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Diversity and Distribution of *Russula* in India with Reference to Central Indian species

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ABSTRACT

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Agaricomycetes, Distribution, Ectomycorrhiza, *Russula*, Sal forest

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An account of mushrooms belonging to genus *Russula* reported from different part of India is given. Total 124 species of the genus were compiled from literature with their records of habitat, distribution and references. *Russula* species were recorded from 13 states of India. Uttarakhand represent the maximum diversity of *Russula* species (57) followed by Kerala (17), Himachal Pradesh (13), West Bengal (13), Jammu and Kashmir and Sikkim 10 species each, Madhya Pradesh (6) and Nagaland (6). Other states from where species recorded include Meghalaya (3), Punjab (2) while Maharashtra and Tamil Nadu are represented by only one species each. Six species of *Russula* namely: *R. adusta*, *R. cinerella*, *R. congoana*, *R. delicula*, *R. leelavathyi* and *R. michiganensis* were recorded and described for the first time from Sal forest of central India (Madhya Pradesh and Chhattisgarh). These fungi are known to form ectomycorrhizal association with sal trees. Among them some species are edible and sold in the local market during rainy season.

Introduction

Members of the *Russula ceae* are characterized by their fleshy and often brightly coloured fruiting bodies with prominent lamellae, a heteromerous context traversed by conducting hyphae, warted, light-colored amyloid basidiospores which exhibit various types of ornamentations. *Russula ceae* was established by Roze in 1876 and it is one of the largest ectomycorrhizal families. The members of this family form ectomycorrhizal association in different angiosperm and gymnosperm trees like *Abies*, *Acer*, *Betula*, *Diospyros*, *Hopea*, *Larix*, *Myristica*,

Rhododendron, *Shorea*, *Tsuga*, *Vateria*, etc. The genus is represented by about 130 taxa from India (Das *et al.*, 2014). North-western subtropical and temperate forests of Himalayan region of Uttarakhand state are represented most *Russula* species. There is a large gap that exists with respect to knowledge diversity of macro-fungi in India. For proper planning and management of forests and the conservation of their biodiversity, characterization, systematics and ecology of these macro-fungi is essential. Many *Russula* species for example, *R. crustosa*, *R. lutea*, *R. olivacea*, *R. parvovirescens*, *R. senecis*, *R. virescens* are edible (Atri *et al.*, 2010; Das *et*

al., 2002; Bhatt and Lakhanpal, 1988a, b; Kalita *et al.*, 2016; Khatua *et al.*, 2015; Semwal *et al.*, 2014). The present paper provides a comprehensive database of diversity of *Russula* species in India. Six species of *Russula* from central India are also described. Edible species are also listed.

Materials and Methods

Specimens of mushrooms were collected from Madhya Pradesh and Chhattisgarh during rainy seasons. Some parts of collected samples were preserved in 70% alcohol just after collection for microscopic study. The fruit bodies of fungi were dried under the sun or in the wooden box lighted with 100W electric bulb. Microscopic slides were prepared by using stain, mountant, clearing and softening chemicals. Slides were observed under advanced research microscope (Leica, Germany) using 5x, 10x, 20x, 40x objectives and 10x and 15x eyepieces.

Observations under phase contrast and dark field were also made whenever required. Photomicrography was done with the help of a digital camera (make, Leica) attached to the advanced microscope. Identification of fungi has been done with the help of published literature, monographs, books, keys, etc. (Abraham *et al.*, 1980; Atri and Kour, 2003; Atri and Saini, 1986, 1990a; 1990b; 1990c; Atri *et al.*, 1992, 1997, 2016; Berkeley, 1851, 1856, 1876; Bhatt *et al.*, 1995, 2007; Buyck and Atri, 2011; Chaudhary and Tripathy, 2016; Crouset *et al.*, 2016; Das, 2013; Das and Sharma, 2001, 2003, 2005b; Das *et al.*, 2002c; 2005a, 2006, 2008; 2010; 2013a,b; 2014; 2017; Dhancholia, 2011; Dutta *et al.*, 2015; Farooq *et al.*, 2013; Ghosh and Das, 2017; Hedawoo, 2010; Joshi *et al.*, 2012; Kaure *et al.*, 2011; Kumar *et al.*, 2014; Manimohan and Deepna, 2011; Mohanan, 2011, 2014; Natarajan and Raman, 1983; Pavithra *et al.*, 2017; Pradeep and Vrinda, 2007, 2010;

Rawla, 2001; Rawla and Sarwal, 1983; Romagnesi, 1945; Saini *et al.*, 2010; Saini and Atri, 1981, 1984, 1989a, b; Saini *et al.*, 1988, 1989; Sarwal, 1984; Sathe *et al.*, 1980; Shaffer, 1962; Shajahan and Samajpati, 1995; Sharma and Das, 2002; Varghese *et al.*, 2010; Vishwakarma *et al.*, 2012; Vrinda *et al.*, Vrinda 1997a, b; Watling and Gregory, 1980))

Results and Discussion

Taxonomic description

Russula adusta (Pers.) Fr. (Figures 1-4)

= *Agaricus adustus* Pers. = *Omphalia adusta* Pers.

Basidiome medium to large sized. Pileus 5-8cm diam, with a deep depression at centre at maturity; margin in rolled when young, becoming uplifted when fully expanded; surface dull white becoming grayish white then dark brown and finally black on handling or aging, non-striate. Lamella adnate, white turning black on handling, more or less crowded with lamellulae of different lengths, sometimes bifurcated close to the stipe; edge smooth, entire. Stipe 4-6 x 1-2cm, central equal, solid; surface chalky white, immediately turning black when handled, odour not distinctive. Context white discolouring blackish on exposure, heteromerous with nests of sphaerocytes. Spores 6-8 x 5-7µm globose to broadly ovoid, strongly amyloid with an ornamentation of prominently verrucose and connective forming a partial reticulum; supra-hilar plage in amyloid. Basidia clavate 31-46 x 7-8µm, tetrasporate. Lamella-edge sterile with crowded macrocystidia 59-80 x 6-8µm, clavate, mucronate with oleaginous refractive contents discolouring black, pleurocystidia similar. Haymenophoral trama heteromorphous with sphaerocytes. Pileipellis an exocutis devoid of dermatocystidia. Caulocystidia, 30-45x5-7µm.

Collection examined

Mycorrhizal on sal (*Shorea robusta*), Amarkantak-Achanakmar Biosphere Reserve, Madhya Pradesh and Chhattisgarh, 24/07/2012, Mycology Herbarium, Tropical Forest Research Institute, Jabalpur TF 2789.

***Russula cinerella* Pat. (Figures 5-7)**

Basidiomes are small to medium sized, pileus 4-7cm diam, convex to applanate, depressed at the centre, surface light grey to brownish orange, silky, dry smooth, margin undulate and incurved. Lamellae adnate, white becoming pale yellowish, crowded up to 5mm wide. Stipe 4-6 x 1.0-1.4cm, cylindrical, solid; surface white. Context up to 5mm thick, white becoming pinkish brown on exposure. Spore-print pale cream. Spores 5-8 x 5-7.5µm, subglobose to ovoid, hyaline, ornamented with very fine, amyloid. Basidia 34-40 x 8-10µm, clavate, bearing 4 sterigmata. Lamella-edge heteromorphous. Cheilocystidia 27-35 x 10-12µm, cylindrical to fusoid, often apically constricted or capitate, hyaline, with numerous refractive contents. Pleurocystidia 31-41 x 8-9µm, sinuous, lanceolate-fusoid, often constricted or mucronate, with abundant granular contents. Hymenophoral trama irregular and intermixed. Pileal surface a disrupted trichodermium subtended by a broad hypodermium. Trichodermium of more or less erect hyphae, 2-3.5 µm diam., sometimes agglutinated into fascicles; dermatocystidia absent. Hypodermium 110-130 µm thick, of tightly interwoven hyphae, slightly agglutinated.

Collection examined

Mycorrhizal on sal, Amarkantak-Achanakmar Biosphere Reserve, Madhya Pradesh and Chhattisgarh, 24/07/2012. Mycology Herbarium, Tropical Forest Research Institute, Jabalpur TF 2788.

