near the cap margin, C: pileocystidia with content indicated in one element as seen in Congo red, content of other pileocystidia is indicated by a plus sign (+). Scale bar = 10 μm.

Russula rutila **Romagn. –** This species has small and in adult fragile basidiomata with very acrid taste; it is well defined with incrusted sulfovanilline positive pileocystidia. Both Sarnari (2005) and Romagnesi (1967) regarded as typical collections with spore warts not exceeding 1 μm height. Besides the variable height of ornamentation we observed also various hyphal endings in pileipellis. These differences correspond to two morphotypes which are compared in table 5 and presented on figures 7-9.

Russula globispora **(J. Blum) Bon –** The species has paler, almost pure white cap with some traces of pinkish or reddish tints on the margin, sometimes also with red margin and discolored centre. When bruised and/or adult, its flesh and gills turn rusty. On the stipe and cap surface, there are often rusty spots which are mostly apparent towards the base of the stipe. Pileocystidia are multi-celled and not incrusted. Spores are subglobose, with isolated spines and in average usually larger than 10 μm. Among our collections, we observed some variability in spore size, branching of hyphae in pileipellis and septation of pileocystidia. We recognized

Figure 7 – Basidiomata of *Russula* cf. *rutila* with low spore ornamentation (SAV F-1497, Bohunický Roháč, Štiavnické vrchy Mts., Slovakia). Photo Per Marstad.

three morphotypes which are compared in the table 6. One of the morphotypes with smaller spores reminds *R. vinosopurpurea* Jul. Schäff. However, our collections of this morphotype did not differ from those of typical *R. globispora* in the field; and *R. vinosopurpurea* is interpreted as lacking spots on the cap and flesh indistinctly turning rusty (Knudsen et al. 2008, Sarnari 2005).

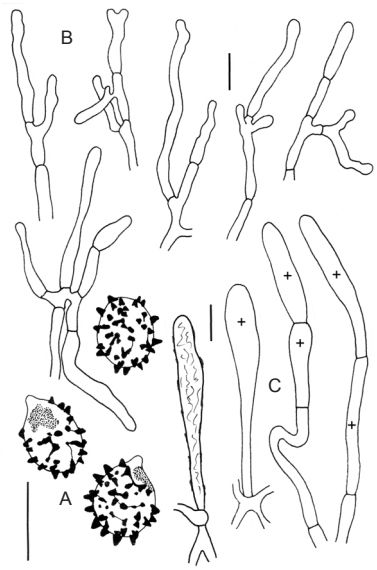

Figure 8 – Microscopical structure of *Russula rutila* (SAV F-1353, Obyce, Pohronský Inovec Mts., Slovakia). A: spores, B: hyphal endings in pileipellis near the cap margin, C: pileocystidia with content indicated in one element as seen in Congo red, content of other pileocystidia is indicated by a plus sign (+). Scale bar = 10 µm.

Other uncertain identifications

Due to several taxonomic problems, some of our identifications are uncertain and, therefore, labeled as "cf." In the text below we discuss differences between characters observed in our collections and those described in the literature.

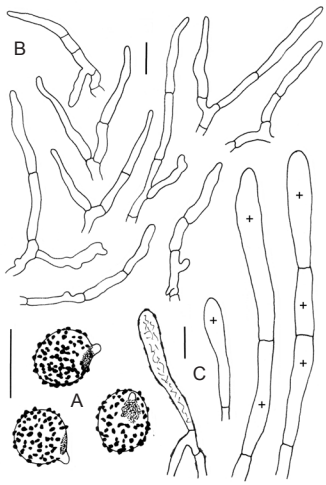

Figure 9 – Microscopical structure of *Russula* cf. *rutila* with low spore ornamentation (SAV F-1568, Sovia dolina, Štiavnické vrchy Mts., Slovakia). A: spores, B: hyphal endings in pileipellis near the cap margin, C: pileocystidia with content indicated in one element as seen in Congo red, content of other pileocystidia is indicated by a plus sign (+). Scale bar = 10 µm.

Table 6 – Comparison of three morphotypes recognized in range of *R. globispora*.

