RUSSULACEAE OF KUMAON HIMALAYA

KANAD DAS & J.R. SHARMA

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(*Russula pectinata, R. amoenicolor* var. *ramgarhensis, R. flavida* var. *dhakurianus, R. delica, R. emetica, R. dafianus* and *Lactarius deliciosus*)

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FOREWORD

India has intensified efforts for survey, inventorization and documentation of all components of its biological wealth, particularly after the recent ratification of international agreements and formulations of several national strategies on biodiversity conservation. The Botanical Survey of India being the premier organisation on plants for this purpose, has contributed immensely in the form of district, state, regional and national floras.

During these studies, lower groups of plants the cryptogams in general- have received less attention. In the recent years, however, efforts have been underway to streamline the studies on Algae, Fungi, Lichens and Bryophytes. Among the cryptogams, the fungi with about 14,500 species known, constitute a dominant group in India after the flowering plants. The fleshy fungi represent the majority of macrofungi and play an important role in being mycorrhyzic, edible, poisonous, decomposer system and raw material for industry.

The authors, Dr. J.R. Sharma and Dr. K. Das have been engaged in the studies on macrofungi of Himalaya. The present publication on such a diverse and complex group, is the first major contribution on fleshy macrofungi from Botanical Survey of India. Every aspect of this treatise proclaims the sound knowledge of the authors and reflect their long experience of working on this interesting and economically important group of plants. I hope, that this book will serve as a useful reference and identification manual and will be welcomed by students, mycologists, agriculturists, mushroom hunters, and foresters all over the world.

I congratulate the authors for accomplishing this arduous, yet masterly task exceedingly well.

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PREFACE

Russulaceae is one of the largest, most beautiful and economically important families of fleshy macrofungi. The family, represented by the genera *Russula* and *Lactarius*, dominates the macrofungal flora in Himalayan forests which provide sufficient vegetational diversity, rich environmental conditions for the growth and development of these fungi. This family includes some of the most poisonous fungi, few edible and medicinally important species besides a very rich percentage of ectomycorrhizal species, serving the obligate requirement of the forest trees. Though so important, yet only a little information is made available particularly from Himalaya.

This manual is divided into three parts. The first part is the "Introduction" giving a general account of the work done on Russulaceae both at international and national level and justifying the objectives of the study. The chapter on "technical terms" deals with the terms used to designate the characters in the manual. This is followed by a chapter on "methodology" depicting the methods of work followed during the course of this study. The chapter on "study area" gives a summary of the different areas surveyed with their names, type of forests, dominant tree species and approx. altitude in meters above mean sea level. The second part deals with the detailed taxonomical descriptions coupled with field photographs, line drawings depicting the macro- and microscopic characters of all the taxa collected from the study area and a parsimonious molecular tree justifying the placement of few confusing taxa. The third part is about the "ecological data" gathered on each taxon during the field survey.

We wish to extend our deep gratitude and indebtedness to Dr. M. Sanjappa, Director, Botanical Survey of India, Kolkata for providing facilities and the financial assistance to the senior author. Special thanks are due to Dr. D. K. Singh and Dr. M. S. Mondal, BSI, Kolkata; to Prof. R.P. Bhatt, H.N.B. Garhwal University, Srinagar for their constant guidance and encouragement being indispensable for the completion of this work.

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(Hong Kong) for providing help in identification, valuable suggestions and critical appreciation through regular correspondence and / or for providing some inaccessible literature. Our sincere thanks are due to Dr. V. K. Bhatt (Dehradun), Dr. G.S. Rawla (Chandigarh), Dr. P. Lakshminarasimhan (ex Indian Liaison officer at Kew), Prof. T.N. Lakhanpal (Shimla) and Prof. K.R. Samaddar (Kalyani) for providing literature and assistance in many ways.

Dr. L. Montoya helped in obtaining the Scanning Electron Microphotographs of basidiospores and Dr. S.L. Miller provided the result of the gene sequencing of some specimens.

Dr. P. Lakshminarasimhan, Royal Botanic Garden, Kew (K) and Mr. J. Vaurus, ABO Akademi University (TUR-A) kindly facilitated the loan of some Type specimens.The curators of the herbaria of Botanical Survey of India, Northern Circle (BSD), University of Ghent (GENT), Instituto de Ecologia (XAL), Museo Cantonale de Storia Naturale (LUG), National Museum of Natural History (PC), University of Wyomimg (Botany Department), ABO Akademi University (TUR-A) and Botany Department, H.N.B. Garhwal University (GUH) are thanked for arranging the submission of the herbarium specimens.

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We alone, however, are responsible for the errors in this book. We shall always welcome suggestions for improvement in the subsequent editions.

We dedicate this work to our dear parents.

K. Das
J.R. Sharma

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INTRODUCTION

The foundation for the systematic study on fungi was laid by Persoon in a series of papers "Observations Mycologicae" (1795-1799) leading to the monumental work, "Synopsis Methodica Fungorum" (1801). E.M. Fries became known as the "Linnaeus of Mycology" for his "Systema Mycologicum" vol. I-III (1821-1832) and "Elenchus Fungorum" vol. I-II (1828) which were the most important works on systematics especially with reference to the Hymenomycetes and remained the starting point for nomenclature of Hymenomycetes until recent past. His final concepts on the group were included in "Hymenomycetes Europei" (1874) according to which hymenomycetes with lamellate hymenophore were grouped in one order i.e. "Lamellato". This order included 20 genera and constituted what came to be known later as Agaricales.

The family Russulaceae, established by Roze (1876) as "Russulariees" (nom. nud) to include the genera *Russula* Pers.: Fr. [from a latin word 'Russulus' (= reddish)] and *Lactarius* Pers.: S.F. Gray [from 'Lac' (= milk)] has generally found its place under the order Agaricales (Singer 1962, 1975, 1986; Smith 1973; Pegler 1977; Stuntz 1977). Kühner (1980), Kreisel (1969) and Hawksworth *et al.* (1983) however, have raised it to the rank of order Russulales. Bucholtz (1902) however, attempted to separate the family from Agaricales and proposed a relationship between two genera of Russulaceae and certain hypogeal and epigeal genera of Hymenogastrales. Malencon (1931) drew a closeness between gasteromycetoid family Asterogastraceae and agaricoid family Russulaceae and postulated a separate order Asterosporales for them. Supporting Malencon (1931), Heim (1938) placed Russulaceae and Elasmomycetaceae under the order Russulales. Singer (1986) placed Russulaceae with family Bondarzewiaceae Kotlaba & Pouzar under a separate suborder Russulineae of the order Agaricales.

The systematic studies on the family Russulaceae started parallel in Europe and North America and many systematists have dealt with the taxonomy of *Russula* and *Lactarius*. A significant start on European *Russula* was made by Maire (1910). He published several classifications of the genus and also improved upon the earlier classification given by Fries (1821, 1836-1838). Knauth & Neuhoff (1937) initiated the monographic study on the genus *Lactarius* for the first time. Neuhoff (1956) recorded 69 species from Europe. Schaeffer (1952) published his monographic work and described 68 species in addition to the identification key for 104 taxa of *Russula*. Similarly, in North America Peck (1872, 1884 & 1907) and Burlingham (1907a, b, 1908, 1910a, b, 1913, 1915, 1918a, b, 1921, 1924, 1932 & 1940) started working on Russulaceae. Burlingham (1915) studied 115 species, placed them in

25 groups and also developed a key for their easy identification. She (1910b) also gave a comprehensive account of *Lactarius* flora of North America.

Rolf Singer (1926), one of the all time great mycologists produced a monograph on the genus *Russula* "Monographie der gattung *Russula*" which he revised in 1932. His works (1923, 1924, 1925, 1926, 1928a, b, 1931, 1932, 1935a, b, 1936, 1938a, b, 1952, 1957, 1958, 1975, 1982, 1986) on the genus from all over the world have undoubtedly proved him the most outstanding worker on Russulaceae known so far. In his publication (1986) Singer has recognized 317 species for the genus *Russula* under 11 sections (*Pellicullariae, Delicoarchaeae, Plorantes, Crassotunicatae, Compactae, Pachycystides, Metachromaticae, Decolorantes, Ingratae, Rigidae* and *Russula*). Following Sydney code (1982), Singer and Machol (1983) published the present status of the genus *Russula*. He also recognized a number of species of *Lactarius* collected and described from all over the world. Singer (1986) treated 122 species of *Lactarius* under 9 sections (*Panuoidei, Lactariopsidei, Polysphaerophori, Dulces, Plinthogali, Albati, Russulares, Lactarius* and *Dapetes*).

Romagnesi also worked actively on Russulaceae of Europe. He (1936, 1940, 1942, 1943a, 1945, 1967, 1970, 1972, 1985, 1996) worked on the *Russula* of France. In his monograph (1987) he gave a very comprehensive account of the genus and divided it into 9 subgenera (*Compacta, Heterophyllidea, Ingratula, Russula, Incrustatula, Tenellula, Polychromidea, Coccinula* and *Insidiosula*). He also investigated the *Lactarius* flora of France (1939, 1943b, 1949, 1958, 1963, 1974). Blum (1964, 1965) during his studies on the *Lactarius* flora of France worked especially on the sections *Aurantiacus, Piperatus* and *Lactarius*. Almost at the same time another European, Pearson (1948) significantly dealt with 66 species of *Lactarius* from Britain and divided them into 8 sections. Another important contribution was made on British *Russula* by Rayner (1968-1970).

Hesler & Smith (1960 a, b) and Smith & Hesler (1962) treated different sections of *Lactarius* occurring in North America. The most comprehensive and detailed study done so far on North American *Lactarius* is their (Hesler & Smith) monumental work i.e. "*North American species of Lactarius*" published in 1979. Here they treated 200 species and 60 varieties and grouped them under 6 subgenera (*Lactarius, Plinthogalus, Lactifluus, Piperites, Tristes* and *Russularia*). Shaffer (1962, 1964, 1970a, b, 1972). Bills (1984, 1985, 1986a-c, 1989) and Bills & Miller, Jr. (1984) described South Appalachian Russulaceae in detail. Miller *et al.* (1973) worked on Russulaceae of Alaska and Canada.

More recently, European *Lactarius* has been revised and an outstanding contribution on the genus is given by Heilmann-Clausen *et al.* (1998). They

divided the genus into 6 subgenera (*Piperites, Russularia, Plinthogalus, Lactifluus, Lactarius, Lactariopsis*) and modified the subgenera *Piperites* and *Russularia* given by Hesler & Smith (1979). Another monographic contribution on European *Lactarius* is given by Bon (1980). Kytovuori (1984) solved the taxonomic riddles within subsection *Scrobiculati* of European *Lactarius*. Studies on European *Lactarius* has been furthered by Basso (1994, 1997, 1998, 1999a, 2000) and Basso *et al.* (2001). She has also published a monographic work "*Lactarius* Pers." under Vol. 7 of Fungi Europaei series in 1999.

Montoya *et al.* (1990, 1996, 1998 & 2003), Montoya & Bandala (2003, 2004 a, b) have made significant contributions on Russulaceae of Mexico.

The work on the rich African flora of Russulaceae particularly on *Russula* has been undertaken by Buyck (1988, 1989a, b, 1991, 1993, 1994, 1995, 1997). His contributions culminated in "Flore illustrée des champignons d'Afrique Centrale" published by the National botanical Garden of Belgium (1993-1997). Currently Buyck (1995) is working on the *Russula* of the world.

The most updated and important contribution on the *Lactarius* flora of Africa and South East Asian tropical Rain forests has come from Verbeken (1995a, b, 1996a-d, 1998a, b, 2000, 2001), Verbeken & Horak (1999, 2000), Verbeken & Walleyn (2000) and Verbeken *et al.* (2000, 2001). Verbeken not only surveyed and studied vigorously but has also emended descriptions different subgenera (*Lactifluus, Plinthogalus, Lactariopsis*). Verbeken (2000) during her studies on tropical African mycoflora emended the subgenus *Plinthogali* and has divided it into three sections, viz., sect. Nigrescentes Verbeken (so far comprising only African representatives), sect. Pseudofuliginosi Verbeken and sect. Plinthogali. Verbeken (1998a) clearly defined all the pattern of pileipellis which has proved to be the most important parameter for the infrageneric classification of *Lactarius*.

Recently, Fatto (1996a, b, 1998a, b, 1999, 2000) has also made some contributions on the *Russula* of North America. Kibby & Fatto (1990) have published a comprehensive key on the *Russula* of North America.

The knowledge on European *Russula* has been enhanced by Krauch (1994, 1998, 1999, 2001), Krauch & Krauch (1995a, b, 1997), Jurkeit & Krauch (2000, 2001) from Germany and Vesterholt (2002) from Denmark.

An outstanding monographic work has been published recently by Sarnari (1998) on the European *Russula*. It deals with the critical analysis of all the nomenclatural problems and is probably the most practical classification of the genus. He has divided the genus into 6 subgenera (*Compactae, Heterophyllidia, Amoenula, Ingratula, Russula* and *Incrustatula*. His study has stressed more on microscopic features.

Adhikari (1988, 1990, 1999), Adhikari & Durrieu (1999) have made contributions on the *Russula* of Nepal, while Ying (1991), Wang (2000), Wang & Liu (2002) have contributed towards the Russulaceae of China.

Others who have contributed significantly to our knowledge of Russulaceae are: (Quelet 1886, Earle 1902a, b, Bataille 1908, Coker 1918, Ferdinandsen & Winge 1923, 1924, Melzer & Zvara 1927a, b, Zvara 1931, Melzer 1932, 1934, Konrad & Josserand 1935, Beardslee & Burlingham 1940, Murril 1948, Schaeffer *et al.* 1949, Schaeffer 1948, 1966, 1968, Pouzar 1968, Svrcek 1967, Groger 1968, Blum & Heim 1970, Heim 1970, 1971a, b, McNabb 1971, Bon & Gaugue 1972, Homola & Shaffer 1975, Homola 1976, Pegler & Fiard 1979, Pegler & Singer 1980, Lalli & Pacioni 1981, 1989, Bon 1988, Ruotsalainen & Vauras 1990, 1994 and Grgurinovic (1997).

The family Russulaceae has had a rich taxonomic history. The earliest infrageneric classification system, based purely on macromorphological and macrochemical characters were gradually replaced by classifications based on microscopic features, especially in the pileipellis. The recent classifications though more successful in approximating a natural classification, are still complex and largely incongruent and have been inadequate in resolving arguments regarding evolutionary relationships. Understanding of modern taxonomic tools will be very handy for solving integrated taxonomic problems such as refinement and circumscription of taxa, delimitation as well as identification of confusing taxa and evolutionary relationships. Phylogenetic analysis based on DNA sequencing of ribosomal genes by Miller & Buyck (2002) has given a hope to understand the evolutionary principles among members of Russulaceae and evaluate characters useful in taxonomy of the family and then construct a more natural classification.