***Russula congoana* Pat. (Figures 8-11)**

Basidiome small to medium sized. Pileus 4-5.5 cm. diam, at first convex then expanded with slight central depression; surface uniformly pastel red to red, smooth finely striate at the margin, sticky. Lamellae adnate, white to pale cream exceeding the gills, up to 5mm wide, close; edge entire, concolourous to the sides. Context thin white. Stipe 2.5-3.5cm x 7-12 mm, central cylindrical equal or slightly broader at the base, solid becoming stuffed and hollow surface creamy white with a pinkish tint at the base, smooth. Odour pleasant, test met distinctive. Spores 4-6 x 3-5µm, subglobose ellipsoid to oblong, densely ornamented with coarse, amyloid, verrucose interconnected by a reticulate system. Basidia clavate, 29-39 x 10-14µm, 4-spored. Macrocystidia scattered on both edges and sides of the lamellae, 33-51 x 9-12µm, clavate to fusiform, frequently mucronate, thin walled. Subpellis slightly gelatinized. Suprapellis composed of erect, shortly cylindrical element, 3-5diam. Pileocystidia numerous, intermixed with hyphae, 33-200 x 4-8µm, cylindrical clavate to fusiform, obtuse or slightly constricted to fusiform, obtuse or slightly constricted at large apex. Clamp connection absent.

Collection examined

Mycorrhizal with sal, Amarkantak-Achanakmar Biosphere Reserve, Madhya Pradesh and Chhattisgarh, 24/07/2012, Mycology Herbarium, Tropical Forest Research Institute, Jabalpur, TF2790.

***Russula delicula* Romagn. (Figures 12-14)**

Basidiome small to medium sized. Pileus 4.5-5.5cm diam, convex becoming uplifted and infundibula form at maturity margin inrolled when young, becoming uplifted when fully expanded; surface yellowish grey with grayish

orange tints, viscid when wet, otherwise dry, non-striate. Lamellae subdecurrent, white, up to 4mm broad, often forked at or near the stipe, interveinose, white to pale buff, close, without lamellulae; edge smooth, entire. Context white. Stipe 15-32 x 1.2-2 mm; central, equal or slightly attenuated below, solid; surface white, smooth, annulus absent.

Odour not distinctive Spores 5.0-8.75 x 5.0-7.5µm, globose to broadly ovoid strongly amyloid with an ornamentation of moderately large verrucose & thin connectives forming a partial to complete reticulum. Basidia 36-41 x 4-7µm, clavate, tetrasporate. Cystidia scattered both on edges & sides of the lamellae, 78-112 X 15-26µm clavate-fusoid sometimes with a long, attenuated neck bearing a small bulk apically, filled with oleaginous refractive contents. Subhymenium pseudoparenchymatous. Hymenophoral trama heteromorphous pileipellis with horizontally arranged non-gelatinized hyphae, devoid of dermatocystidia.

Collection examined

Mycorrhizal on sal, Amarkantak-Achanakmar Biosphere Reserve, Madhya Pradesh and Chhattisgarh, 24/07/2012, Mycology Herbarium, Tropical Forest Research Institute, Jabalpur, TF 2792.

Russula leelavathyi K.B. Vrinda, C.K. Pradeep & T.K. Abraham (Figures 15-17)

Basidiome small to medium sized pileus 3-5cm diam., fleshy, convex than expanded with a central depression; surface uniformly ivory to grayish white, areolately cracked forming patches of ivory squamules on a off white ground, entire at the disk; margin radially plicato-striate for two third of radius from the margin and cracking along radial striae to expose underlying white context below, gelatinized under wet weather. Lamellae

adnexed to subdecurrent, white up to 3mm white, heteromerous with thin walled hyaline hyphae 2-6mm wide intermixed with sphaerocytes 17-23µm. Stipe 3-5cm x 5-13mm, central, cylindrical, equal, solid, becoming stuffed; surface white, smooth. Basidiopores 7.5-6.25 x 7.5-7.5µm, subglobose to broadly ovoid, hyaline with an ornamentation of coarse, amyloid, verrucose and scattered fine connectives forming a pilus reticulum. Basidia clavate 45-56 x 7-9 µm, tetrasporate.

Lamella edge sterile, cheilocystidia 33-35 x 9-10µm, clavate, fusoid, lageniform often with actually pointed or mucronate apex. Macrocystidia 73-87 x 4.7-6.5µm, ventricose, fusoid to acuminate, thin-walled, with granular contents, numerous both on sides and edges of the lamellae. *Hymenophoral trama heteromerous* composed of thin-walled, hyaline hyphae, intermixed with sphaerocytes. Pileipellis distinctly two layered an upper epithelial layer and a lower loosely interwoven gelatinized layer. Stipitipellis with abundant caulocystidia 20-40 x 7-12µm similar to cheilocystidia. The furcated lamellae together with lack of lamellulae are characteristic feature of this species.

Collection examined

Mycorrhizal on sal, Amarkantak-Achanakmar Biosphere Reserve, Madhya Pradesh and Chhattisgarh, 24/07/2012, Mycology Herbarium, Tropical Forest Research Institute, Jabalpur, TF 2793.

Russula michiganensis Shaffer (Figures 18-20)

Sporocarp small to medium sized. Pileus up to 2.5-6cm diam, convex to broadly convex with a central depression becoming uplifted in older ones; surface grayish brown becoming black on aging, non-striate.

Table.1 Distribution of *Russula* mushroom in India

S. N.	Name of fungus	Habit	Distribution	Reference
1.	<i>Russula abbotensis</i> K. Das & J.R. Sharma	-	From Abbot Mount, Champawat, Uttarakhand	Das and Sharma (2005a)
2.	<i>Russula aciculocystis</i> Kauffman ex Bills & O.K. Mill.	-	Thiruvananthapuram, Kerala	Pradeep and Vrinda (2010); Mohanan (2011, 2014)
3.	<i>Russula adusta</i> (Pers.) Fr.	in leaf litter and ectomycorrhizal with <i>Vateriaindica</i>	From Kailana, Chakrata, Mayawati, Jageshwar, Uttarakhand; Malappuram and Thiruvananthapuram, Kerala and Mangalore, Karnataka	Saini and Atri (1984); Atri and Saini (1990b); Das and Sharma (2005b);Pradeep and Vrinda, (2010);Mohanan (2011, 2014); (Pavithra <i>et al.</i> , (2017)
4.	<i>Russula aeruginea</i> Lindblad:-Fr.	-	Puliebbie, Zakhama and Pherma forest ranges, Nagaland	Kumar <i>et al.</i> , (2014)
5.	<i>Russula alachuana</i> Murrill	-	Kailana, Chakrata, Uttarakhand	(Atri, Saini, 1986).
6.	<i>Russula albida</i> Peck	-	Nagdev-Jhandidhar Forest, Punjab and Khirsu Forest, Uttarakhand	Bhatt <i>et al.</i> , (1995)
7.	<i>Russula albonigra</i> (Krombh.) Fr.	Ectomycorrhizal on sal in sal forest	Deoban, Chakrata, Uttarakhand, Gidhani and Jhargram, West Bengal	Saini and Atri (1984); Atri and Saini (1986, 1990a);Shajahan and Samajpati (1995)
8.	<i>Russula alnetorum</i> Romagnesi	in leaf litter in the forest range	Mankoi and Chungtia, Nagaland	Kumar <i>et al.</i> , (2014)
9.	<i>Russula alutacea</i> (Fr.)	on wood	Gulmarg, Jammu	Berkeley