Characters compared	*R. globispora* typical	*R.* cf. *globispora*	*R.* cf. *vinosopurpurea*
Spore size	mostly longer than 10 µm	mostly longer than 10 µm	mostly shorter than 10 µm
Spore ornamentation	very prominent	moderately prominent	very prominent
Pileocystidia septation	mostly 1-2 celled	mostly 2 and more celled	mostly 1-3 celled
Branching of hyphal endings in pileipellis	subapical cells unbranched	subapical cells mostly branched	subapical cells unbranched or branched

***Russula* cf. *blumiana* Bon** – Two collections (SAV F-1567 and SAV F-2296) from the locality Sovia dolina have some characters typical for *R. blumiana*. As described by Sarnari (2005), the cap is yellow with reddish margin, spore print is yellow, taste not strongly acrid, spores moderately large with chained warts which are occasionally connected with fine lines and only 0.8–1 µm high, pileocystidia uni-celled and broadly clavate. Under the microscope, it reminds *R. decipiens*, but it has more line connections on spores. Although Sarnari (2005) did not mention any incrustation on cystidia, we observed distinct incrustation on the base of pileocystidia. Sarnari (2005) included the species in the supplement at the end of the second part of his monograph on *Russula*; his description of the species is very brief and the line drawings of pileocystidia show no basal septa; he maybe overlooked the incrustation. Our collections are also similar with *R. quercilicis* Sarnari, but the terminal part of the pileocystidia is not as inflated as described by Sarnari (1998).

***Russula* cf. *convivialis* Sarnari –** We collected this fungus repeatedly in the locality Horné Majere (SAV F-2342, SAV F-3103) under an old oak standing at locality edge near the forest road. The soil of this place was disturbed and with some humid spots. *Russula convivialis* is a typical member of *R.* subgenus *Tenellula* Romagn. with its small fragile basidiomata, darker ochraceous spore print and mild flesh. Macroscopically, our collections remind photos of *R. convivialis* by Sarnari (2005), with typically distant and somewhat anastomosed gills, color of caps and brownish discoloration restricted to the base of stipe. Sarnari (2005) also described similar structure of pileipellis, irregular pileocystidia with variable shape, size and number of cells and slender attenuated hyphal endings. We have also observed in pileipellis the brownish necropigment which is mentioned by Sarnari. Spore ornamentation consists of low warts which are connected in chains or, occasionally, by line connection, but are more likely zebrate than reticulate. However, our spores are narrowly ellipsoid and larger, c. 8.5-9.5 × 6.5-8 µm, Sarnari described spores of *R. convivialis* as ovoid and up to 8.8 µm long. Sarnari knows the species only from three localities of deciduous oak forests in Italy which, together with the differences observed in spore size and ornamentation does not allow us to consider our collections conspecific with *R. convivialis*.

***Russula* cf. *cremeoavellanea* Singer –** *R. cremeoavellanea* is a species with pale yellow-ochraceous cap, mild flesh with tendency to become grayish, yellow spore print, spores with isolated spines, and incrusted narrow pileocystidia with weak sulfovanilline reaction. The characters of our collection from Obyce (SAV F-1379) agree with those described by Romagnesi (1967) or Sarnari (2005). However, these two publications mention *Betula* as the host tree. As birch was not present in the locality, our collection needs additional detailed comparison to confirm its conspecificity with *R. cremeoavellanea*.

***Russula* cf. *delica* Fr.** – Delimitation of *R. delica* and *R. chloroides* (Krombh.) Bres. is based on central depression of cap, length of stipe, width and density of gills and prominence of spines on spores (Romagnesi 1967, Sarnari 1998, Knudsen et al. 2009). As some collections share characters of both species, there are several varieties of both species recognized in the literature (e.g. Sarnari 1998). We treated

as *R.* cf. *delica* all our collections which did not exhibit characters typical for *R. chloroides* (narrow crowded gills, deeply depressed cap, longer stipe and more prominent spore ornamentation). In our opinion, the group needs critical taxonomical revision based on type studies and molecular support.

***Russula* cf. *galochroides* Sarnari** – It is a species from *Russula* subsect. *Griseinae* Jul. Schäff. with cream spore print, mild flesh, spores without suprahilar spot and scattered pileocystidia. The species is typical with white cap, narrow hyphal endings in pileipellis and ellipsoid spores with distinct warts which are connected by numerous line connections (Sarnari 1998). Our collection from Obyce (SAV F-1383) has terminal cells in pileipellis near margin very narrow (up to 4 μm wide) and spores with almost isolated warts. Another similar species of the section with white cap is *R. galochroa* (Fr.) Fr. that has spores with isolated warts, but the hyphal endings in pileipellis are much wider (3.5-9.0 μm).

***Russula* cf. *illota* Romagn. –** One collection from Horné Majere (SAV F-2276) has spores very similar to those of *R. illota*, but its small basidiomata lack the distinct spots on gills and stipe that are typical of this last species. The spines are weakly crested and with frequent line connections forming an almost complete reticulum. Romagnesi (1967) described the form of crests as very variable among collections; therefore, it is possible that our collection is only a form of *R. illota* without developed rusty spots on gill edge and stipe surface.