WORK DONE IN INDIA AND KUMAON HIMALAYA

The taxonomic study of fungi dates back to Linnaeus who is considered as the first person to name a mushroom from India in the 18th century. Most of the macrofungi were collected incidently by naturalists and plant taxonomists during their study on Indian flora. Records and descriptions of these collections are scattered in the literature.

Berkeley (1851, 1852, 1854 & 1876) rendered an invaluable service by reporting many Indian Agaricales including nine species of *Russula* and five species of *Lactarius*, collected from Eastern and Western Himalaya by Hooker (1848-1850). All the collections are deposited in the herbarium of the Royal Botanic Gardens, Kew (K). After that, the study paused for a century till Ramakrishnan *et al.* (1953) recorded *Russula lepida* from Tamil Nadu and Chona *et al.* (1958) *Lactarius cilicioides* from Delhi.

Besides, the contributions from Patil & Thite, 1978 (Western India), Natarajan 1978, Sathe & Daniel 1980, Vrinda *et al.* 1997 (South India), Ray & Samajpati 1980 (Eastern India), Shajahan & Samajpati 1995 (Eastern Himalaya), a number of valuable contributions have been made by Bakshi (1974), Sharma *et al.* (1978), Kumar *et al.* (1979), Watling & Gregory (1980), Abraham *et al.* (1980, 1981), Saini & Atri (1981-1993), Saini *et al.* (1982-1993), Manjula (1983), Rawala & Sarwal (1983), Sarwal (1984), Abraham & Kaul (1985), Atri & Saini (1986-1990), Atri *et al.* (1991-1997), Rawala (1994-2002), Bhatt & Lakhanpal (1988, 1990), Bhatt *et al.* (1999, 2000), Das & Sharma (2001-2004), Sharma & Das (2002, 2003), Das *et al.* (2002-2005), Sharma *et al.* (2004) on the Russulaceous flora of western Himalaya.

The family Russulaceae was known only by 192 taxa from India out of which only nine taxa namely *Russula delica*, *R. densifolia*, *R. foetens*, *R. gracillima*, *R. heterophylla*, *R minutula* var. *robusta*, *R. nitida*, *R. versicolor* and *Lactarius subisabellinus* var. *murrillianus* were reported from Kumaon Himalaya (Rawla 2001 & 2002) till the present study was undertaken.

Keeping in view the vast area, presence of suitable microclimates, plenty of mycorrhizal hosts, favourable ecological conditions, the reported number of taxa appeared an underestimate and called for a thorough and systematic exploration of the group in Kumaon Himalaya. Further, many of the reported species were not thoroughly worked out in the light of modern taxonomic tools and their taxonomic circumscription remained insufficiently or incompletely known. The ecological data like mycorrhizal hosts, distribution, frequency of occurrence and constancy of species in different woodlands of different climatic zones was also unknown or not completely known. To fill all these gaps the present study on Russulaceae of Kumaon Himalaya was undertaken.

ECONOMIC IMPORTANCE

Out of the three well known functional groups (soil inhabiting, wood inhabiting saprotrophs & necrotrophs and ectomycorrhizals) to which the macrofungi are attributed, the family Russulaceae belongs to the ectomycorrhizals. The family includes a very rich percentage of ectomycorrhizal species serving the obligate requirement of the forest trees besides some of the most poisonous fungi, few edible and medicinally important species.

Most of the members of Russulaceae are found closely associated with forest trees such as *Quercus*, *Rhododendron*, *Shorea*, *Pinus*, *Cedrus*, *Abies*, etc. forming a symbiotic association between the fungal hyphae and the rootlets of forest trees. During this association, the accumulated soluble carbohydrates in rootlets of plant growing in strong sunlight, production of one or more

growth promoting or growth inhibiting metabolites, in addition to thiamine and one or more B vitamins attract the fungal symbionts from the soil to grow on the surface of roots and cause infection. The fungi in turn provide phosphorus, water and produce substances related to auxin that result in characteristic morphogenesis in short roots with which the symbiotic association has been established. These ectomycorrhizal fungi also provide some non nutritional benefits to tree seedlings such as ameliorating the effect of toxic heavy metals (Wilkins 1991; Wilkinson & Dickinson; 1995), reducing host water deficit under conditions of mild drought (Parke *et al.* 1983) and protecting seedlings from infection by soil born root pathogen (Marx 1972; Chakravarty and Unestam 1987). In India also, the members of the family have been introduced (Singh & Lakhanpal 2000) in Mycorrhizal biotechnology in the forest nurseries to get the significant growth and development of seedlings of important forest trees.

Some members of the Russulaceae like *Lactarius deliciosus* and *L. sanguifluus* are taken as food in Europe, Asia and North Africa. *Lactarius resimus, L. scrobiculatus, L. torminosus* and *L. piperatus* are highly prized in many countries of the world where they are mostly salted or pickled. In Africa, some species viz., *Lactarius edulis, L. gymnocarpoides, L. longisporus, L. xerampelinus* (Verbeken *et al.* 2000) are reported edible and have familiar local vernacular names. *Lactarius deliciosus, L. sanguifluus, L. subpurpureus, L. hygrophoroides, L. paradoxus, Russula virescens* and *R. brevipes* are eaten as delicacies in Himalayan villages. *Lactarius subpurpureus* is more popularly called as 'khooni cheuon' by the local Himalayan people.

However, some species such as *Russula foetens, R. subnigricans* (Hongo, 1960), *R. emetica, Lactarius helvus, L. pallidus, L. baliophaeus* and *L. brachystegiae* are known to contain irritant principles which bring about "gastro-enteritis" by direct action on the mucous lining of the intestine. They are rated among the highly poisonous fungi responsible for carrying specific poisoning.

A few members of *Russula* such as *R. delica* and others are considered as a good source for certain enzymes, especially tyrosinase. Species of the genus *Lactarius* are a good source of various raw materials for drug production. Lactaroviolin isolated from *L. deliciosus* has the antimicrobial (antibiotic) activity against *Mycobacterium tuberculosis*. Similarly, *L. chrysorheus* shows antibiotic activity against gram negative bacteria such as, *Escherichia coli* and *Shigella sonnei* whereas, *L. deliciosus* and *R. delica* show the antimicrobial activity against *Bacillus cereus* and *E. coli*.

TECHNICAL TERMS

A brief account of the technical terms to denote the morphology of various structures is presented below. An excellent account of these structures has also been given by Singer (1962, 1975, 1986); Largent (1973); Hesler & Smith (1979); Ammirati *et al.* (1985); Verbeken (1998) and Heilmann-Clausen *et al.* (1998).

1. Macromorphology :

(a) Pileus :

(i) Size : Size of the pileus is measured at its widest dimension. It ranges from a few millimeters to about 280 mm. It is often variable among collections of the same species from different locations.

(ii) Shape : The outlook of the pileus is sometime characteristic for a given species. One of the most commonly found pileal shapes in young stage is **convex** i.e. regularly rounded or of an inverted bowl. The width of a convex cap (pileus) is normally greater than its height. Most convex caps continue to enlarge laterally with age, causing the width / height ratio to increase. Often this results a shape of **planoconvex**, then appearing almost flat i.e. a shape called **applanate**. Margin of the cap starts turning upwards to give at first a shape called **planoconcave** and finally becoming **uplifted**. Sometimes a cap contains a protrusion or bump called an umbo and the cap is called **umbonate**. The umbo occasionally could be sharply delineated but not elongated, giving the pileus a breast-shaped structure, known as **papillate**. The opposite condition from a bump is the development of a depression in the centre of the pileus. The pileus is called **depressed** and is often correlated with uplifting of the pileal margin. The depression may resemble a funnel, called **infundibuliform**. The depression might be of small diameter (narrowly depressed) or of large diameter (broadly depressed). Fig. 1 shows different shapes of pileus.

(iii) Colour : The colour exhibited by basidiocarps is as varied as in flowers. Common terms for colour used here are after Kelly & Judd (1955). As colour is often affected by the age of basidiocarps and the environment, so the colour range of young and old basidiocarps of one type is always recorded.

(iv) Margin : Margin of a pileus may vary from completely unexpanded to completely expanded. If the margin is rolled inward so that it points towards itself, it is called **inrolled**. When it is less curved i.e. pointing to the gills, is called **incurved**. It might be more or less parallel or pointing to the stipe and termed **decurved**. As the pileus expands, the margin usually

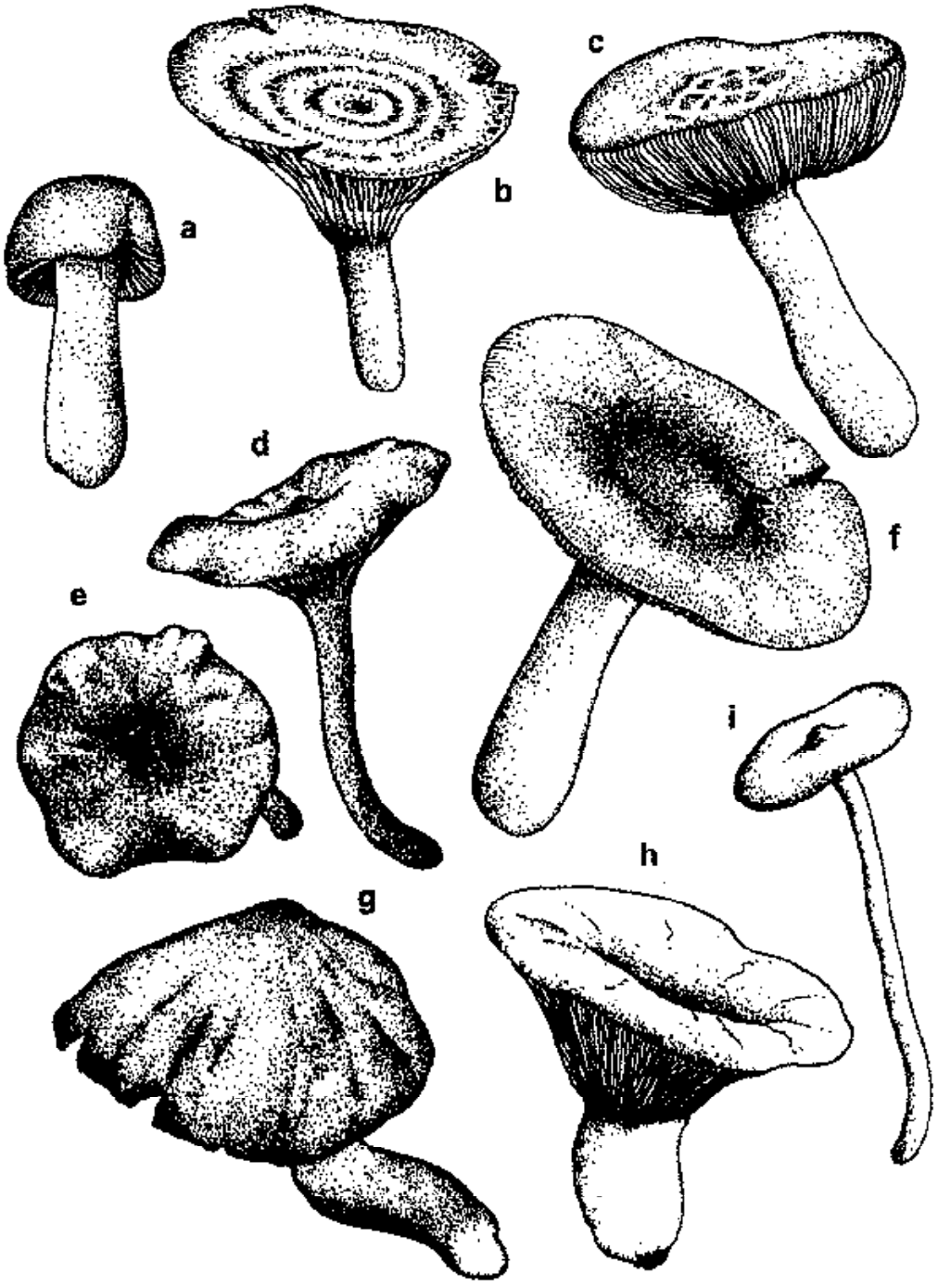


Fig. 1. Shape of pileus: a. Convex b. Planoconcave c. Applanate d, e & i. Papillate f. Depressed g. Umbonate h. Infundibuliform.

becomes pulled upwards to become plane or pointed upward, called **uplifted**. The Shape of the pileal margin of a young basidiocarp begins to be a perfect circle, a condition known as **entire**. As the basidiocarp gets older, the margin becomes interrupted to different degrees. If the interruptions are regular, like the edge of a scallop, the margin is said to be **crenate**. If the margin is broadly wavy, it is termed **undulating**. Often the surface of the margin appears to have lines of varying lengths oriented radially. The lines or striations might represent an image of gills seen through the top of a wet pileus, a condition known as **translucent-striate**. If the lines are not the image of the lamellae, but the part of the pileus itself, the margin is **striate**. When the lines form definite grooves, the margin is called **sulcate**. If small bumps are present on the striae, the margin is called **tuberculately striate**. In certain species particularly belonging to *Lactarius* the margin is characteristically hairy and this is very helpful in their identification. Fig. 2 shows different types of margins.

(v) Surface : The system of hyphae which comprise the surface of pileus is called **pileipellis** or **pileus cuticle**. The surface can be shiny, as if it were polished or it can be dull, lacking a lustre.The surface of the cap is dry if it has no moisture at all. Some caps have a tacky to sticky feeling when moist, due to water absorbtion by the surface. As a result the surface shows a liquid glue or jelly like consistency. If the consistency of the surface is like liquid glue, then it is called **glutinous** and if it is jelly-like, then the surface is **gelatinous**. Depending upon the strickyness, the surface may be **subviscid** or **viscid**.

The hyphae of pilear surface are arranged and associated in various ways. Often the cap is bald, evenly smooth like a waxed surface a condition described as **glabrous**. If the pileus is covered with a fine powder as if it were sprinkled with a very fine flour, it is **pruinose**. When the powder is bran-like in size and the pileus appears scurfy, it is **furfuraceous**. Sometimes, the hyphae agglutinate laterally on the pilear cuticle and form a texture with visible filaments or fibrils. A cap with this type of surface is called **fibrillose** and **appressed fibrillose** when the fibrils are appressed on it. When the fibrils have the appearance of cotton flannel, the term **floccose** is used. If the fibrils are densely matted and wooly, like a woolen blanket, the term **tomentose** (**velvety**) is used. A condition close to tomentose where the fibrils are matted and interwoven, appearing like a felt, is called **matted-fibrillose**. Agglutination of fibrils can occur at the tips of the hyphae as well as laterally. When the tips stick together, a scale is formed. A scaly surface is called **squamose**.