	Fr. \equiv <i>Agaricus alutaceus</i> Fr.,		and Kashmir	(1876)
10.	<i>Russula amoena</i> Quél.	-	Palakkad, Kollam, Wayanad, and Thiruvananthapuram, Kerala	Vrinda <i>et al.</i> , (1997c); Pradeep and Vrinda (2010); Mohanan (2011)
11.	<i>Russula amoenicolor</i> Romagn.	-	Jabbar Khet, Mussoorie, Uttarakhand	Rawla and Sarwal (1983).
12.	<i>Russula amoenicolor</i> var. <i>Ramgarhensis</i> K. Das, J.R. Sharma & R.P. Bhatt	-	Ramgarh, Nainital, Uttarakhand	Das <i>et al.</i> , (2005a).
13.	<i>Russula amoenolens</i> Romagn.	From Nagdev-Jhandidhar Forest	Khirsu, Uttarakhand	Bhatt <i>et al.</i> , (1995)
14.	<i>Russula anatine</i> Romagn.		Dafia Dhura, Pithoragarh; Dhakuri, Bageshwar, Uttarakhand	Das and Sharma (2003)
15.	<i>Russula appendiculata</i> K. Das, S.L. Mill. & J.R. Sharma	Associated with Pinus	Gagar, Nainital, Uttarakhand	Das <i>et al.</i> , (2006a)
16.	<i>Russula arunii</i> S. Paloi, A.K. Dutta & K. Acharya	On the base of <i>Pterigotaalata</i> (Stercaliaceae)	West Bengal, (Botanical Garden of the Ballygunge Science College campus, Kolkata)	in Crous <i>et al.</i> , (2017)
17.	<i>Russula atropurpurea</i> (Krombh.) Britzelm.	In leaf litter and ectomycorrhizal with <i>Vateria indica</i>	Chakrata, Uttarakhand; Malappuram and Nilambur, Kerala and Mangalore, Karnataka	Atri, Saini 1986; Saini, Atri (1989b); Pavithra <i>et al.</i> , (2017); Mohanan (2011, 2014)
18.	<i>Russula atropurpurea</i> Peck.	From conifer dominated forest under pine	Gulmarg, Jammu and Kashmir	Dar <i>et al.</i> , (2010)
19.	<i>Russula aurata</i> Fr.	-	Deoban, Chakrata, Uttarakhand	Atri and Saini, (1986); Saini and Atri (1989b); Saini <i>et al.</i> , (1989)

20.	<i>Russula aurea</i> Pers.	From conifer dominated forest	Gulmarg, Jammu and Kashmir	Dar <i>et al.</i> , (2010)
21.	<i>Russula aureorubra</i> K. Das, A. Ghosh, Baghela&Buyck	In temperate broadleaf forest associated with <i>Lithocarpus</i>	Sikkim	in Das <i>et al.</i> , (2017)
22.	<i>Russula aurora</i> (Krombh.) Bres.	-	Chakrata, Mussoorie, Uttarakhand	Saini <i>et al.</i> , (1989)
23.	<i>Russula azurea</i> Bres.	Growing solitary on humicolous soil under <i>Juniperusrecurva</i>	Churdhar, Himachal Pradesh	Saini <i>et al.</i> , (2010)
24.	<i>Russula brevipes</i> Peck = <i>Russula brevipes</i> var. <i>acrior</i> Shaffer	In forest areas	Jageshwar,Mayawati, Champawat, Uttarakhand; Nagaland (Puliebbie, Zakhama, Chungtia) and Namcha forest ranges and Jammu and Kashmir	Das and Sharma (2005b); Kumar <i>et al.</i> , (2014); Watling and Gregory (1980)
25.	<i>Russula brevipes</i> var. <i>acrior</i> Shaffer	-	Lohaghat, Mayawati, Champawat; Sandev, Pithoragarh, Uttarakhand	Das and Sharma (2005b)
26.	<i>Russula brunneoviolacea</i> Crawshay var. <i>macrospora</i> M. Kaur, NS Atri, S. Sharma & Y. Singh	Growing solitary on humicolous soil in <i>Abiespindrow</i> forest	Narkanda, Himachal Pradesh	Kaur <i>et al.</i> , (2011)
27.	<i>Russula buyckii</i> K. Acharya, S. Paloi& A.K. Dutta	Growing under <i>Castanopsis</i> sp., among mosses	Darjeeling, West Bengal	Paloi <i>et al.</i> , (2016)
28.	<i>Russula brunneoviolacea</i> var <i>rubeogrisea</i> Romang,	Growing solitary on humicolous soil in a broad leaved forest	Hattu Peak, Himachal Pradesh	Kaur <i>et al.</i> , (2011)
29.	<i>Russula californiensis</i> Burl	Growing on hard ground in August	Kasauli, Himachal Pradesh	Chaudhary, Tripathy (2016)
30.	<i>Russula cinerella</i> Pat.	-	Wayanad, Kerala	Mohanani (2011, 2014)
31.	<i>Russula cinnabarina</i> Berk.	On clay bank	Darjeeling, West Bengal	Berkeley (1851)
32.	<i>Russula claroflava</i>	-	Amravati,	Hedawoo

	Grove		Maharashtra	(2010)
33.	<i>Russula compacta</i> Frost	-	Abbot Mt., Sandev, Dafia Dhura, Uttarakhand	Das and Sharma (2005b)
34.	<i>Russula congoana</i> Pat.	-	Mussoorie, Uttarakhand; Ernakulam, Kollam, Malappuram, Wayanad and Thiruvananthapuram, Kerala	Sarwal (1984); Pradeep and Vrinda (2010); Varghese <i>et al.</i> , (2010); Mohanan (2011)
35.	<i>Russula consobrina</i> (Fr.) Fr.	-	Jamnotri, Hanumanchatti, Uttarakhand	Atri and Saini (1986, 1990a)
36.	<i>Russula cremeoavellanea</i> Singer	-	North West Himalayas, Himachal Pradesh	Sharma <i>et al.</i> , (2016)
37.	<i>Russula crustosa</i> Peck.	Solitary-scattered under <i>Picea smithiana</i> , <i>Pinus walitiana</i> , <i>Quercus incana</i> and <i>Rhododendron arboretum</i>	Shimla, Himachal Pradesh	Bhatt and Lakhnpal (1988a)
38.	<i>Russula cyanoxantha</i> (Schaeff.) Fr.	Ectomycorrhizal on sal	Gidhanisal forest, West Bengal; Chakrata, Kailana; Joshimath, Oli Forest; Ramgarh; Lohaghat, Champawat; Dafia Dhura, Maitly, Uttarakhand	Shajahan and Samajpati (1995); Atri and Saini (1986, 1990c); Das and Sharma (2005b).
39.	<i>Russula dafianus</i> K. Das & J.R. Sharma	-	Dhakuri, Bageshwar; Dafia Dhura; Pithoragarh, Uttarakhand	Das and Sharma (2005b)
40.	<i>Russula decipiens</i> (Singer) Bon	-	Mukteshwar, Nainital, Uttarakhand	Das and Sharma (2005b)
41.	<i>Russula decolorans</i> (Fr.) Fr.	-	Kumaon and Champawat, Mayawati; Mornoulla, Almora; Nainital, Ramgarh;	Das and Sharma (2003)

			Uttarakhand	
42.	<i>Russula delica</i> Fr.	Ectomycorrhizal on sal	Gidhani and Jhargram, West Bengal and Chakrata, Deoban and Nainapeak Uttarakhand	Shajahan and Samajpati (1995); Atri and Saini (1986)
43.	<i>Russula delicula</i> Romagn.	-	Thiruvananthapuram and Wayanad, Kerala	Pradeep and Vrinda (2010); Mohanan (2011, 2014)
44.	<i>Russula densifolia</i> Secr. ex Gillet	-	Jammu and Kashmir	Watling and Gregory (1980)
45.	<i>Russula dhakuriana</i> K. Das, J.R. Sharma & S.L. Mills	Associated with <i>Rhododendron</i>	Dhakuri, Bageshwar, Uttarakhand, Himalaya	Das <i>et al.</i> , (2006a)
46.	<i>Russula dissimulans</i> Shaffer	-	Adwani Forest, Uttarakhand	Bhatt <i>et al.</i> , (1995)
47.	<i>Russula dubdiana</i> K. Das, Atri & Buyck	On ground under <i>Castanopsis hystrix</i> in subtropical to temperate broad-leaved forest	Sikkim	Das <i>et al.</i> , (2013)
48.	<i>Russula emetica</i> (Schaeff.) Pers. \equiv <i>Agaricus emeticus</i> Schaeff.	-	Khasi Hills, Meghalaya and clay banks, Darjeeling, West Bengal	Berkeley (1856)
49.	<i>Russula farinipes</i> Romell	Growing in the mixed forest dominated by <i>Pinus wallichiana</i> and <i>Quercus incana</i>	Himachal Pradesh	Saini and Atri (1989)
50.	<i>Russula firmula</i> Jul. Schäff.	-	Jammu and Kashmir	Watling, Gregory (1980)
51.	<i>Russula flavidavar. Dhakurianus</i> K. Das, J.R. Sharma & R.P. Bhatt	-	Dhakuri, Bageshwar, Uttarakhand	Das and Sharma (2005a)
52.	<i>Russula flocculosa</i> Burl.	-	Chobattakhal, Phaedkhal, Pauri Garhwal, Uttarakhand	Bhatt <i>et al.</i> , (2007)