***Russula* cf. *laeta* F.H. Møller & Jul. Schäff. –** Romagnesi (1967) recognized several species in range of *R. laeta,* with red cap, yellow spore print, isolated spines and incrustation on pileocystidia. However, all these taxa accepted by Romagnesi are treated as varieties of *R. laeta* in recent publications (Knudsen et al. 2009, Sarnari 2005). We collected several specimens especially in the locality Obyce. Our collections show large variability in spore ornamentation and form of pileocystidia, which suggests reliability of Romagnesi's classification. For example, the collection SAV F-1392 has more prominent spines on spores and SAV F-1572 has more connected spines on spores. Most collections correspond to typical *R. laeta* as described by Sarnari (2005) and Knudsen et al. (2009).

***Russula* cf. *lividopallescens* Sarnari** – Our collections from Sovia dolina (SAV F-1571) and Obyce (SAV F-1378) are very close to the description of *R. lividopallescens* by Sarnari (2005). They have white cap with pink margin, yellow spore print, mild taste, numerous clavate pileocystidia, cylindrical hyphal endings in pileipellis near the margin of pileus and spores with chained warts forming an incomplete reticulum. Our collections have pileocystidia 8-11 μm wide, but Sarnari described only 4-7 μm wide pileocystidia for the species. Sarnari did not describe sulfovanillin reaction of the pileocystidia, but he classified the species in *Russula* subsect. *Integriforminae* Bon, group of *R. romellii* which is characterized by scattered inconspicuous pileocystidia with weak sulfovanillin reaction. Our collections have relatively numerous and very conspicuous pileocystidia with strong sulfovanilline reaction and remind *R. decipiens*.

***Russula* cf. *melliolens* Quél. –** We have two collections (SAV F-1602 and SAV F-2366) with paler discolored caps, which are untypical for *R. melliolens*. The spores of the first collection from Sovia dolina correspond to the typical *R. melliolens*, but the caps are uniformly ochraceous and lack any trace of red. The second collection from Horné Majere has less discolored cap, more prominent spines on spores and narrower spores, which may correspond to *R. dryophila* Sarnari.

***Russula* cf. *poikilochroa* Sarnari** – This taxon is a typical member of *Russula* sect. *Atropurpurinae* Romagn. It has a purple cap with greenish, grayish or paler shades, acrid taste and white spore print. It differs from *R. atrorubens* Quél. by wider spores, and from *R. fragilis* (Pers.: Fr.) Fr. in smaller spores. Spores are similar to *R. poikilochroa*, but our collections differ by the absence of fruity or pelargonium smell and distinctly acrid taste. This taxon was collected also in the Vihorlat Mts. (E Slovakia); it is described and discussed in detail by Adamčík et al. (2006).

***Russula* cf. *sororia* (Fr.) Romell** – One collection from Sovia dolina (SAV F-1607) has completely white cap with rusty spots, which is untypical for *R. sororia*. As characters of spores

as well as other characters fit well to this species, we consider our collection a white form of *R. sororia*. Such a white form has never been described in the literature.

***Russula* cf. *tinctipes* J. Blum ex Bon** – It is a very distinct species with yellow spore print, beautiful bright red cap, mild taste, indistinct pileocystidia without incrustation, and subglobose spores with fine low warts occasionally connected by fine lines. One of our collections from Obyce (SAV F-1387) has all characters similar to the description by Romagnesi (1967), but we observed also distinct incrustation on the base of the pileocystidia. In some collections of *R. tinctipes*, Sarnari (2005) also observed such incrustation, but he treated the presence or absence of such incrustation as included in the variability of the species.

***Russula* cf. *zonatula* Ebbesen & Jul. Schäff.** – The species is described from Denmark and Sarnari (2005) synonymised it with *R. rhodella* E.-J. Gilbert. Our collections from Sovia dolina (SAV F-1008, SAV F-1014) correspond to the description and illustration by Galli (1996) and Pidlich-Aigner (2004), but the cap color is paler as illustrated by original authors (Schaeffer 1933). Moreover, the species was described from beech forests. According to observations by Juhani Ruotsalainen (pers. comm.), the spores of authentic material are similar to those observed on our collections.

ACKNOWLEDGEMENTS

We are very grateful to Per Marstad (Norway) who kindly gave us permission to publish the photos of *Russula* species he took during our joint field excursions in Slovak oak forests. Viktor Kučera is acknowledged for accompanying us during the field excursions. The Slovak Grant Agency VEGA (grant no. 02/0140/08 and no. 02/0028/11) supported this study.

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