A **smooth** surface has no cracks, wrinkles or pits. The surface can be split, usually in a radial manner, with the splits normally extending through

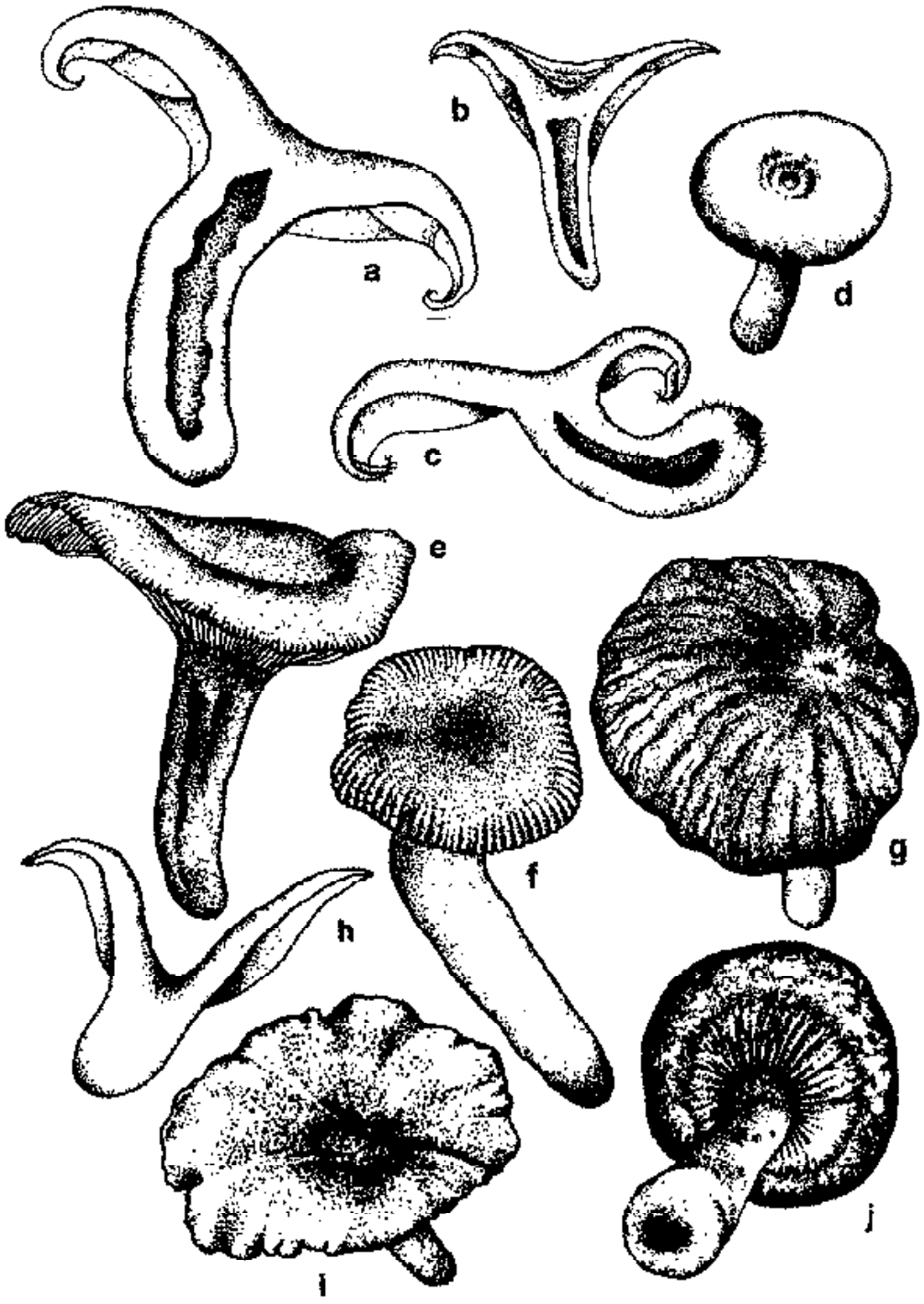


Fig. 2. Margin of pileus: a. Inrolled b. Decurved c. Incurved d. Entire e. Crenate f. Tuberculately striate g. Irregularly lobed h. Uplifted i. Irregularly wavy to folded j. Hairy.

the cuticle. In this case, the pileus is called **rimose**. If the splits and cracks are deep, cutting the surface into rather large segments, the surface is called **lacirate**. If the surface gets torn into shreds or splits are irregular and results in the formation of block-like areas like those formed when a mud flat dries up, the surface is **areolate**. A finely and irregularly wrinkled cap surface is **rugulose** while a coarsely wrinkled one is called **rugose**.

(b) Lamellae :

(i) Attachment : The manner in which the lamellae are attached to the apex of the stipe is an important feature. The situation where the lamellae (gills) do not meet the stipe at all, is termed **free**. **Adnexed** applies to the situation where the gills appear as if only a portion of their width is attached and the resultant shape is as if a large triangular piece had been removed from that portion of the gill where it meets the stipe. **Emarginate** applies if the gills appear sharply adnexed. **Notched** describes gills that appear as if a small notch has been taken out at the point where they meet the stipe. The situation where the gills are more or less squarely attached to the stipe, meaning along most of the gill width, is called **adnate. Decurrent** is the term used when the gills run down the stipe. If the distance down the stipe is relatively short, the attachment is said to be **subdecurrent**. Fig. 3 shows different types of attachments of lamellae.

(ii) Spacing : This is an arbitrary feature but is sometimes useful in differentiating closely related taxa. The spacing of gills is considered from the margin excluding the lamellulae. To make the spacing more specific terms like **distant** (up to 4 per cm), **subdistant** (5-6 per cm), **close** to **rather crowded** (7-10 per cm) and **crowded** (more than 10 per cm) are used in this manual.

(iii) Margin : The feature of the gill edge is important. When the colour of the gill edge is same as the face, it is **concolorous** and it is called **marginate** when different. When the gill edge is minutely torn or fringed and the tears are so large that the edge appears toothed like the edge of a saw, it is **serrate** or **serrulate**. If the margin is regularly wavy like the edge of a scallop, the term **crenate** is used and it is **crisped** the waviness is quite small, more or less regular.

(iv) Branching : Some basidiocarps produce gills that are branched or **forked**. Short veins may connect the face of one gill to another or extend into the interspace between two gills. Gills of this nature are described as **interveined**.

(v) Colour : It is very important to note the colour of young and mature gills. Colour changes after bruising are also very important and should be recorded carefully. In case of *Lactarius*, colour of the cut edges (after reacting with the latex) also forms an important character.

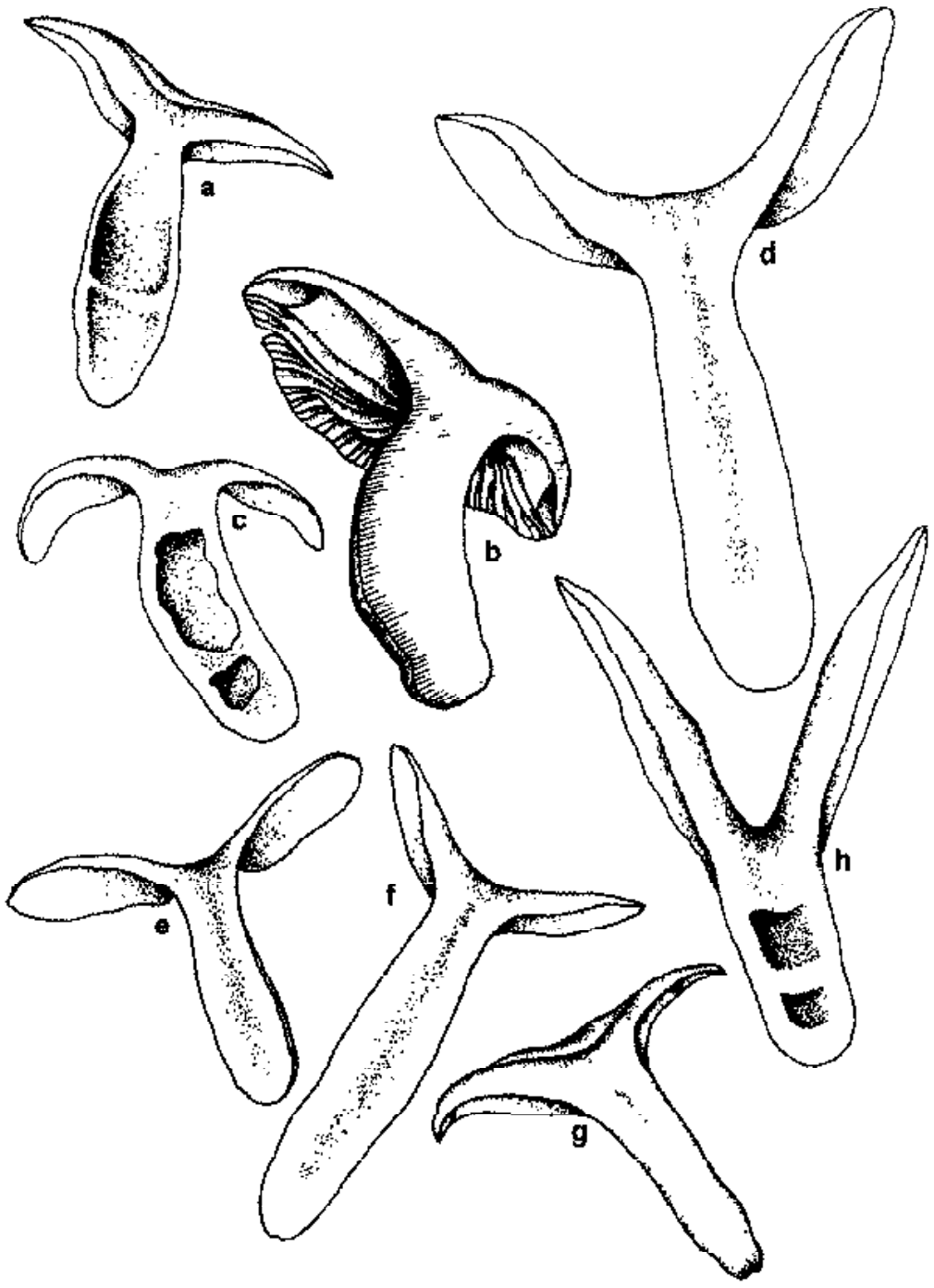


Fig. 3. Lamellar attachment: a. Adnate b. Adnate to adnexed c. Adnexed d & f. Adnexed to subdecurrent e. Notched g. Subdecurrent h. Decurrent.

(vi) Lamellulae : Some gills do not extend the full distance from the cap edge to the stalk and such short gills of different lengths are called **lamellulae.**

(c) Stipe : It refers to the stalk or stem of the basidiocarp. The length of the stipe is measured from the substrate to the attachment with the pileus. The width at the thickest portion is recorded.

(i) Attachment to the pileus : The usual pattern called **central** for the stipe is to attach in the center of the pileus. If the attachment is at the margin of the pileus, it is called **lateral.** Any attachment intermediate between central and lateral is termed **excentric.**

(ii) Shape : Stipe having same diameter from apex to base in longitudinal view, is **cylindric.** It may be **tapered** in one direction or another. A club shaped stipe, is termed **clavate** or **subclavate.**

(iii) Surface : The surface can be smooth without any striation. The surface may be **ridged** or **wrinkled.** If the ridges are just fine lines, and the lines tend to be longitudinal and more or less parallel to one another, the surface is called **longitudinally striate.** If the striations are interconnected and form wrinkles, the surface is **rugulose** (finely wrinkled) or **rugose** (coarsely wrinkled). When the wrinkles are more definite and have rounded edges, the surfaces are called **veined.** When the wrinkles are irregular and broad giving the surface an irregular wavy shape, the surface is called **longitudinally grooved** (*L. capitatus*). Occasionally, the surface appears **scaly** or **scurfy.** Sometimes the surface has nearly transparent spots (scrobiculate) (*L. mayawatianus*) or pits (pitted) (*L. abbotanus*).

(iv) Context : The context of the stipe varies from the **solid** (hyphae closely packed) to **hollow** (centre becomes empty), **stuffed** is an intermediate condition between solid and hollow. The context on exposure usually does not change in colour, but sometimes such a colour change on exposure is characteristic.

(v) Colour : Colour of the stipe from base to apex is recorded and varies mostly from white to yellowish, pink red or brown to black. The stipe may be concolorous with pileus or differently coloured. Sometimes, the colour at stipe base (*R. mukteshwaricus*) or at stipe apex (*R. brevipes*, var. *acrior*) is important and help in sepration of closely allied taxa. Colour changes after bruising also form an important taxonomic character in certain species.

(d) Spore print : The colour of spores en masse, is mostly white to pale yellow and usually does not form as imporant taxonomic character. However, in case of the subgenus *Amoenula*, the colour codes of Romagnesi (1996) helped to some extent in the segregation of closely related himalayan taxa.

(e) Latex : The flesh and gills of *Lactarius* produce a milk-like or watery substance referred to as **latex**. It is the most important identififying character of the genus.

2. Micromorphology

(a) (Pileipellis) and **(stipitipellis) :** Fig. 4

The hyphal arrangement and shape of terminal cells in the upper most layer i.e. suprapellis and the next layer i.e. subpellis are important features in the separation of taxa at various levels. In case of *Lactarius*, terminology used to define the arrangement specifically, is following Verbeken 1998, Heilmann-Clausen *et al.* 1998.

(a1) Pellis without inflated elements or sphaerocytes, composed entirely of filamentous hyphae :

(i) Cutis : Consisting of thin-walled hyphae, which are more or less repent and parallel or slightly intermixed.

(ii) Ixocutis : Like a cutis, but the upper layers of hyphae embedded in a gelatinous layer.

(iii) Trichoderm : Consisting of thin-walled hyphae, which are ascending from a basal layer and then ascending or oblique. In the most typical case all terminal elements are ascending and form a dense turf of erect hyphae.

(iv) Ixotrichoderm : Like a trichoderm, but with the ascending hyphae embedded in a gelatinous layer.

(v) Lamprotrichoderm : Like a trichoderm but the ascending terminal elements are clearly differentiated and thick-walled.

(a2) Pellis with a distinct layer of inflated elements or sphaerocytes:

(i) Epithelium : Cellular to subcellular structure, pseudoparenchymatic structure, with upper layer of more or less isodiametric cells.

(ii) Palisade : Upper layer of ascending, elongated, hair-shaped elements and an underlying dense and compact layer of isodiametric cells.

(iii) Lampropalisade : A palisade with thick-walled terminal elements.

(iv) Hymeniderm : Special case of palisade where the terminal elements are not elongated and septate but clavate; the underlying layer of isodiametric cells is often rather thin, the whole structure reminding of a hymenium.