53.	<i>Russula foetens</i> Pers.	On humicolous soil, under <i>Quercusincana</i> ,	Joshimath, Nainital, Chakrata, Deoban, Jamnotri, Uttarakhand; Summer Hills, Simla, Himachal Pradesh	Saini and Atri (1984); Saini and Atri (1981)
54.	<i>Russula fragrantissima</i> Romagn	-	Nongkham, Namcha and Tigit forest range, Nagaland and Jammu and Kashmir	Kumar <i>et al.</i> , (2014); Watling and Gregory (1980)
55.	<i>Russula furcata</i> Pers.	Clay banks	Sinchal, Sikkim, Himalayas	Berkeley (1856)
56.	<i>Russula grata</i> Britzelm.= <i>Russula laurocerasi</i> Melzer	Growing solitary on humicolous soil under <i>Quercusincana</i>	Thiruvananthapuram, Kerala and Himachal Pradesh	Pradeep and Vrinda (2010); Saini and Atri (1989)
57.	<i>Russula griseocarnosa</i> X.H. Wang, Zhu L. Yang & Knudsen	-	Sikkim	in Das <i>et al.</i> , (2010)
58.	<i>Russula grossa</i> Berk.	on earth and mossy bank	Darjeeling, West Bengal	Berkeley (1851)
59.	<i>Russula himalayana</i> Rawal & Sarwal	On humus under <i>Aesculus</i> and <i>Acer</i>	Jabbar Khet, Mussoorie, Uttarakhand	Rawla and Sarwal (1983)
60.	<i>Russula hookeri</i> S. Paloi, A.K. Dutta & K. Acharya	Growing solitary - group of two, under <i>Castanopsis</i> sp. among the mosses	Darjeeling, West Bengal	Paloi <i>et al.</i> , (2015)
61.	<i>Russula hygrophytica</i> Pegler	-	Ernakulam, Perumbavoor and Thiruvananthapuram, Kerala	Mohanan (2011, 2014)
62.	<i>Russula indica</i> Sathe & J.T. Daniel	-	Idukki, Kerala	in Sathe <i>et al.</i> , (1980); Florence (2004)
63.	<i>Russula indoarmeniaca</i> A. Ghosh, K. Das & R.P. Bhatt	From broadleaf forest	Baniyakund, Rudraprayag, Uttarakhand	Ghosh <i>et al.</i> , (2016)
64.	<i>Russula intervenosa</i> Paloi, A.K. Dutta & K. Acharya	Associated with <i>Shorea robusta</i>	Lodhasuli forest, Paschim Midnapur, West Bengal	in Crous <i>et al.</i> , (2016)
65.	<i>Russula kanadii</i> A.K.	Growing solitary under	Gurguripal forest,	Dutta <i>et al.</i> ,

	Dutta& K. Acharya	<i>Shorearobusta</i> tree	West Midnapur District, West Bengal	(2015)
66.	<i>Russula khanchanjungae</i> Van de Putte, K. Das &Buyck (as ' <i>khanchanjungae</i>)	in mixed forest with <i>Abiesdensa</i> , <i>Betulautilis</i> and <i>Rhododendronbarbatum</i>	Sikkim	in Das <i>et al.</i> , (2010)
67.	<i>Russula leelavathyi</i> K.B. Vrinda, C.K. Pradeep& T.K. Abraham	On sandy soil, associated with <i>Hopeaparviflora</i>	Thiruvananthapuram, Malappuram and Wayanad, Kerala Madhya Pradesh	Vrinda <i>et al.</i> , (1997a); Pradeep and Vrinda (2007, 2010); Mohanan (2011, 2014)
68.	<i>Russula lepida</i> Fr.	ectomycorrhizal on sal; on clay bank, Darjeeling, WB; reported edible from Tapovan, Dehradun, Uttarakhand	Gidhani and Jhargramsals forest, West Bengal; Uttarakhand	Shajahan and Samajpati (1995); (Berkeley (1851); Semwal <i>et al.</i> , (2014)
69.	<i>Russula lepidicolor</i> Romagnesi	growing scattered on humicolous soil in <i>Cedrusdeodara</i> forest	Nagar Forest, Manali, Himachal Pradesh	Saini <i>et al.</i> , (2010)
70.	<i>Russula lutea</i> , Bhatt <i>et al.</i> , 1988a, b	Solitary-scattered, associated with <i>Cedrusdeodara</i> , <i>Piceasmithiana</i> , <i>Pinuswalitiana</i> , <i>Quercusincana</i> and <i>Rhododendron arboreum</i> and humicolous soil in sal forests	Shimla, Himachal Pradesh and lower Shiwalik Hills of Uttarakhand	Bhatt and Lakhanpal (1988b); Semwal <i>et al.</i> , (2014)
71.	<i>Russula luteotacta</i> Rea	-	Thiruvananthapuram, Ernakulam and Perumbavoor, Kerala	Pradeep and Vrinda (2010); Mohanan (2011, 2014)
72.	<i>Russula mariae</i> Peck	On soil under Hopeaponga, <i>H. parviflora</i> , <i>Vateriaindica</i> , <i>Diospyrosmalabarica</i> forming ectomycorrhiza	Shenkily, Kulathupuzha, Wayanad, Kerala	Mohanan (2014)
73.	<i>Russula martinica</i> Pegler	On soil underHopeaparviflora	Malappuram, Nilambur, Kerala	Mohanan (2011, 2014)
74.	<i>Russula mayawatiana</i> K. Das, S.L. Mill. & J.R. Sharma	Associated with <i>Quercus</i> and <i>Rhododendron</i>	Champawat, Mayawati, Uttarakhand	Das K <i>et al.</i> , (2006a)

75.	<i>Russula michiganensis</i> Shaffer	Under <i>Hopea</i> , <i>H. parviflora</i> , <i>Vateria indica</i> and <i>Diospyros malabarica</i>	from Wayanad and Ernakulam, Kerala	Mohanan (2011, 2014)
76.	<i>Russula minutulavar. Minutula</i> Velen.	-	Kailana, Dhobighat, Alumandi, Mussoorie, Joshimath, Uttarakhand	Saini and Atri (1984); Saini <i>et al.</i> , (1989)
77.	<i>Russula mukteshwarica</i> K. Das, S.L. Mill., J.R. Sharma & R.P. Bhatt	In close association with <i>Myrica</i> , <i>Quercus</i> and <i>Rhododendron</i>	Uttarakhand, Himalayas	Das K <i>et al.</i> , (2005)
78.	<i>Russula mussooriensis</i> Rawla & Sarwal	-	from Jabbar Khet, Mussoorie, Uttarakhand	Rawla and Sarwal (1983)
79.	<i>Russula mustelina</i> Fr., Oli Forest	-	Chakrata, Kailana, Uttarakhand	Saini and Atri (1984); (Atri and Saini (1986, 1990c)
80.	<i>Russula natarjanii</i> K. Das, J.R. Sharma & Atri	Associated with <i>Quercus</i> species in moist, temperate, deciduous/mixed forests	Dhakuri, Bageshwar, Uttarakhand	Das <i>et al.</i> , (2006b)
81.	<i>Russula nauseosa</i> (Pers.) Fr.	On ground amongst pine litter	Gulmatg, Jammu and Kashmir	Abraham <i>et al.</i> , (1980); Watling and Gregory (1980)
82.	<i>Russula nigricans</i> Fr.	-	Chakrata, Uttarakhand	Saini and Atri (1984); Saini <i>et al.</i> , (1988)
83.	<i>Russula nobilis</i> Velen	In forest	Pherma and Mankoi, Nagaland	Kumar <i>et al.</i> , (2014)
84.	<i>Russula obscuricolor</i> K. Das, A. Ghosh & Buyck	On soil in mixed broad leaf forest associated with <i>Castanopsis</i>	Sikkim	(in Das <i>et al.</i> , (2017)
85.	<i>Russula ochroleuca</i> (Pers.) Fr. Gray.	In forest ranges	Lahorijan, Puliebbie, Zakhama, Nagaland	Kumar <i>et al.</i> , (2014)
86.	<i>Russula ochroleuca</i> (Pers.) Fr.	-	Chakrata, Uttarakhand	Saini <i>et al.</i> , (1989)
87.	<i>Russula odorata</i> Romagn.	-	Jabbar Khet, Mussoorie,	Rawla and Sarwal