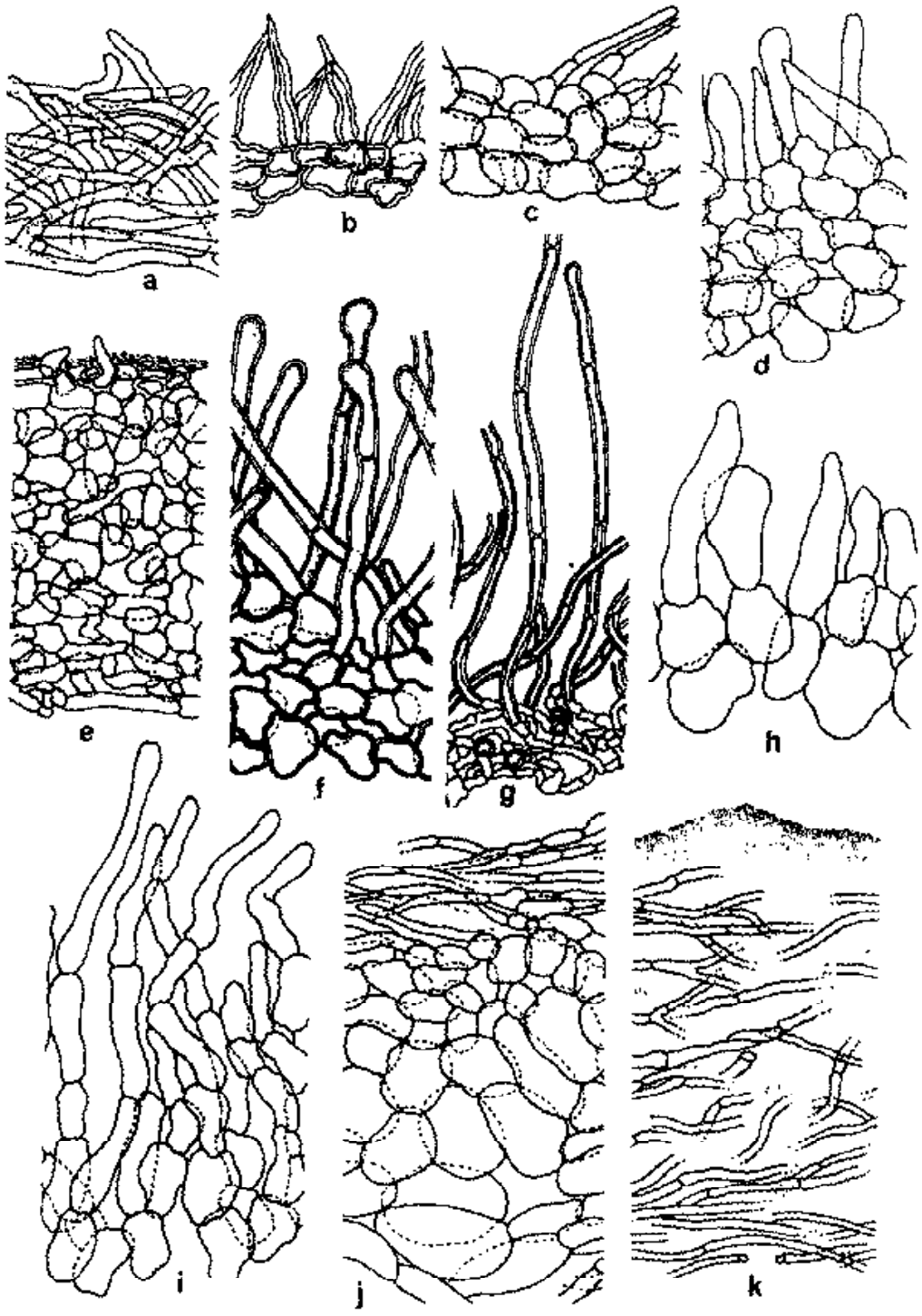


Fig. 4. Pileipellis: a. Trichoderm b. Lampropalisade c. Hyphoepithelium d. Palisade e. Hyphoepithelium f. Lampropalisade g. Lamprotrichoderm h. Hymeniderm i. Trichopalisade j. Two layered; suprapellis hyphal, subpellis cellular (pseudoparenchymatous) k. Ixocutis.

(a3) Pellis with isodiametric cells or sphaerocytes, but never forming a distinct layer :

(i) Trichopalisade : Between a trichoderm and a real palisade. This may look like a trichoderm where parts of the ascending, anticline hyphae are inflated or almost rounded. It may also be a structure where some of the terminal elements are ascending from isodiametric cells, others are ascending from hyphae.

(ii) Lamprotrichopalisade : A trichopalisade where the terminal elements have thickened walls.

In case of some species of *Russula*, walls of some hyphae of pellis may be incrusted due to the deposition of various materials. Often, the pellis of the species of *Russula* is characterised with hyphae and distinctly differentiated cells with dense contents, termed **dermatocystidia**. They are called **pileocystidia** on the surface of pileus and **caulocystidia** when present on the stipe surface.

The cystidia may be **cylindric** having parallel sides, a rounded apex and relatively narrow width; resembling a cylinder in shape. Cystidia which appear club shaped, are called **clavate**. The term **fusoid** or **fusiform** applies where cystidia are spindle shaped; tapered at both ends. The shape may be **ventricose** which is broadest in the middle and tapering towards ends. The apex of cystidia may be pointed i.e. **acute**. In **capitate** cystidia, the apices are rounded or with a round distinct head. Apex may be **mucronate,** narrowing abruptly into a pointed protuberance.

(b) Hymenium :

(i) Basidia : The basidium is typically single celled and thin walled. Normally, it bears 4-basidiospores and is **subclavate** to **clavate** when mature. Basidium bears the basidiospores on sickle-shaped apical extensions, called **sterigma** (**sterigmata** = plural).

(ii) Basidiospores : Fig. 5

Spore shape is determined with the help of spore quotient. **Quotient** (Q = L/W) is calculated considering the mean value of length and width. The shape of spores is distinguished as: **globose** (Q = 1.00 1.05); **subglobose** (Q = 1.05 1.15); **broadly ellipsoid** (Q = 1.15 1.30) and **ellipsoid** (Q = 1.30 1.60).

The ornamentations of spores are observed in Melzer's reagent. Basidiospores of Russulaceae are mainly amyloid (a blue to black reaction). Based on four variables i.e. the height of the ornamentation, the shape of

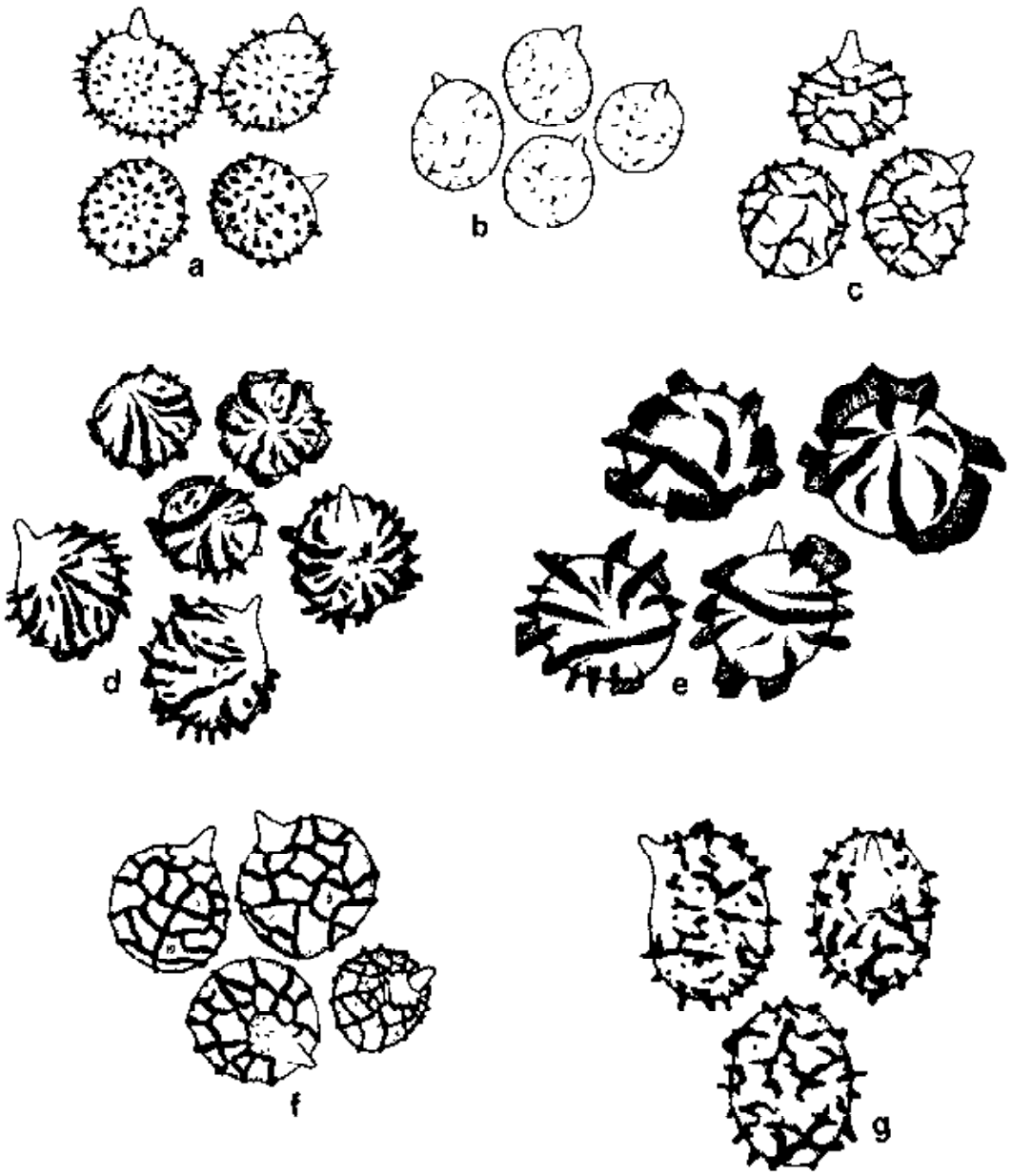


Fig. 5. Basidiospores: a. Isolated warty b. Warty with short ridges c. Partial (incomplete) reticulum d. Zebroid e. Winged f. Reticulate g. Broken reticulum.

the basal ornamentation, the degree and mode of connection between the basal units and finally the overall pattern are considered in an analysis of spore ornamentation. These patterns are described below.

- The **isolated warty** to **spinose** type lacking significant amyloid connecting lines between the elements. The warts or verrucae may be rounded, cylindrical, conic, acute or irregularly shaped.
- With **warts and short ridges** (crests), but mostly unconnected.
- **Broken reticulum** i.e. many of the ridges are so placed that the ends are continued to form reticulation.
- '**Zebroid pattern**' i.e. composed of unconnected ridges and warts, running parallel and resembling the strips on a zebra.
- **Partial reticulum** i.e. in a number of instances the lines fuse to form an enclosed area often more or less pentagonal or hexagonal in shape. Type three differs from type five in that the ridges seldom actually connect to each other.
- **Reticulate** i.e. the meshes of reticulum are mostly complete, and unconnected warts and ridges are rare to scattered.
- **Winged** i.e. occasionally, the ridges of basidiospores are too long and give winged appearance.

(iii) Hymenial cystidia : Fig. 6

(1) **Pleurocystidia and Cheilocystidia** : They are the commonest type of cystidia found both in *Lactarius* and *Russula* and arise usually from deep in the hymenium and may be thin- or thick-walled. They are called pleurocystidia (face of lamellae) or cheilocystidia (edge of lamellae) and play and important role in the identification of the taxa in Russulaceae. In the genus *Lactarius*, the ends of the lactifers also project beyond the hymenium and are called **pseudocystidia**. To differentiate the true cystidia from the pseudocystidia, the term, **pleuromacrocystidia** and **cheilomacrocystidia** have been used in case of *Lactarius* (Heilmann-Clausen *et al.* 1998). In case of *Russula*, as there are no lactifers and pseudocystidia, so the terms pleurocystidia and cheilocystidia only are used to represent the hymenial cystidia.

The cystidia may be **cylindric**, **fusiform, clavate**, **ventricose** or **lanceolate** (narrowly elliptical, tapering to each end). The apex may be **rounded, capitate**, **mucronate, moniliform** (cylindric but contracted at regular intervals like a string of beads) or **appendiculate** (with small appendages) or **lageniform** (like

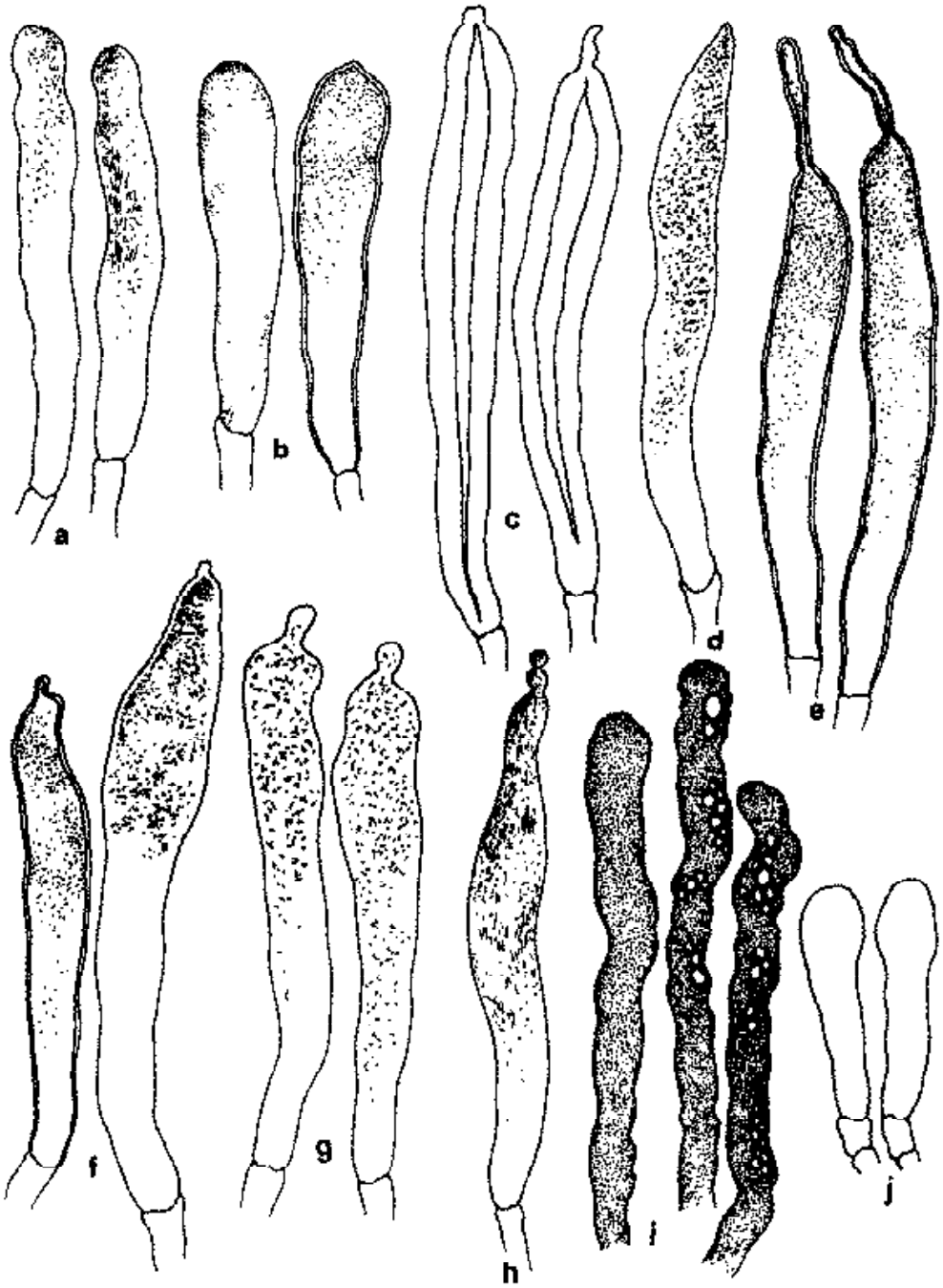


Fig. 6. Macrocystidia (a-h): a. Cylindrical b. Clavate c. Very thick-walled d. Fusiform e. Appendiculate (lageniformed or tailed) f. Mucronate g. Capitate h. Moniliform i. Pseudocystidia j. Paracystidia.

a gourd); or **aculeate** (tapered so that only the very basal portion is relatively swollen). Cystidia may be characterized with needle-like granular dense contents.

(2) **Paracystidia**: The smooth, sterile, cylindrical to clavate organs of the same size as basidia found near the edge of lamellae in species of *Lactarius* are called paracystidia. They are always thin-walled with round apices and without specific contents.

(c) Subhymenium :

The subhymenium is a region of tissue from which the hymenial elements originate. In Russulaceae, subhymenial layer is mainly **cellular** i.e. composed of mostly isodiametric to ellipsoid cells.

(d) Trama :

It is the central (core) sterile tissue of the hymenophore. One of the most striking characters of *Lactarius* is the presence of Lactiferous hyphae (lactifers) distributed all through the trama. The trama of *Russula* and *Lactarius* is termed heteromerous because of the presence of **sphaerocytes (globose cells)**. These sphaerocytes occur in clusters, called **rosettes**. The complexes of sphaerocytes mostly consist of only one primary rosette in *Lactarius*, while in *Russula* several primary rosettes accumulate, resulting in much larger complexes of sphaerocytes than observed in *Lactarius*. Traditionally, the hymenophoral trama in *Russula* is considered cellular, i.e. composed of numerous rosettes, and in *Lactarius* composed mostly of filamentous hyphae intermixed with some sphaerocytes in tropical species. But there is no clear cut distinction as some temperate species also contain sphaerocytes in gill trama.

(e) Lactifers :

They are the latex containing hyphae which are mostly non-septate, often branched and 4 15 µm broad. Under the microscope, the latex observed in lactifers appears as an emulsion of numerous very small guttules (0.5 1 µm in diam.). The guttules of this emulsion sometimes conglomerate to larger guttules but the emulsion changes quickly into small, bent crystals. Thus, the contents of the lactifers in dried material look like a dense mass.

METHODOLOGY

A. Collecting

Collections were made during the survey and collection tours undertaken every year during June to October to different parts of Kumaon Himalaya (Pl. 1-4). Members of Russulaceae are fragile (brittle), so one representative specimen of each species was collected and wrapped in waxed or blotting paper in such a way that moisture did not enter. The wrapped basidiomes were then placed in a basket and carried to base camp for further study. Additional specimens of each species were brought to the base camp in separate paper bags. The specimens were properly labelled with collection number, type of habitat, date of collection, frequency of occurrence, name of the associated host, forest type and name of the collector.

All the collections have been deposited in the Cryptogamic Herbarium (BSD), Botanical Survey of India, Northern Circle, 192, Kaulagarh Road, Dehradun 248 195, and a part in the Herbarium, Department in Botany, H.N.B. Garhwal University, Srinagar (GUH) India. Isotypes and paratypes of most of the specimens are also deposited with : A. Verbeken, University of Ghent (GENT), Gent, Belgium; Dr. L. Montoya, Instituto de Ecologia (XAL), Xalapa, Mexico; Dr. M.T. Basso, Via Valbona 61, Alassio-Moglio (SV), Italy & Herbarium, Museo Cantonale di Storia Naturale (LUG), Lugano, Switzerland; Dr. B. Buyck, National Museum of Natural History (PC), Paris, France; Dr. S.L. Miller, University of Wyoming, USA and Mr. J. Vauras, Herbarium TUR, (TUR-A), University of Turku, Finland.

B. Preservation

(i) Dry preservation : Freshly collected specimens were kept in the base camp for 24 hours and then wrapped in a sheet of filter paper and kept in the open air under sunlight or near the artificial fire place. Larger specimens were sectioned longitudinally and then dried. Dried specimens were poisoned with mercuric chloride solution (1:1000 ml) or paradichlorobenzene and dried again to avoid insect damage. These specimens were then enclosed in the standard herbarium packets with naphthalene balls.

(ii) Wet preservation : It was done for some specimens in alcohol-formalin solution following Ainsworth 1971 [Formalin (40%) 25.0 mg; Alcohol (95%) 50.0 ml; Water 1000.0 ml]

C. Macroscopic studies

The shape, size and identity of the Russulacean taxa fade away considerably on drying. Therefore, all the specimens were studied for their

macroscopic characters after reaching at base camp and on the date of collection. Measurements of pileus, lamellae and stipe were made on mature basidiocarp only. Following macroscopic features were noted:

(i) Pileus : Shape (before and after maturity), size, pileipellis texture, colour, colour change after bruising and details of margin.

(ii) Lamellae : Attachment of lamellae, spacing (density) of lamellae (excluding lamellulae); details of margin, forkation, colour, presence or absence of lamellulae and taste.

(iii) Stipe : Length and width, shape stipitipellis surface, overall colour and colour change after bruising.

(iv) Context of pileus and stipe : Solid or hollow, colour change after bruising, odour and taste (distinctive or not).

(v) Spore print : Spore prints were obtained in the base camp by placing the pileus down on both a white and black piece of paper and covering the whole with a jar or by placing both the basidiocarp and paper in a plastic sandwitch bag. In case, where only one or two specimens were found, a small hole was made in the paper for the stipe without removing it (Malloch 1971) or a piece of pileus was removed and put on a piece of paper.

(vi) Chemical spot tests : The spot tests for colour reactions on fresh specimens were recorded following Largent *et al.* 1977 with 10% aqueous NH_4OH, (10gm of NH_4OH dissolved in 90 ml of water) Sulfobenzaldehyde (SBA), Sulfovanillin (Purevanillin 2gm; distilled water-6 ml; conc. sulphuric acid-16ml), 10% aquous KOH and results recorded only wherever they were significant and helped taxonomically. However, in *Russula* the reaction with $FeSO_4$ shows a change in colour to salmon pink except in a few species. This reaction is recorded as $FeSO_4$(+) or $FeSO_4$(-).

D. Microscopic studies

In the laboratory, microscopical characters were studied with the freehand sections of fresh as well as preserved material. The observations were made at original magnification of 1500x for basidiospores, 1000x or 5oox for cystidia, basidia and hyphae and of 500x for other microstructures. Measurements of basidiospores, basidia and cystidia have been represented by numbers carrying the length and breadth separated by a sign (x). However, exceptionally small or large basidiospores are represented by including the respective numbers in parentheses.

(i) Basidiospores : Basidiospores (mostly taken from the spore print) were mounted in Melzer's reagent (Iodine-1.5 gm, Potassium-Iodide-5 gm,

Plate 1: a, b & c. Typical temperate deciduous forests.

Plate 2: a, b & c. Himalayan coniferous forests.

Plate 3: Russulas on the forest floor growing either closely to the forest trees forming mycorrhizae (a & b) or in a characteristic fashion forming fairy ring (c).

Plate 4: a & b. Confirmation of ethnomycological data in the field c. *Russula virescens* growing in close association with the roots of *Pinus wallichiana*.

Chloral hydrate-100 gm and distilled water-100 ml) following Largent *et al.* (1977) and examined under oil immersion to study ornamentations. Basidiospores were usually measured in face and / or side views. The length (L) and width (W) of at least 20 species (selected at random basis) is measured. Spore measurement of length and width is experessed as a range, with the length given first. **Quotient** (**Q** = **L/W**) was calculated considering the mean value of length and width. The measurements presented in this mannual are excluding the height of ornamentation.

(ii) Hymenium : Hymenium was studied with the freehand sections of mostly dry material. A wedge shaped section of pileus was removed. From this piece of tissue tangential sections were cut through the pileus including lamellae. Thin sections were mounted in 5% KOH (5 gm KOH dissolved in 95ml water); Lactophenol (5gm lactic acid, 5 gm phenol, 10gm glycerine, 5ml water); cotton blue (50ml of 1% aquous solution of Cotton Blue, 100gm Lacticacid, 100gm phenol, 150ml glycerine, 50ml H_2O); Carbol (0.1% cotton blue in 60% lactic acid); Fuchsin and Congo red (2gm of Congo Red dissolved in 98ml water).

(iii) Pileipellis and stipitipellis : Thin sections were cut from the wedge shaped tissue taken from pileus and stipe to observe the details of pileus cuticle (pileipellis) and stipe cuticle (stipitipellis). The arrangement of hyphae in suprapellis and subpellis, shape of the terminal cells of hyphae and shape of dermatocystidia (if present) were also recorded.

E. Ecological Studies

Following features were noted in the field for each species:

(i) Substratum : exposed or shady, moist or dry, type of forest, etc.

(ii) Habit : erect, decurrent, inverted, solitary, gregarious, caespitose or crowded, etc.

(iii) Prevalence : abundant, common and rare.

(iv) Mycorrhizal association : mycorrhizal associations were ascertained in almost all the recorded species of *Lactarius* and *Russula* with roots of hardwood or coniferous trees by establishing the association between the fungal hyphae and the rootlets.

F. Presentation

The distinguishing characters of the family Russulaceae are followed by a key to the genera. Each genus and all subgenera under each genus are defined with a summary of the identifying features as found applicable to

the Himalayan collections. All the species and varieties belonging to a subgenus are keyed out based on the characters gathered from the materials studied and as applicable to the Indian specimens. The genera, subgenera under each genus and species under each subgenus are treated alphabetically.

Each taxon is provided with a currently accepected correct taxonomic name, detailed description depicting the macro- and microscopic features coupled with field photographs and line drawings. Data about the frequency status, associated host plant(s) and forest type(s) is provided under "Ecology". The personnel experience and judgment supported by the number of basidiomes encountered at each study site and then averaged for each forest type formed the basis for assigning the frequency status to each taxon as *Rare:* (1-10 basidiomes, present in 5-10 of the localities surveyed); *Common* (approx. 100 basidiomes; present in about 50% of the localities surveyed) and *Abundant:* (>100 basidiomes, present in almost all the localities surveyed). Under the "specimens examined" each collection no. is preceded by the name of the state, district, place of collection, month of collection and the name of the collector(s). The critical "notes" including the distinguishing characters of each taxon and its separation from the closely related taxa are given at the end of the description.

The chapter on ecological studies includes a summarized account of forest types, mycorrhizal hosts, altitudinal range of distribution and frequency of occurrence for each taxon recorded during the course of this study. It is followed by the analysis of the data and a note on the conservation status of Russulaceae.

A parsimonious molecular tree based on the sequencing of ribosomal DNA (Fig. 79) was obtained from Dr. S.L. Miller, Wyoming University, USA. for certain specimens whose detailed morphological and anatomical features were not enough to justify their position. These studies not only confirmed the status of some new taxa but also proved their closeness with the already described taxa.

Russula abbotensis Das & Sharma and *R. vaurasiana* Das & Sharma are new species while *R. amoenicolor* Romagnesi var. *ramgarhensis* Das, Sharma & Bhatt and *R. flavida* Frost var. *dhakurianus* Das, Sharma & Bhatt are new varieties proposed in this manual. *Russula nothofaginea* Singer and *R. decipiens* (Singer) Svrcek have been recorded from India for the first time. All the taxa proposed as *Russula* sp. in this work are under consideration of publication with suitable specific epithets and expected to appear in the ensuing volumes of MYCOTAXON.

STUDY AREA

Kumaon is one of the five geographical zones i.e.- Nepal, Kurmanchal, Kedarkhand, Jalandharkhand and Kashmir of the Himalaya. It is believed that the word Kumaon is derived from "Kurmanchal" which means the land of Kurmavatar (The tortoise incarnation of Lord Vishnu).

Kumaon Himalaya extends from 78° 45' to 81° 05' East and 28° 45' to 30° 49' North, covering an area of about 21035 sq. Km. It is separated from Nepal by the river Kali in the East and Kailas Mansarover region of Tibet is to the North. The Garhwal Himalaya are in the West, while Uttar Pradesh borders it in the South. The region is spread over 6 districts, 31 cities and towns and about 7238 villages.

Geographically, Kumaon can be divided into four almost parallel zones: 1. Tarai-Bhabar-Shivaliks, 2. Lesser Himalaya, 3. Greater Himalaya and 4. Tethys or Trans Himalaya. Except for the tarai, Kumaon is totally hilly, beginning at 250 meters above mean sea level (msl) and rising up to 7816 meters msl. The region may be divided into three major climatic zones, viz., i) tropical or subtropical up to 1500 m, ii) temperate (1500-2800 m), iii) alpine zone (above 2800 m).

Since Kumaon is a region of great physical diversities, its climate is also diversified depending upon situation, aspect and elevation. The basic patterns of climate as determined by monsoonal rhythm are divided into four principal seasons, viz., the winter (December March), the summer (March June), the season of rains (June September) and the season of retreating monsoon (September November).

Temperature is low for nine months of the year. During the coldest month of January, typical ridge and high locations along the lesser Himalaya and low altitude valleys record a mean monthly temperature between 5.5° and 8° C and between 13° and 21° C along the foothills. By March, the temperature begins to rise progressively till early June when hill locations record a mean monthly temperature between 19° and 22° C, while it ranges between 30° to 40° C in foothills.