			Uttarakhand	(1983)
88.	<i>Russula olivacea</i> (Schaeff.) Fr.	In dense clusters, around trunks, in pine forest	Shyrwat, Shillong, Meghalaya	Kalita <i>et al.</i> , (2016)
89.	<i>Russula parazurea</i> Jul. Schäff.	-	Chennai, Tamil Nadu	Natarajan and Raman (1983c)
90.	<i>Russula parvovirescens</i> Buyck, D. Mitch. &Parrent	Solitary, on ground, in Pine forest	Shyrwat, Shillong, Meghalaya	Kalita <i>et al.</i> , (2016)
91.	<i>Russula pauriensis</i> A. Ghosh, K. Das &Buyck	On soil in mixed broadleaf forest associated with <i>Quercus</i>	Uttarakhand	in Das <i>et al.</i> , (2017)
92.	<i>Russula peckii</i> Singer	-	from North West Himalayas, Himachal Pradesh	Sharma <i>et al.</i> , (2016)
93.	<i>Russula pectinata</i> (Bull.) Fr.	-	JabbarKhet, Mussoorie, Uttarakhand	Rawla and Sarwal (1983)
94.	<i>Russula pectinata</i> Fr.	On humicolous soil under <i>Quercusincana</i> , mycorrhizal with sal	Chakrata, Uttarakhand and Gidhanisal forest, West Bengal	(Saini SS, Atri NS, 1989); (Shajahan M and Samajpati N, 1995)
95.	<i>Russula periglypta</i> Berk. & Broome	On soil under <i>Vateriaindica</i> , <i>Hopeaparviflora</i> and <i>Diospyrosmalabarica</i>	Thiruvananthapuram, Nilambur and Malappuram, Kerala	Pradeep and Vrinda (2010); Manimohan, Deepna (2011); Mohanan (2011, 2014)
96.	<i>Russula persicina</i> Krombh.	-	Jammu and Kashmir	Watling and Gregory (1980)
97.	<i>Russula petersenii</i> A. Ghosh& K. Das	On the soil under <i>Rhododendron</i>	Uttarakhand	Ghosh and Das (2017)
98.	<i>Russula praetervisita</i> Sarnari	-	Dhakuri, Bageshwar; Mayawati and Mornoula, Champawat, Uttarakhand	Sharma <i>et al.</i> , (2005)
99.	<i>Russula</i>	-	Phedkhal,	Bhatt <i>et al.</i> ,

	<i>pseudolepida</i> Singer		PauriGarhwal; Mandal, Chamoli, Uttarakhand	(2007)
100.	<i>Russula puellaris</i> var <i>puellaria</i> Fr.	Solitary on humicolous soil among <i>Fragaria</i> sp., under <i>Cedrusdeodara</i>	Narkanda, Himachal Pradesh	Kaur <i>et al.</i> , (2011)
101.	<i>Russula puellaris</i> var. <i>atrii</i> K. Das, S.L. Mill. & J. R Sharma	Associated with <i>Quercus</i> and <i>Rhododendron</i>	Dhakuri, Bageshwar, Uttarakhand, (Himalayas)	Das <i>et al.</i> , (2006a)
102.	<i>Russula pulverulenta</i> Peck	-	Teka, Gandra, PauriGarhwal, Uttarakhand	Bhatt <i>et al.</i> , (2007)
103.	<i>Russula purpureonigra</i> Petch	-	Thiruvananthapuram and Malappuram, Kerala	Pradeep and Vrinda (2010); Manimohan and Deepna (2011)
104.	<i>Russula rajendrae</i> A. Ghosh& K. Das	On the soil under <i>Quercus</i>	Uttarakhand	Ghosh and Das (2017)
105.	<i>Russula raoultii</i> Quél.	-	DafiaDhura, Pithoragarh; Mornoulla, Almora, Uttarakhand	Das and Sharma (2003)
106.	<i>Russula rhodomelanea</i> Sarnari	-	Dhakuri, Bageshwar, Uttarakhand	Das and Sharma (2001b)
107.	<i>Russula romagnesiana</i> Schaffer	-	Thiruvananthapuram, Kerala	Pradeep and Vrinda (2010)
108.	<i>Russula rubra</i> (Lam.) Fr.= <i>Russula rubra</i> var. <i>hymenocystidiata</i> Atri& Kour	-	Punjab	Atri and Kour (2003)
109.	<i>Russula sanguinaria</i> (Schumach.)Rauschert = <i>Russula rosacea</i> (Pers.) Gray ≡ <i>Agaricusroseus</i> Schaeff .	In pine wood; on the ground	Sikkim, Himalayas and Mussoorie, Uttarakhand	Berkeley (1851a); Mundkur (1938)
110.	<i>Russula sarnarii</i> A. Ghosh, K. Das & R.P. Bhatt	Growing under <i>Pinus</i> forest	Uttarakhand	Ghosh <i>et al.</i> , (2017)
111.	<i>Russula sanguinea</i> Fr.	-	from Jammu and	Watling and

	= <i>Agaricus sanguineus</i> Bull.		Kashmir	Gregory (1980)
112.	<i>Russula schaefferina</i> Rawla & Sarwal	-	Mussoorie, Uttarakhand	Rawla and Sarwal (1983)
113.	<i>Russula senecis</i> S. Imai	In association with <i>Vateria indica</i> , dipterocarp forests, and under <i>Lithocarpus</i> and <i>Castenopsis</i>	Western Ghats Sikkim West Bengal	Natarajan <i>et al.</i> , (2005); Das (2009); Das <i>et al.</i> , (2010); Khatua <i>et al.</i> , (2015)
114.	<i>Russula sharmae</i> K. Das, Atri & Buyck	On ground under <i>Lithocarpus pachyphyllus</i> in mixed forest	Sikkim	Das <i>et al.</i> , (2013)
115.	<i>Russula shingbaensis</i> K. Das & S.L. Mill.	On ground, sub-alpine forest, under <i>Abies densa</i> , Shingba <i>Rhododendron</i> wildlife sanctuary	North district, Sikkim	Das <i>et al.</i> , (2014).
116.	<i>Russula sikkimensis</i> K. Das, Atri & Buyck	On ground in <i>Abies densa</i> sub-alpine mixed forest	Sikkim	Das <i>et al.</i> , (2013)
117.	<i>Russula silvicola</i> Shaffer, Beih., Khirsu	-	Pauri Grahwal, Uttarakhand	Bhatt <i>et al.</i> , (2007)
118.	<i>Russula subfoetens</i> W.G. Sm.	Solitary on humicolous soil under <i>Cedrus deodara</i> and <i>Quercus incana</i>	Chakrata, Uttarakhand	Atri and Saini (1986); Saini and Atri (1989a)
119.	<i>Russula thindii</i> K. Das & S.L. Mill.	On ground, coniferous forest, <i>Abies densa</i> , Shingba <i>Rhododendron</i> wildlife sanctuary,	North district, Sikkim	Das <i>et al.</i> , (2014)
120.	<i>Russula tsokae</i> K. Das, Van de Putte & Buyck	Under <i>Tsugadumosa</i> forest	Sikkim	in Das <i>et al.</i> , (2010)
121.	<i>Russula vaurasiana</i> K. Das & J.R. Sharma	Associated with <i>Quercus</i> in temperate mixed forest	Uttarakhand	Das and Sharma (2005b)
122.	<i>Russula velenovskyi</i> Melzer & Zvára	In Oli Forest	Joshimath, Uttarakhand	Atri and Saini (1986); Saini and Atri (1989b)
123.	<i>Russula vesca</i> Fr.	Ectomycorrhizal on sal,	Gidhani and Balibhasa forest, West Bengal	Shajahan and Samajpati (1995)
124.	<i>Russula virescens</i> (Schaeff.) Fr.,	-	Dhobighat, Mussoorie;	Saini <i>et al.</i> , (1988)