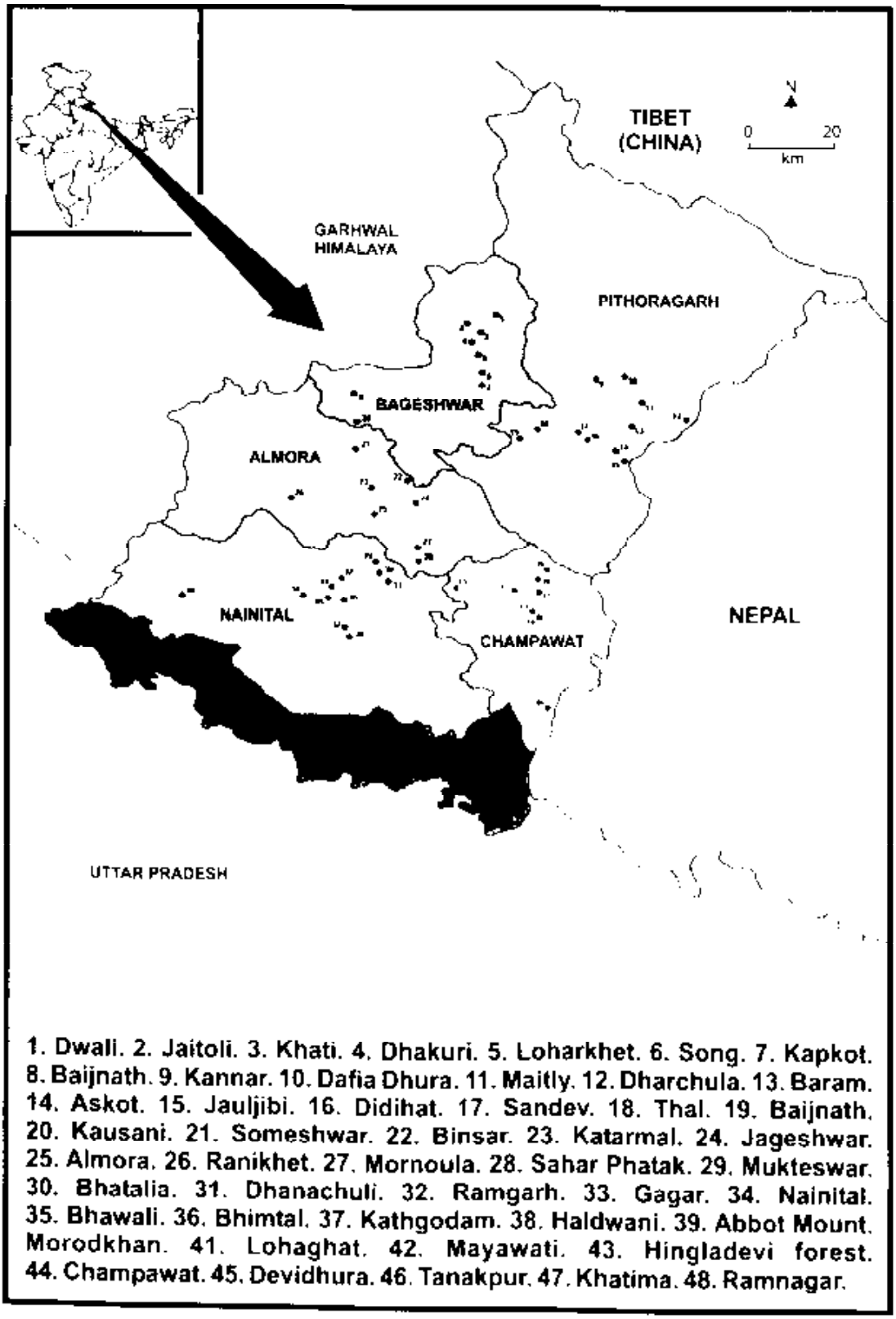
The rainy season (monsoon) usually commences by middle of June and is associated with lowering of temperature during the following months. July is the rainiest month, when temperature falls down to 30°-36° C in the foothills. By November, the temperature begins to lower down at all locations and the month of December marks the advent of the winter season.

During the course of these studies regular and repeated survey and collection tours, each of 8 to 25 days duration were undertaken every year

from July to October. The various places surveyed, their approximate altitude, major forest type and dominant tree species growing there are given in the following pages.

Survey site	District	Forest type	Dominant tree species	Altitude (m)
(1)	(2)	(3)	(4)	(5)
Abbot Mount	Champawat	Deciduous, Coniferous, Mixed	*Quercus*, *Cedrus*	2018
Almora	Almora	Coniferous	*Pinus*	1650
Askot	Pithoragarh	Coniferous	*Pinus*	1600
Baijnath	Bageshwar	Coniferous	*Pinus*	1200
Baram top	Pithoragarh	Coniferous	*Pinus*	1400
Bhatalia	Nainital	Mixed	*Quercus*, *Cedrus*	1800
Bhowali	Nainital	Coniferous	*Pinus*	1706
Binsar	Almora	Deciduous	*Quercus*, *Rhododendron*	2310
Champawat	Champawat	Coniferous, Deciduous	*Cedrus*, *Quercus*	1670
Chilta Devi forest	Bageshwar	Alpine medow	———	3000
Dafia Dhura forest	Pithoragarh	Deciduous	*Quercus*, *Rhododendron*	2300
Dandeshwar	Almora	Coniferous	*Cedrus*	1800
Devidhura	Champawat	Coniferous	*Pinus*	2000
Dhakuri	Bageshwar	Mixed	*Quercus*, *Abies*	2700
Dhakuri top	Bageshwar	Deciduous	*Quercus*, *Rhododendron*	2900
Dhanachuli-bend	Nainital	Deciduous	*Quercus*	1500
Didihat	Pithoragarh	Mixed	*Quercus*, *Cedrus*	1750
Dwali	Bageshwar	Mixed	*Quercus*, *Cupressus*	2575

(1)	(2)	(3)	(4)	(5)
Furti (3 km away From Mayawati)	Champawat	Mixed	*Quercus*, *Pinus*, *Rhododendron*	1950
Gagar	Nainital	Mixed	*Quercus*, *Pinus*	1900
Haldwani	Nainital	Deciduous	*Haldina*, *Quercus*	800
Hingladevi forest	Champawat	Deciduous	*Quercus*	1900
Jageshwar	Almora	Coniferous	*Cedrus*	1870
Jaitoli	Bageshwar	Deciduous	*Quercus*	2440
Jauljibi	Pithoragarh	Deciduous	*Shorea*	1400
Kaladhungi	Nainital	Deciduous	*Shorea*	1700
Kannar	Pithoragarh	Deciduous	*Quercus*, *Rhododendron*	2100
Katarmal	Nainital	Coniferous	*Pinus*	1800
Kausani	Bageshwar	Coniferous	*Pinus*	1890
Khati	Bageshwar	Deciduous	*Quercus*	2210
Lohaghat	Champawat	Coniferous	*Cedrus*	1750
Loharkhet top	Bageshwar	Deciduous	*Quercus*	1800
Maitly	Pithoragerh mixed, deciduous	Coniferous,	*Pinus*, *Quercus*	1600
Mayawati	Champawat	Mixed	*Quercus*, *Rhododendron*, *Cedrus*	1800
Mornoula	Almora mixed	Deciduous,	*Quercus*	2110
Mukteshwar	Nainital	Mixed	*Quercus*, *Cedrus*	2290
Nainital &	Nainital	Mixed	*Quercus*,	2200-
	Naina peak		*Pinus*,	2700
			Cupressus	
Ogla	Pithoragarh	Deciduous	*Quercus*	1600



1. Dwali. 2. Jaitoli. 3. Khati. 4. Dhakuri. 5. Loharkhet. 6. Song. 7. Kapkot. 8. Baijnath. 9. Kannar. 10. Dafia Dhura. 11. Maitly. 12. Dharchula. 13. Baram. 14. Askot. 15. Jauljibi. 16. Didihat. 17. Sandev. 18. Thal. 19. Baijnath. 20. Kausani. 21. Someshwar. 22. Binsar. 23. Katarmal. 24. Jageshwar. 25. Almora. 26. Ranikhet. 27. Mornoula. 28. Sahar Phatak. 29. Mukteswar. 30. Bhatalia. 31. Dhanachuli. 32. Ramgarh. 33. Gagar. 34. Nainital. 35. Bhawali. 36. Bhimtal. 37. Kathgodam. 38. Haldwani. 39. Abbot Mount. Morodkhan. 41. Lohaghat. 42. Mayawati. 43. Hingladevi forest. 44. Champawat. 45. Devidhura. 46. Tanakpur. 47. Khatima. 48. Ramnagar.

Plate 5: Study area: Kumaon Himalaya, Uttaranchal.

(1)	(2)	(3)	(4)	(5)
Binsar (from Almora)		Coniferous	*Pinus*	
Phurkiya	Bageshwar	Subalpine, tree line	*Rhododendron*, *Quercus*	3200
Ramgarh	Nainital	Mixed	*Quercus*, *Pinus*	1789
Ramnagar	Nainital	Deciduous	*Shorea*	300
Ranikhet	Almora	Coniferous	*Pinus*	1830
Sahar Phatak	Almora	Deciduous	*Quercus*	2100
Sandev	Pithoragarh	Deciduous, Mixed	*Quercus*	1900
Someshwar	Almora	Deciduous	*Quercus*	1400
Song	Bageshwar	Mixed	*Quercus*	1200
Tanakpur	Champawat	deciduous	*Shorea*	800

ABBREVIATIONS

ca	*circa*; about
Col.	Collector
etc.	et. cetera; and others
et al.	*et alie*; and others
Fig.	Figure(s)
i.e.	that is
IUCN	International Union for Conservation of Nature and Natural Resources
KD	Kanad Das
m	meter
ml	milliliter
mm	millimeter
Pl.	Plate
SB	Sulfobenzaldehyde
sp.	species
sp. nov.	species nova
sq. km	square kilometer
SV	Sulfovanilline
µm	micro meter
var.	variety
var. nov	*variety nova*
viz.	*videlicet*; namely

Family **Russulaceae** Lotsy
Vortr. Bot. Stammesgesch **1**: 708 (1907)

Basidiomes stipitate; pileus often vividly coloured, fleshy and typically brittle with basidiospores produced on lamellae; lamellae attached or free, crowded to distant, with or without lamellulae; stipe usually central, usually not annulate or volvate; spore print white, cream color, buff, ochraceous or yellowish orange, basidiospores globose to elliptical, lacking apical germpore, ornamentation mostly amyloid, composed of isolated warts or in combination with fine lines or ridges or wings of parallel arrangement; basidia subclavate to clavate; 2-4 spored; lamellar trama composed of filamentous hyphae; hymenial cystidia often present; pileipellis hyphal or pseudoparenchymatous or in combination of both; dermatocystidia sometimes present; pilear and stipe trama often composed of hyphae and groups of sphaerocytes; clamp connections absent; mostly ectomycorrhizal. The family has two genera: *Lactarius* and *Russula*.

KEY TO THE GENERA

1a. Latex present, exuding when the basidiome is cut or broken; lamellar trama usually lacking sphaerocytes, except where it grades into the pilear trama ..... **Lactarius**

b. Latex lacking; lamellar trama usually containing sphaerocytes..... ..... **Russula**

Genus **Lactarius** Pers.: S.F. Gray
Nat. Arr. Brit. Pl. **1**: 623, 1821

Basidiomes stipitate; pileus convex, infundibuliform to uplifted at maturity, dry to viscid, azonate to zonate, smooth to velvety white to vividly coloured; margin entire or forked, smooth, crenate or wavy, naked to hairy; lamellae adnate to decurrent, crowded to distant, white to yellowish, unchanging or changing after bruising; lamellulae usually present; stipe central, rarely excentric, smooth to pruinose or pitted; taste mild or acrid; odor spicy, fruity, aromatic, fishy or indistinguished; latex transparent (watery), white, yellow, orange, red, brownish, bluish, unchanging or changing on exposure; spore print whitish, basidiospores globose to ellipsoid, ornamentation amyloid, with warts, lines or heavy ridges forming incomplete or complete reticulum to zebroid (parallel) or winged pattern; basidia mostly subclavate to clavate, 2-4 spored; pleuromacrocystidia, pleuropseudocystidia, cheilomacrocystidia, and paracystidia mostly present; pileipellis ixocutis, trichoderm, lamprotrichoderm, hyphoepithelium, hymeniderm, palisade, trichopalisade or lampropalisade; hymenophoral trama usually lacking sphaerocytes; pilear trama with characteristic lactiferous hyphae (lactifers) and sphaerocytes. About 450 taxa in the world; 75 taxa in India and 33 taxa from Kumaon Himalaya.

Type species : **Lactarius piperatus** (L.: Fr.) Pers.

Literature : Burlingham 1908; Hesler & Smith 1979; Bon 1980; Kytovuori 1984; Singer 1986; Grgurinovic 1997; Heilmann-Clausen *et al.* 1998; Basso 1999.

KEY TO THE SUBGENERA

1a. Latex yellow, orange, reddish brown, blue, white or transparent; pileipellis ixocutis to trichoderm subgenus ..... subgenus **Piperites**

(P. 68)

b. Latex white to yellowish white; pileipellis lamprotrichoderm, hyphoepithelium, trichoepithelium, lamproepithelium, hymeniderm, trichopalisade, palisade or epithelium 2

2a. Pileus mostly grayish to blackish; pileipellis palisade to trichopalisade or hymeniderm ..... subgenus **Plinthogali**

(P. 99)

b. Not with the above combination of characters 3

3a. Latex white to yellowish white, unchanging; pileipellis an epithelium to a hyphoepithelium ..... subgenus **Russularia**

(P. 112)

b. Not with the above combination of characters 4

4a. Pileipellis a lampropalisade; hymenophoral trama cellular .... subgenus **Lactifluus**

(P. 51)

b. Not with the above combination of characters 5

5a. Elements of suprapellis erect to suberect, typically thick walled..... ..... subgenus **Lactariopsis**

(P. 38)

b. Elements of suprapellis repent, thin walled ..... subgenus **Lactarius**

(P. 43)

Subgenus **Lactariopsis** (Henn.) R. Heim
Prodr. Fl. Mycol. Madagascar *36*, 1938; Emend Verbeken, Mycotaxon **66**: 387, 1998

Pileus dry, convex with depressed center, infundibuliform at maturity; pileipellis subvelvety to velvety, white to yellowish pink; margin incurved to uplifted; lamellae subdecurrent, white to greenish yellow; latex white, slowly greenish yellow to brilliant yellow on exposure; basidiospores broadly ellipsoid, ornamentations of low warts or ridges, sometimes forming incomplete reticulation; pleuromacrocystidia and cheilomacrocystidia present; pileipellis a lamprotrichoderm. Two taxa in India, both known from Kumaon Himalaya.

KEY TO THE SPECIES

1a. Basidiospores 6.5-8.5 x 5-6.5 µm; lamellae distant ..... **L. subvellereus** var. **subdistans**

b. Basidiospores 7.5-11 x 7-9 µm; lamellae close ..... **L. vellereus**

Lactarius subvellereus Peck

Bull. Torrey Bot. Club **25**: 369, 1898. var. **subdistans** Hesler & Smith, North American Species of Lactarius, 203, 1979; Das & Sharma, Ann. For. **13**(2005)2; Phytotax. **4**(2004)5.

Pl. 6; fig. 7

Pileus 55-110 mm diam., convex when young, depressed to vase shaped in age, sometimes torn from the margin towards the center; cuticle dry velvety, azonate, white to yellowish white, tinged pale yellowish to greyish; margin decurved and sometimes uplifted. Context white, gradually yellow and orange with KOH. Lamellae subdecurrent, distant (3-4 per cm) with 2 rows of lamellulae, forked, white, light greenish yellow when mature, dark yellowish to dark brown after bruising. Stipe 25-40 x 14-20 mm, white to yellowish white, velvety, cylindric or tapering at base; context white, gradually light greenish yellow. Latex white, slowly light greenish to brilliant yellow on exposure,. Taste acrid. Odour pleasant. Spore print white.

Basidiospores 6.5 - 8.5 x 5-6.5 µm, amyloid, broadly ellipsoid, ornamentation with very low warts (up to 0.5 µm high). Basidia 48-60 x 7-10 µm, clavate, 4-spored. Pleuromacrocystidia cylindrical, subfusoid to somewhat acute, 60-80 x 4.5-8 µm. Cheilomacrocystidia 43-55 x 3.8-6 µm, subfusoid to somewhat acute. Pileipellis a lamprotrichoderm. Pileocystidia 130-190 x 3-5 µm, thick walled; wall up to 1.82 µm thick.

Ecology : Abundant, grows in close ectomycorrhizal association with *Quercus leucotrichophora* A. Camus in moist subtropical to temperate deciduous forests.

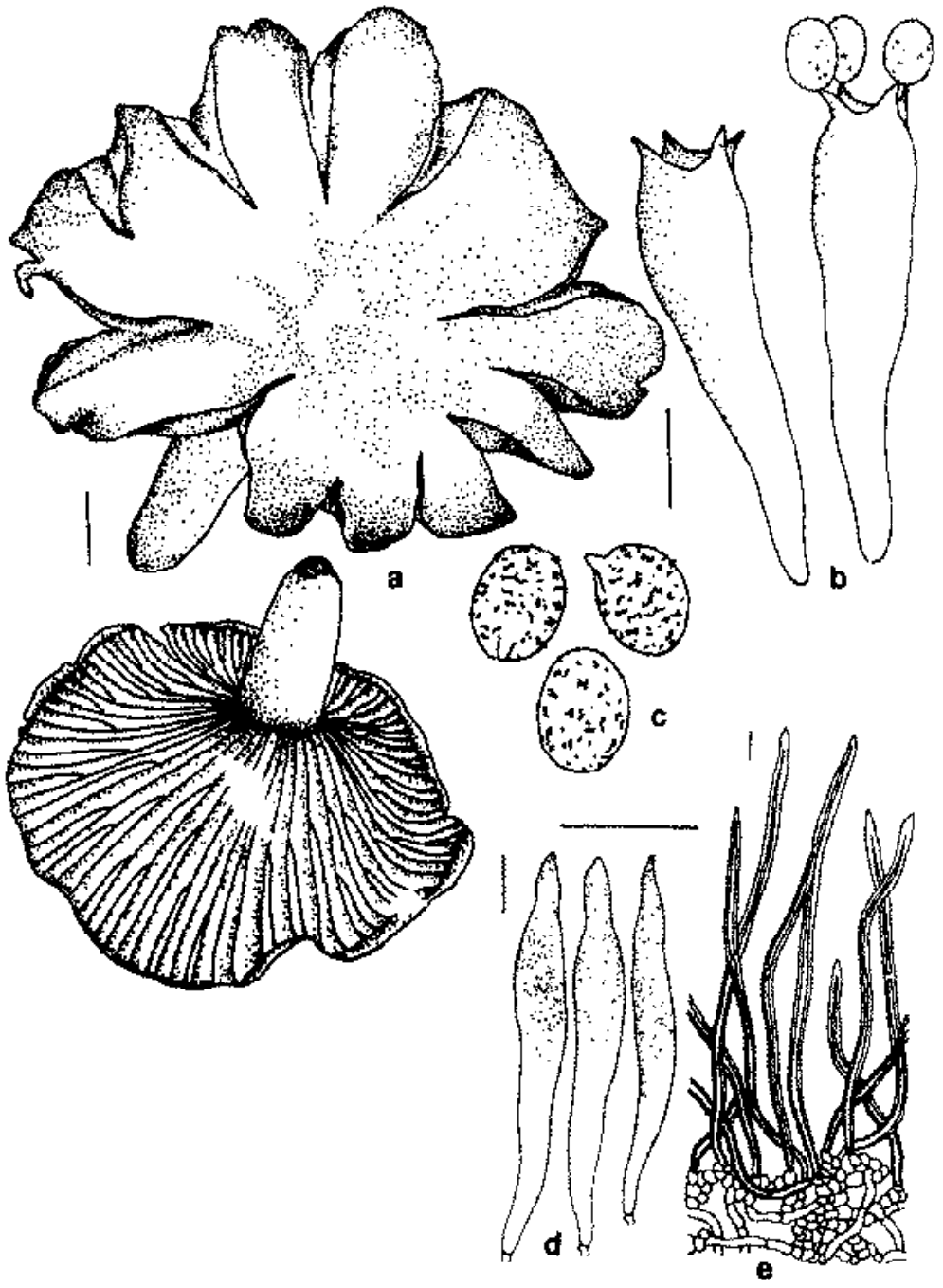


Fig. 7. *Lactarius subvellereus* var. *subdistans*: a. Basidiomes b. Basidia c. Basidiospores d. Pleuromacrocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

Specimens examined : Uttaranchal, Nainital, Mukteswar, August, 2002, **col.** K.Das, KD2161; Uttaranchal, Champawat, Abbot Mount, September, 2002, **col.** K. Das & J.R. Sharma, KD4517, KD4527, KD4530; Uttaranchal, Pithoragarh, Sandev, September, 2002, **col.** K. Das & J.R. Sharma, KD4012.

Notes : L. subvellereus var. *subdistans* is characterized morphologically by whitish, velvety pilear surface, distant forked gills, white latex which slowly turns yellow on exposure and anatomically by the presence of thick walled lamprocystidia in pileipellis and inamyloid spores with very low warts.

The present variety resembles closely with *L. subvellereus* var. *subvellereus* Peck and *L.vellereus* var. *virescens* Hesler & Smith. However, the close to crowded lamellae in the former and larger spores [7.5-9 (10) x 7.5-9 µm] in the latter, easily separate them from the present taxon.

Lactarius vellereus (Fr.) Fr.

Epicr. Syst. Mycol., 340, 1838. *Agaricus vellereus* Fr., Syst. Mycol. **1**, 76, 1821; Berk., Hook.J. Bot. **4**(1852); Rawla, Bio. Ind. (2002) 243; Rawla, Ind. Sci. Cong. Proc. (1994) 32; Atri *et al.*, Curr. Res. Pl. Sci. (1994) 90; Das & Sharma, Phytotax. 4(2004)4. Pl. 6; fig. 8

Pileus 80-280 mm diam., convex with depressed center, broadly infundibuliform at maturity; pileipellis tomentose to subvelvety, yellowish white to buff; margin inrolled to incurved. Lamellae adnate to subdecurrent, close (5-7 per cm), forked, yellowish white to light yellow with ochraceous edges. Stipe 30-65 x 20-50 mm velutinous, mostly cylindric, yellowish white. Context solid, white to light yellow on exposure. Latex white, slowly light greenish yellow on exposure. Taste mild. Spore print white.

Basidiospores 7.5-11 x 7-9 µm, globose to ellipsoid (Q=1.03-1.40); ornamentation amyloid, composed of irregular to linear warts, forming almost complete reticulum. Basidia 50-60 x 8-10 µm, cylindric to subclavate, 4-spored. Pleuromacrocystidia 58-80 x 8-10 µm, abundant, mucronate to moniliform. Cheilomacrocystidia 25-40 x 5-8 µm, cylindric to clavate. Pileipellis a lamprotrichoderm; pileocystidia 80-200 x 5-7 µm, cylindric, thick walled.

Ecology : Rare, grows in ectomycorrhizal association with *Quercus* sp. in moist subtropical to temperate deciduous forests.

Specimens examined : Uttaranchal, Nainital, Mukteswar, August, 2002, **col.** K. Das, KD2123; Uttaranchal, Bageshwar, Dhakuri, September, 2003, **col.** K. Das, KD7099.

Notes : The whitish to buff, larger basidiocarps becoming broadly infundibuliform at maturity are sufficient to recognize this species in the field from a distance. The larger basidiocarps and basidiospores, closer lamellae and shape of hymenial cystidia separate *L. vellereus* from *L. subvellereus* var. *subdistans*.

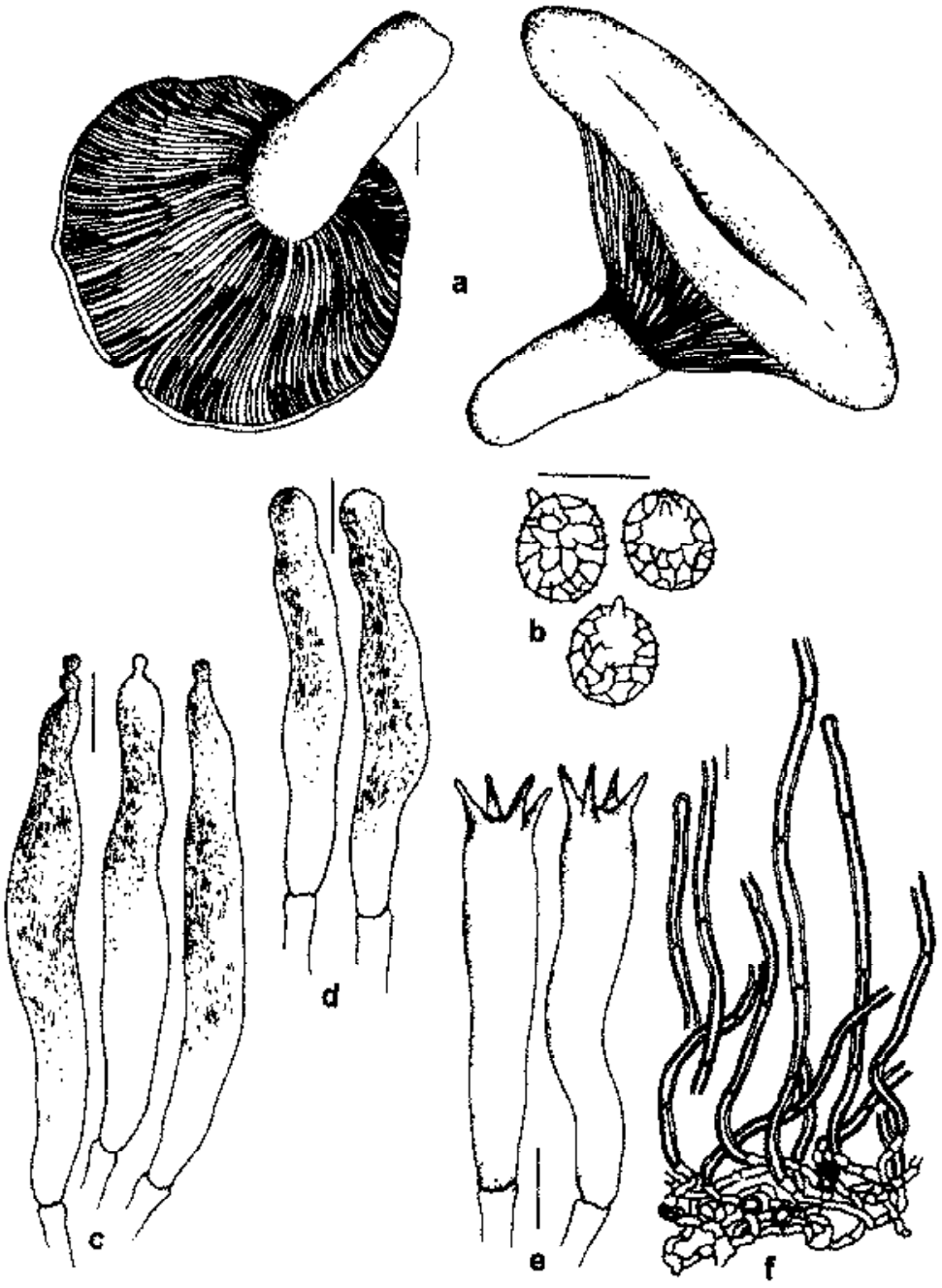


Fig. 8. *Lactarius vellereus*: a. Basidiomes b. Basidiospores c. Pleuromacrocystidia d. Cheilomacrocystidia e. Basidia f. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

Plate 6: a & b. *Lactarius subvellereus* var. *subdistans* c & d. *L. vellereus*.

Subgenus **Lactarius** Pers. : S.F. Gray
Nat. Arr. Brit. Pl. 1: 623, 1821.

Pileus dry, glabrous, azonate, whitish, margin incurved to uplifted; lamellae broadly adnate to decurrent; stipe subclavate, cylindric or tapered towards base, solid; latex white, light greenish yellow on exposure; basidiospores subglobose to ellipsoid, ornamentation amyloid, composed of irregular warts, isolated or sometimes connected to form somewhat broken reticulum; hymenial cystidia present; pileipellis two layered, subpellis cellular, suprapellis composed of mostly repent hyphae. Three taxa in India; all occur in Kumaon Himalaya.

KEY TO THE SPECIES

1a. Pileus 84-130 mm diam; lamellae distant without any forkation ..... **L. dwaliensis**

b. Pileus smaller 40-90 mm diam; lamellae distant to rather crowded, repeatedly forked 2

2a. Latex yellow on exposure ..... **L. piperatus**

b. Latex olive green on exposure .....**L. piperatus** var. **glaucescens**

Lactarius dwaliensis K.Das, J.R. Sharma & Verbeken

Mycotaxon **88**: 334, 2003. Pl. 7; fig. 9

Pileus 84-130 mm diam., convex with decurved margin, planoconvex to umbilicate with depressed center when mature; pileipellis dry, shiny, glabrous, azonate, white. Lamellae subdecurrent to decurrent, distant (3-4 per cm) with 3 rows of lamellulae, yellowish white. Stipe 50-145 x 17-30 mm, cylindrical, white to yellowish white. Context white, gradually light greenish yellow when bruised. Latex copious, white, slowly light greenish yellow on exposure. Spore print white.