Chakrata, Deoban,
Uttarakhand

Table.2 Distribution of 124 species of *Russula* in different states of India

S. No.	State	Number of species	Percentage (%)
1.	Himachal Pradesh	13	9.2
2.	Jammu and Kashmir	10	7.1
3.	Karnataka	2	1.4
4.	Kerala	17	12.1
5.	Madhya Pradesh	6	4.3
6.	Maharashtra	1	0.7
7.	Meghalaya	3	2.1
8.	Nagaland	6	4.3
9.	Punjab	2	1.4
10.	Sikkim	10	7.1
11.	Tamil Nadu	1	0.7
12.	Uttarakhand	57	40.4
13.	West Bengal	13	9.2
	Toal	141	100

Table.3 Edible species of *Russula*

S. No.	Name of species	Place	Reference
1.	<i>Russula crustosa</i>	Himachal Pradesh	Bhatt and Lakhnupal (1988a, b)
2.	<i>Russula lepida</i>	Tapovan, Dehradun, Uttarakhand	Semwal <i>et al.</i> , (2014)
3.	<i>Russula lutea</i>	Himachal Pradesh and Uttarakhand	Bhatt and Lakhnupal (1988b); Semwal <i>et al.</i> , (2014)
4.	<i>Russula olivacea</i>	Meghalaya	Kalita <i>et al.</i> , (2016)
5.	<i>Russula parvovirescens</i>	Meghalaya	Kalita <i>et al.</i> , (2016)
6.	<i>Russula senecis</i>	West Bengal	Khatua <i>et al.</i> , (2015)
7.	<i>Russula virescens</i>	Uttarakhand	Saini <i>et al.</i> , (1988)

Fig.1-4 *Russula adusta*, 1 basidiocarps, 2 basidia, 3 basidiospores (100x).

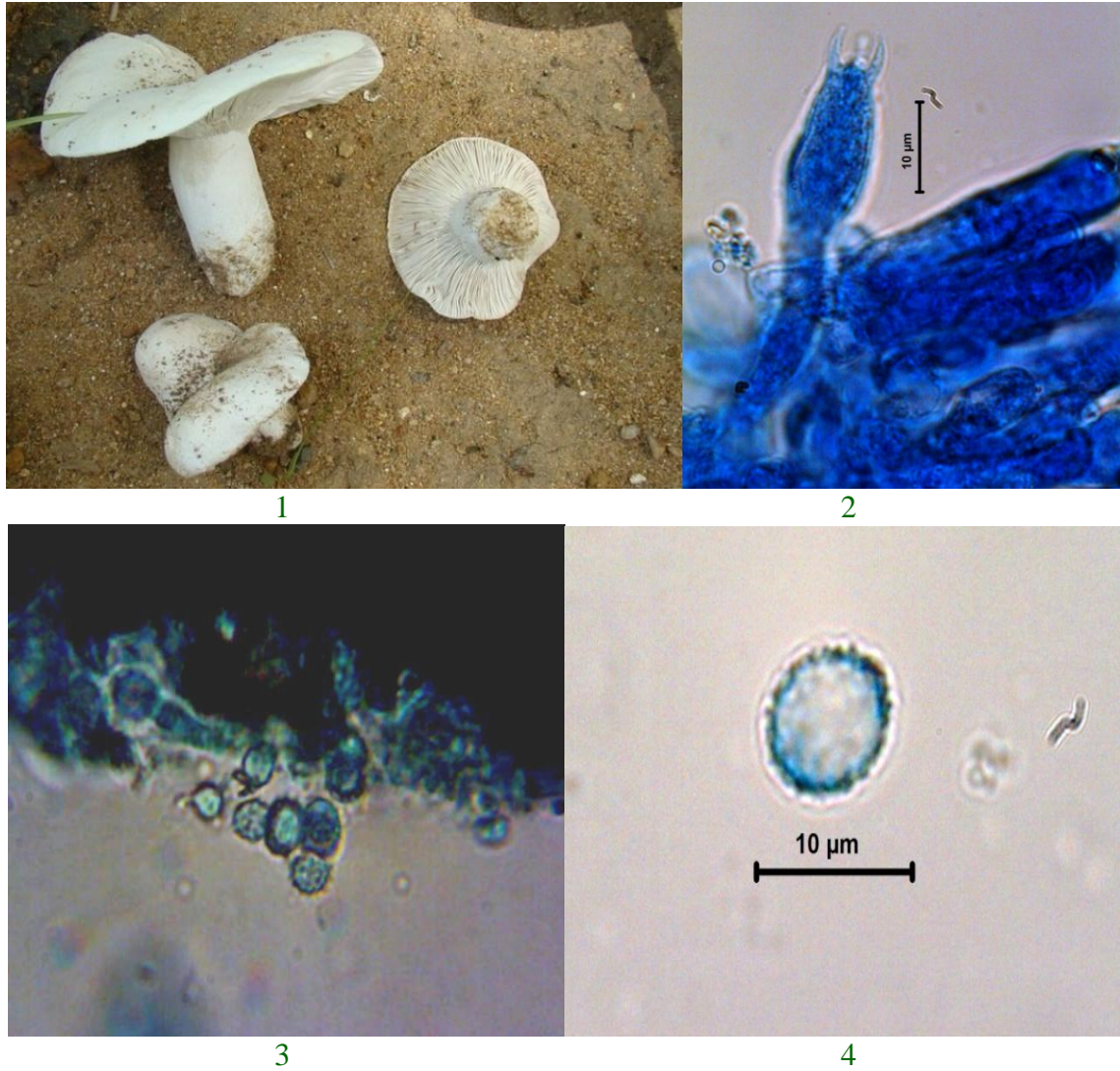
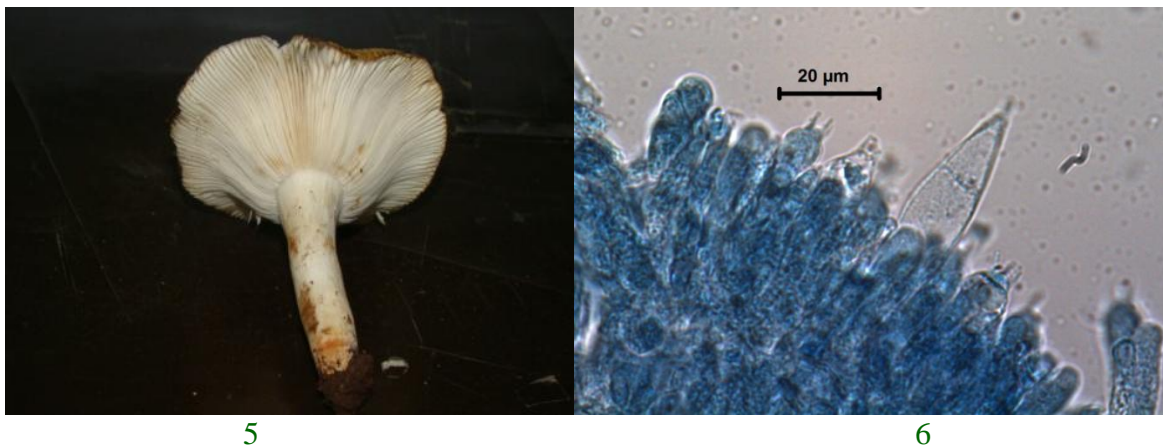


Fig.5-7 *Russula cinerella*, 4 basidiocarp, 6 basidia and 6 basidiospores





7

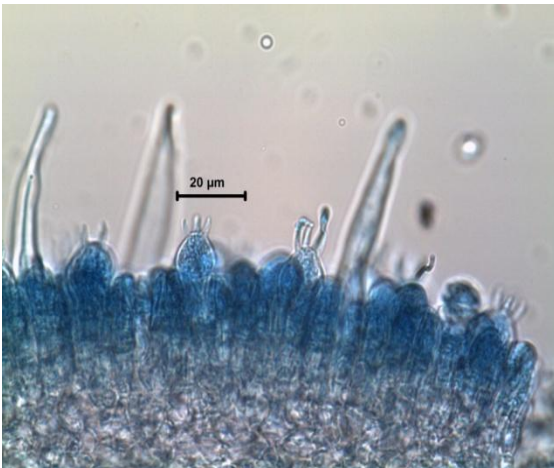
Fig.8-11 *Russula congoana*, 8-9 basidiocarp habit, 10 basidia and 11 basidiospores



8



9



10



11

Fig.12-14 *Russula delicula*, 12 basidiocarp, 13 basidia, 14 basidiospores

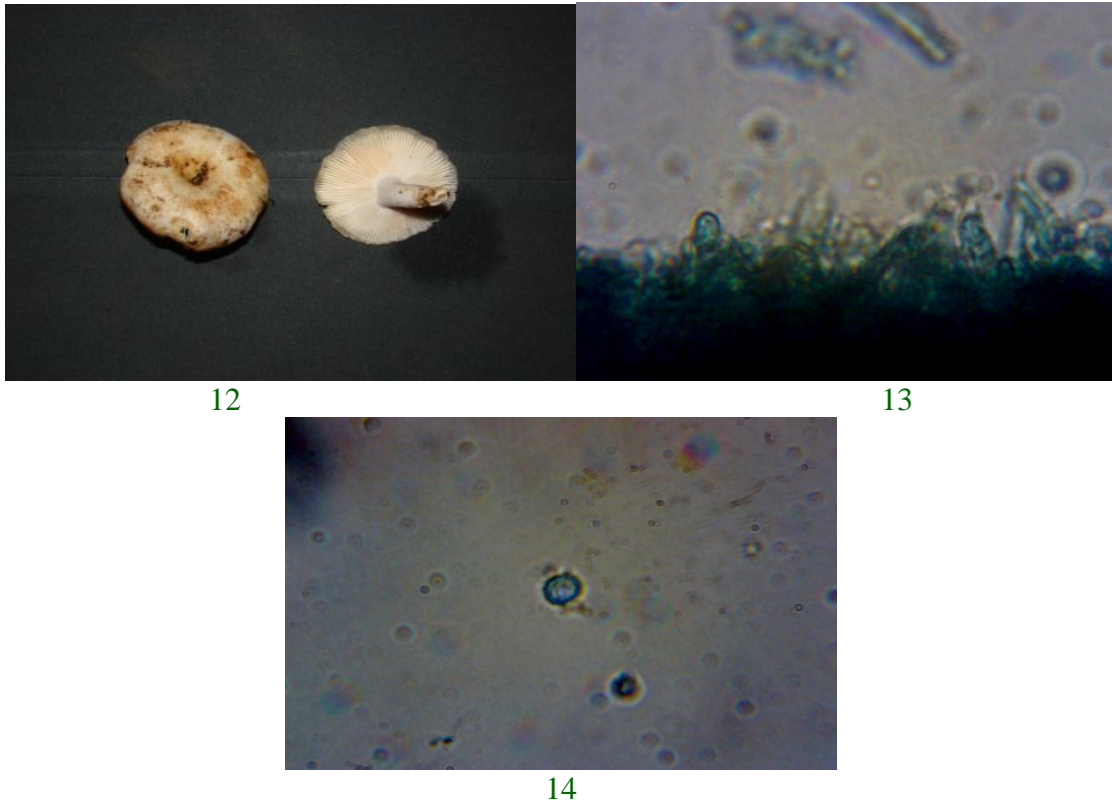


Fig.15-17 *Russula leelavathyi*, 15-16 basidiocarp, 17 basidia and basidiospores

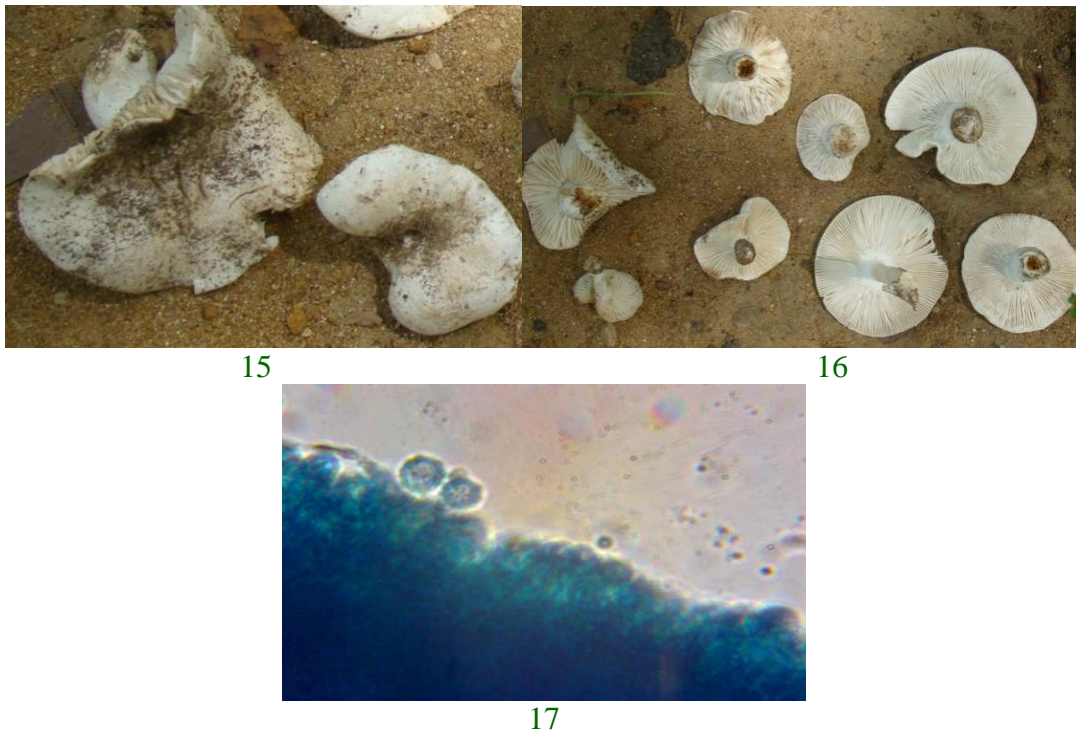


Fig.18-20 *Russula michiganensis*, 18 basidiocarps different developing stages, 19 tetrasporatebasidia with developing basidiospores, 20 basidiospores

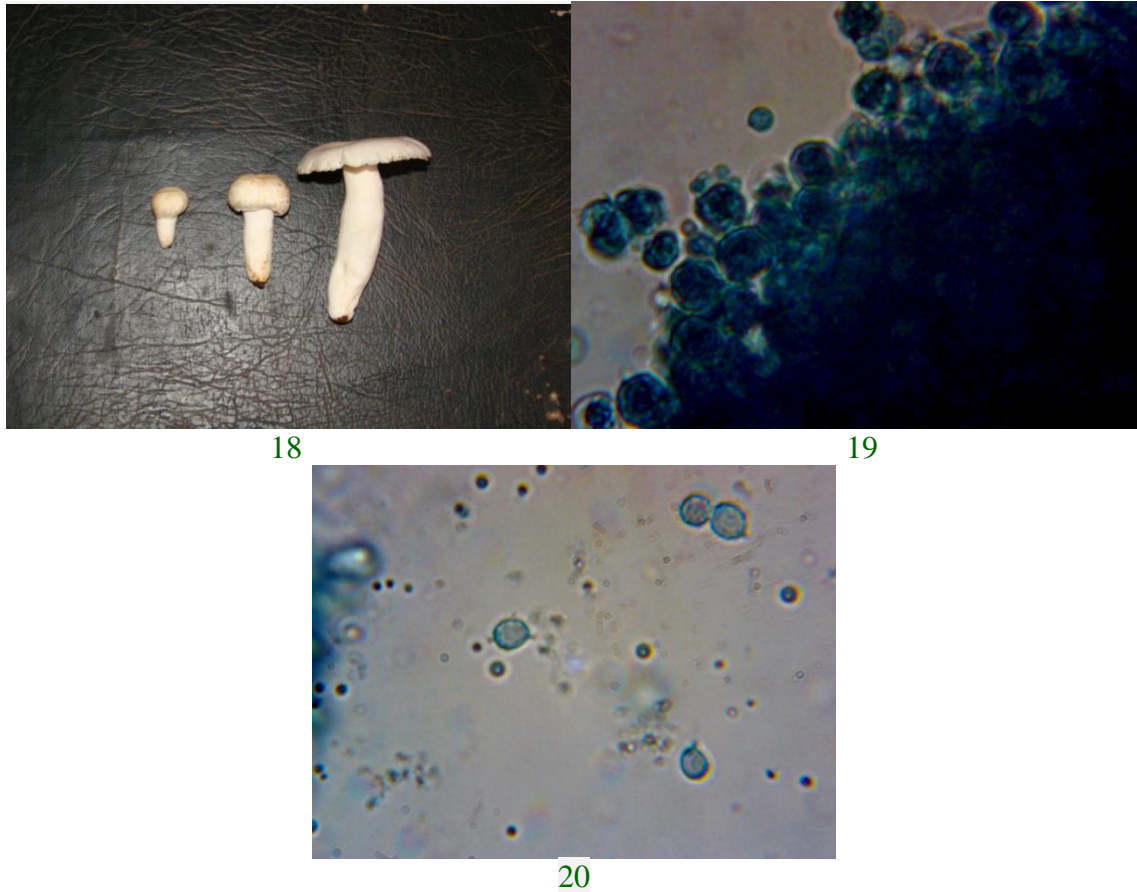


Fig.21 Tribal women selling *Russula* species in local market at Bajag in Dindori, Madhya Pradesh along with other mushroom (*Astraeushygrometricus*)



Lamellae adnate, white turning grayish black to black on handling, more or less crowded with lamellulae of different lengths, with plenty of bifurcations; edge smooth, entire. Context white up to 5mm thick. Discolouring blackish on exposure, heteromerous with nests of sphaerocytes. Stipe 3-6-5cm x 9-17mm central, equal, solid; surface chalky white, turning black when handled. Annulus absent. Odour not distinctive. Spores 5-8 x 3-5 µm, subglobose to broadly ovoid ornamentation hardly up to 0.4 µm high small to medium sized warts and thick and fine ridges are connected to form a partial reticulum; Suprahilar phage inamyloid. Basidia clavate, 24-26 x 4-6µm, tetrasporate. Lamella-edge sterile with macrocystidia and leptocystidia. Macrocystidia 26-29 x 5-10µm, cylindrical, thin-walled with refractive contents, concentrated near tip. Pleurocystidia abundant 27-55 x 4-7µm subcylindrical with capitate apices or round with 2 or 3 sub-apical constriction, at times curved with scarcely visible contents, projecting prominently beyond the hymenium, very abundant. Subhymenium pseudoparenchymatous, hymenophoral trama heteromorphous with sphaerocytes.

Collection examined

Mycorrhizal on sal, Amarkantak-Achanakmar Biosphere Reserve, Madhya Pradesh and Chhattisgarh, 24/07/2012, Mycology Herbarium, Tropical Forest Research Institute, Jabalpur, TF 2787.

Russula mushrooms distributed in different states of India are presented in Table 1. Total 124 species were recorded from 13 states. States-wise status of species is presented in Table 2. Edible species are presented in Table 3.

Russula adusta formed mycorrhizal association with sal (*Shorearobusta* Gaertn.)

trees in central India. Its ectomycorrhizal association were reported in trees like, *Hopea ponga*, *H. parviflora*, *Myristicamalabarica*, *Vateria indica*, and *Diospyros malabarica*. The species is distributed at different places in India: Kailana, Chakrata, Lohaghat, Mayawati, Jageshwar and Champawat in Uttarakhand (Saini and Atri 1984; Atri and Saini 1990b); Malappuram, Thiruvananthapuram in Kerala (Pradeep and Vrinda, 2010; Mohanan, 2011, 2014) and Mangalore in Karnataka (Pavithra *et al.*, 2017). In the present study it is being reported from Amarkantak-Achanakmar Biosphere Reserve in Madhya Pradesh and Chhattisgarh, India.

Russula cinerella is being reported mycorrhizal with sal from Amarkantak-Achanakmar Biosphere Reserve, Madhya Pradesh and Chhattisgarh. It was also reported from Wayanad, Kerala growing solitary or scattered in large groups on soil under *Hopea parviflora*, *Vateria indica*, and *Diospyros malabarica* (Mohanan, 2011; 2014). The species is also reported to be distributed in Madagascar (Patouillard, 1924).

Russula congoana and *R. delicula* form ectomycorrhizal association with sal (*Shorearobusta* Gaertn.). *R. congoana* has worldwide distribution. It was earlier recorded from moist deciduous forests of India from Mussoorie, Uttarakhand (Sarwal 1984) and Ernakulam, Kollam, Malappuram, Wayanad and Thiruvananthapuram, Kerala. It is also distributed in moist-deciduous to evergreen forests and occurs solitary or scattered on soil under *Hopea ponga*, *H. parviflora*, *Myristica malabarica*, *Vateria indica*, and *Diospyros malabarica* forming an ectomycorrhizal association. The species can be easily recognized by distinct pastel red pileus and the heavy ornamented spores. It is an edible species (Pradeep and Vrinda 2010; Varghese *et al.*, 2010;

Mohanani 2011, 2014). *R.deliculais* widely distributed in moist deciduous forests of India and reported from Thiruvananthapuram and Wayanad, Kerala (Pradeep and Vrinda 2010; Mohanani 2011, 2014). *Russula leelavathyi* has worldwide distribution in North America, Europe and moist deciduous forests of India it was reported growing on sandy soil and was associated with *Hopea parviflora* from Thiruvananthapuram, Malappuram and Wayanad, Kerala (Vrinda *et al.*, 1997a; Pradeep and Vrinda 2007, 2010; Mohanani 2011, 2014). In the present study it was also recorded from Amarkantaka-Achanakmarsal forest of Chhattisgarh and Madhya Pradesh.

Russula michiganensis is recorded on sal from Amarkantaka-Achanakmarsal forest of Chhattisgarh and Madhya Pradesh. Earlier the species was recorded from moist deciduous forests of India forming ectomycorrhizal association with *Hopea pona*, *H. parviflora*, *Vateria indica* and *Diospyros malabarica* in Wayanad and Ernakulam, Kerala (Mohanani 2014). This mushroom has worldwide distribution. *Russula senecis*, an edible mushroom grows in association with *Vateria indica* plants among the dipterocarp forests of Western Ghats (Natarajan *et al.*, 2005), and in mixed forests in Sikkim (Das, 2009; Das *et al.*, 2010) is collected from forests and sold in West Bengal (Khatua *et al.*, 2015)

Many of *Russula* species are edible. *Russula crustosais* an edible mushroom reported from Shimla, Himachal Pradesh (Bhatt and Lakhanpal 1988a). *R. luteais* another edible mushroom growing in associated with *Cedrus deodara*, *Picea smithiana*, *Pinus walitiana*, *Quercus incana* and *Rhododendron arboreum* in Shimla and lower Shiwalik Hills of Uttarakhand (Bhatt and Lakhanpal 1988b), another edible mushroom, *R. lepida* was recorded on humicolous soil from sal forests (Semwal *et al.*, 2014). Other

edible species include *R. olivacea* and *R. parvovirescens* growing in pine forest at Shillong in Meghalaya (Kalita *et al.*, 2016). *R. senecis* collected by tribes in West Bengal (Khatua *et al.*, 2015).

In the present study out of six species reported some species for example, *R. congoana* collected from sal forest of Chhattisgarh and Madhya Pradesh are also edible, these mushrooms were collected by the local tribal people and sold in local market (Figure 21).

Mushrooms belong to genus *Russula* are widely distributed in India. 124 species of the genus are listed from 13 states. Uttarakhand represent the maximum diversity of *Russula* species and over 40% species recorded from this state only. Six species namely: *Russula adusta*, *R. cinerella*, *R. congoana*, *R. delicula*, *R. leelavathyi* and *R. michiganensis* are described occurring in sal forest of central India. These fungi form ectomycorrhizal association with sal trees and some edible species are also collected by the local people and sold in the local market.

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