Basidiospores (7.6) 8-10.5 x 7.2-8.6 µm (Q = 1.00-1.20), subglobose to broadly ellipsoid; ornamentation amyloid, up to 0.5 µm high, composed of irregular warts, often aligned and connected; plage inamyloid. Basidia 45-55 x 9-11 µm, cylindric to subclavate, 4-spored. Pleuromacrocystidia 45-65 x 4-7 µm, abundant, narrowly cylindric, with rounded or slightly tapering apices and granular contents. Pleuropseudocystidia 50-70 x 4-6 µm, scarce, cylindric to subclavate, sometimes with mucronate apices. Lamellae edge sterile; marginal cells 20-30 x 4-7 µm. Cheilomacrocystidia 40-55 x 5-7 µm, cylindric with acute apices and needle like contents. Subhymenial layer up to 22 µm thick. Hymenophoral trama cellular, composed of abundant sphaerocytes with some hyphae; lactifers, up to 10 µm broad. Pileipellis

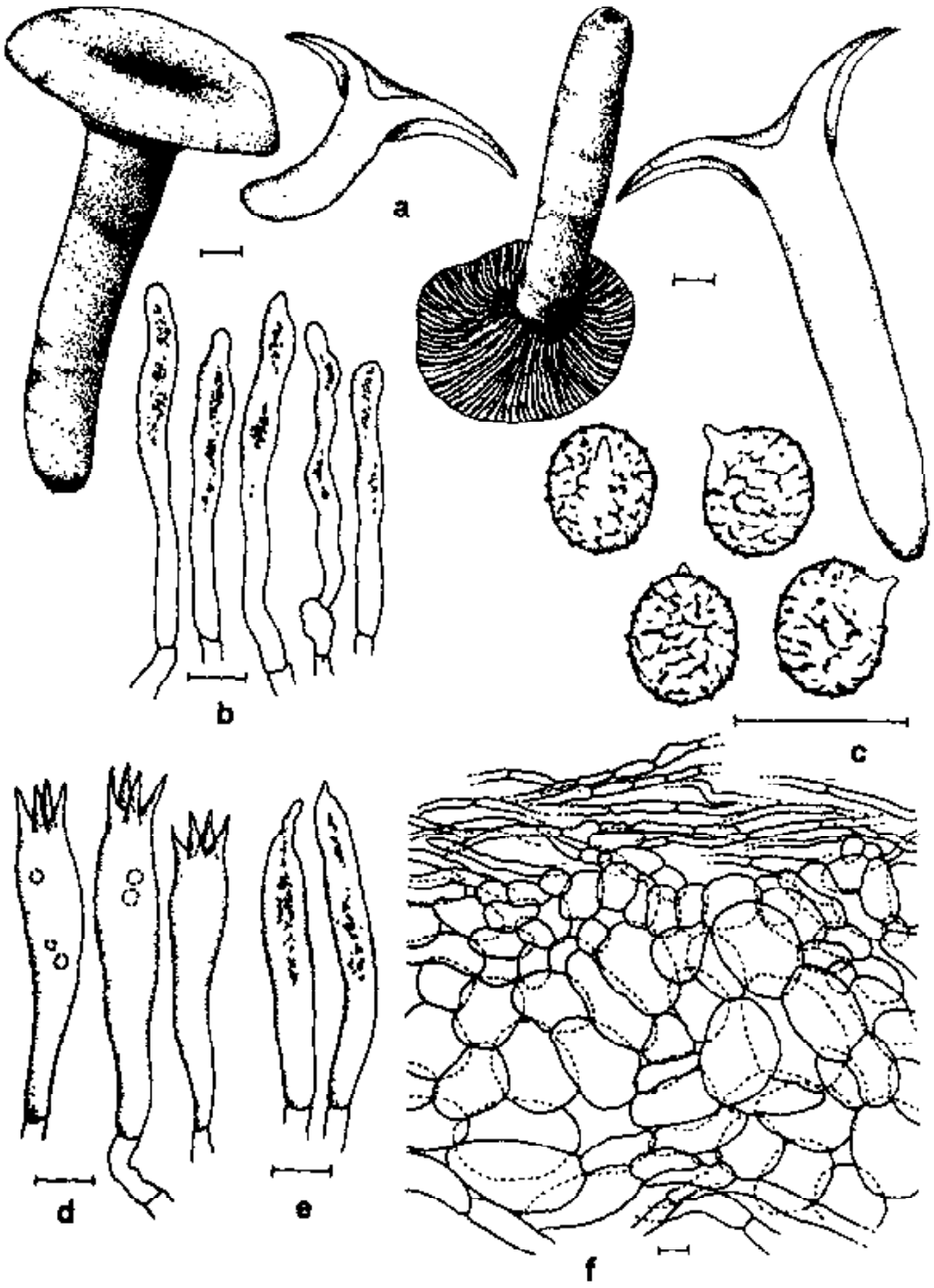


Fig. 9. *Lactarius dwaliensis*: a. Basidiomes b. Pleuromacrocystidia c. Basidiospores d. Basidia e. Cheilomacrocystidia f. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

two layered; subpellis up to 125 µm thick, composed of globose to subglobose cells of 10-40 µm diam.; suprapellis 30-50 µm thick, composed of mostly repent hyphae; hyphae thin-walled, frequently septate, 3-4 (6) µm broad.

Ecology : Rare, grows in ectomycorrhizal association with *Quercus leucotrichophora* A. Camus in subtropical to temperate deciduous forests.

Specimens examined : Uttaranchal, Bageshwar, Dwali, October 3, 1999, **col.** K. Das, KD612; Uttaranchal, Bageshwar, Khati, October5, 1999, **col.** K. Das & J.R. Sharma, KD698.

Notes : Lactarius dwaliensis can easily be distinguished in the field by white, smooth, shiny pileus with usually long, white stipe, white context, distant lamellae and the white latex changing to greenish yellow on exposure. Microscopically the two layered pilipellis with a suprapellis of repent hyphae and cellular subpellis, is very distinct. The combination of characters places the species in the subgenus *Lactarius* (sensu Heilmann-Clausen *et al.* 1998), where it reminds of *L. piperatus* (L.: Fr.) Pers. and related species.

Lactarius dwaliensis differs from *L. subpiperatus* Hongo because the latter has smaller basidiocarps and spores (6-7.5 x 5-6 µm) and lacks pleuromacrocystidia (Hesler & Smith 1979). *L. neuhoffii* Hesler & A.H. Sm. also seems closely related to the present new taxon, but differs by having denser lamellae, shorter stipe (30-50 mm) and the more velvety basidiocarps (Hesler & Smith 1979).

Lactarius piperatus (Fr.) S.F. Gray

Nat. Arr. Brit. Pl. 1: 623, 1821. *Agaricus piperatus* Fr., Syst. Mycol. 1: 76, 1821; Atri & Saini, Geo. N. R. **5**(1986) 102; Saini & Atri, Ind. Phytopath. **46**(1993) 361; Bhatt & Lakhanpal, Ind. Phytopath. **43**(1990) 161; Das & Sharma, Phytotax. **4**(2004)5. Pl. 7; fig. 10

Pileus 42-90 mm. diam., convex with depressed center, broadly infundibuliform to uplifted at maturity; pileipellis dry, smooth, cracked (areolate), often concentrically wrinkled towards margin, white to yellowish white, cream, sometimes with brownish tinge at maturity; margin incurved to decurved, often plane to uplifted at maturity. Lamellae crowded, repeatedly forked, yellowish white to cream, yellow to brilliant yellow after bruising; lamellulae numerous. Stipe 35-70 x 15-25 mm, subclavate, cylindric or slightly tapering downwards, dry, smooth, yellowish white, becoming brownish at base. Context solid, white, slowly lemon yellow on exposure. Latex white, slowly light to lemon yellow on exposure. Taste slowly acrid. Spore print white.

Basidiospores 7-11 x 5.8-7.6 µm, subglobose to ellipsoid (Q=1.11-1.45); ornamentation amyloid, composed of minute warts and ridges (less than

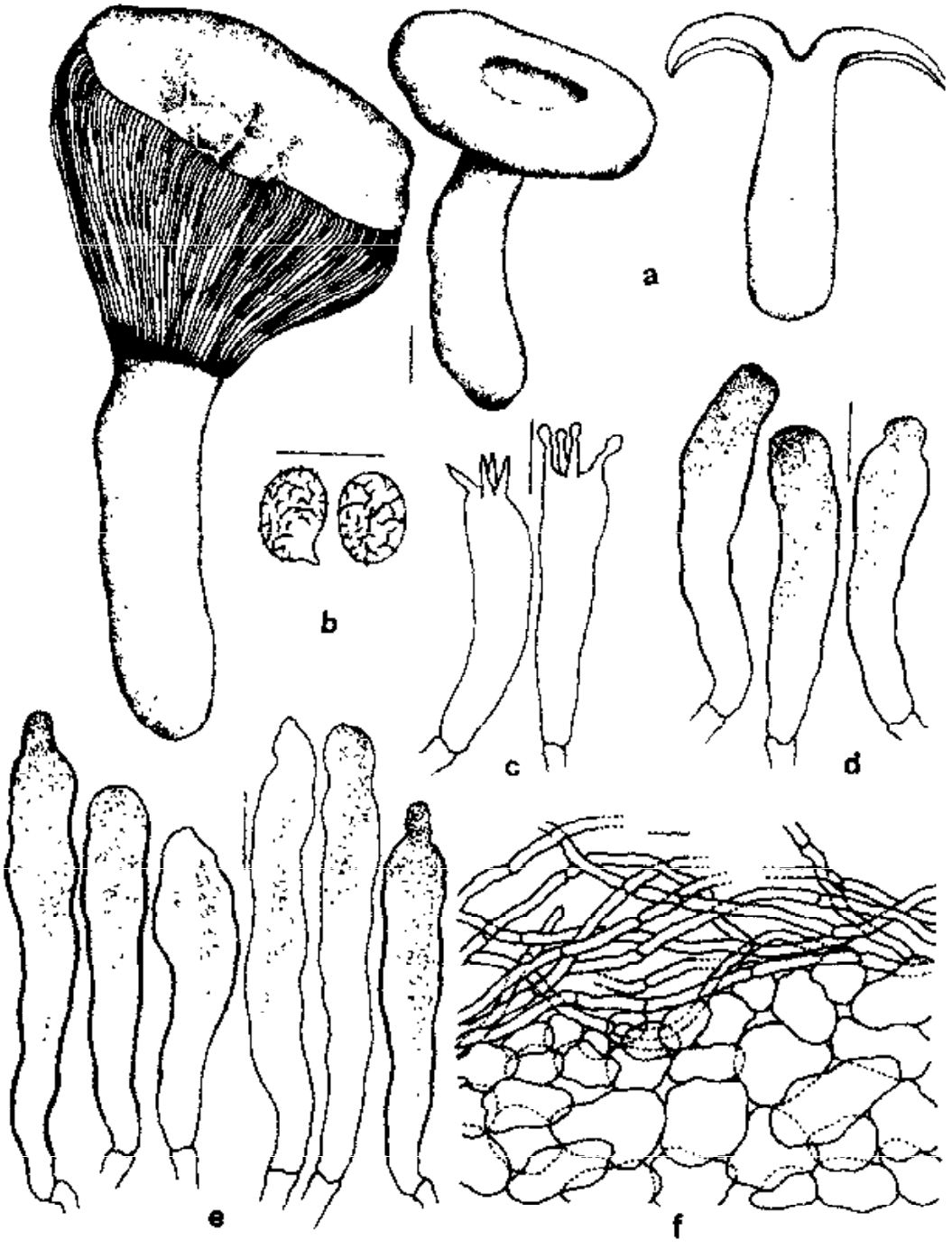


Fig. 10. *Lactarius piperatus* var. *piperatus*: a. Basidiomes b. Basidiospores c. Basidia d. Cheilomacrocystidia e. Pleuromacrocystidia f. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

0.5 µm high), mostly isolated, sometimes aligned forming an incomplete reticulum. Pleuromacrocystidia 40-60 x 6-9 µm, emergent up to 30 µm, subcylindric to subclavate, content refractive. Pleuropseudocystidia up to 7 µm broad, cylindrical. Gill edge sterile. Cheilomacrocystidia 35-50 x 5.5-9 µm, abundant, subclavate to clavate, content refractive. Pileipellis a hyphoepithelium, two layered; suprapellis composed of repent to suberect hyphae (up to 4 µm broad); subpellis cellular. Stipitipellis same as pileipellis.

Ecology : Abundant, grows in ectomycorrhizal association with the species of *Quercus*, *Cedrus*, *Pinus* in subtropical to temperate deciduous, coniferous and mixed forests.

Specimens examined : Uttaranchal, Bageshwar, Loharkhet top, September 15, 2003, **col.** K. Das & J.R. Sharma, KD7002, KD7005; *ibid.* October 26, 2003, **col.** K. Das & J.R. Sharma, KD7076; Uttaranchal, Champawat, Mayawati, September 2002, **col.** K. Das & J.R. Sharma, KD4558; Uttaranchal, Almora, Mornoula, October 2002, **col.** K. Das & J.R. Sharma, KD4594; Uttaranchal, Champawat, Lohaghat, September 2002, **col.** K. Das & J.R. Sharma, KD4510; Uttaranchal, Champawat, Abbot Mt., September 2002, **col.** K. Das & J.R. Sharma, KD4533; Uttaranchal, Almora, on the way to Binsar (6 Km. before), August 2001, **col.** K. Das, KD908; Uttaranchal, Pithoragarh, Sandev, September 2001, **col.** K. Das, KD4015.

Notes : Lactarius piperatus var. *piperatus* is one of the most abundant *Lactarius* found in all types of forests in Kumaon Himalaya. Microscopically *Lactarius piperatus* var. *piperatus* is somewhat close to *L. dwaliensis*. But the latter however, differs from the present species by having distant lamellae and exceptionally long stipe. Further, the pilear surface never cracks in *L. dwaliensis* and remains smooth throughout, while the surface starts cracking in the present taxon with age.

Lactarius piperatus (Fr.) S.F. Gray

var. **glaucescens** (Crossl.) Hesler & A.H. Smith, North American Species of Lactarius, 186, 1979. *Lactarius glaucescens* (Cross., Naturalist **1900**: 5, 1900. *Agaricus piperatus* Fr., Syst. Mycol. **1**: 76, 1821; Atri *et al.*, J. Ind. Bot. Soc. **72**(1993) 158; Das & Sharma, Phytotax. **4**(2004)5.

Pl. 7; fig. 11

Pileus 40-70 mm diam., convex with depressed center, gradually infundibuliform to slightly uplifted; pileipellis dry, glabrous, areolate, yellowish white to cream; margin regular, inrolled, incurved at maturity. Lamellae broadly adnate to decurrent, crowded, often forked, yellowish white to cream, greenish yellow to olive green after bruising; lamellulae numerous. Stipe 29-50 x

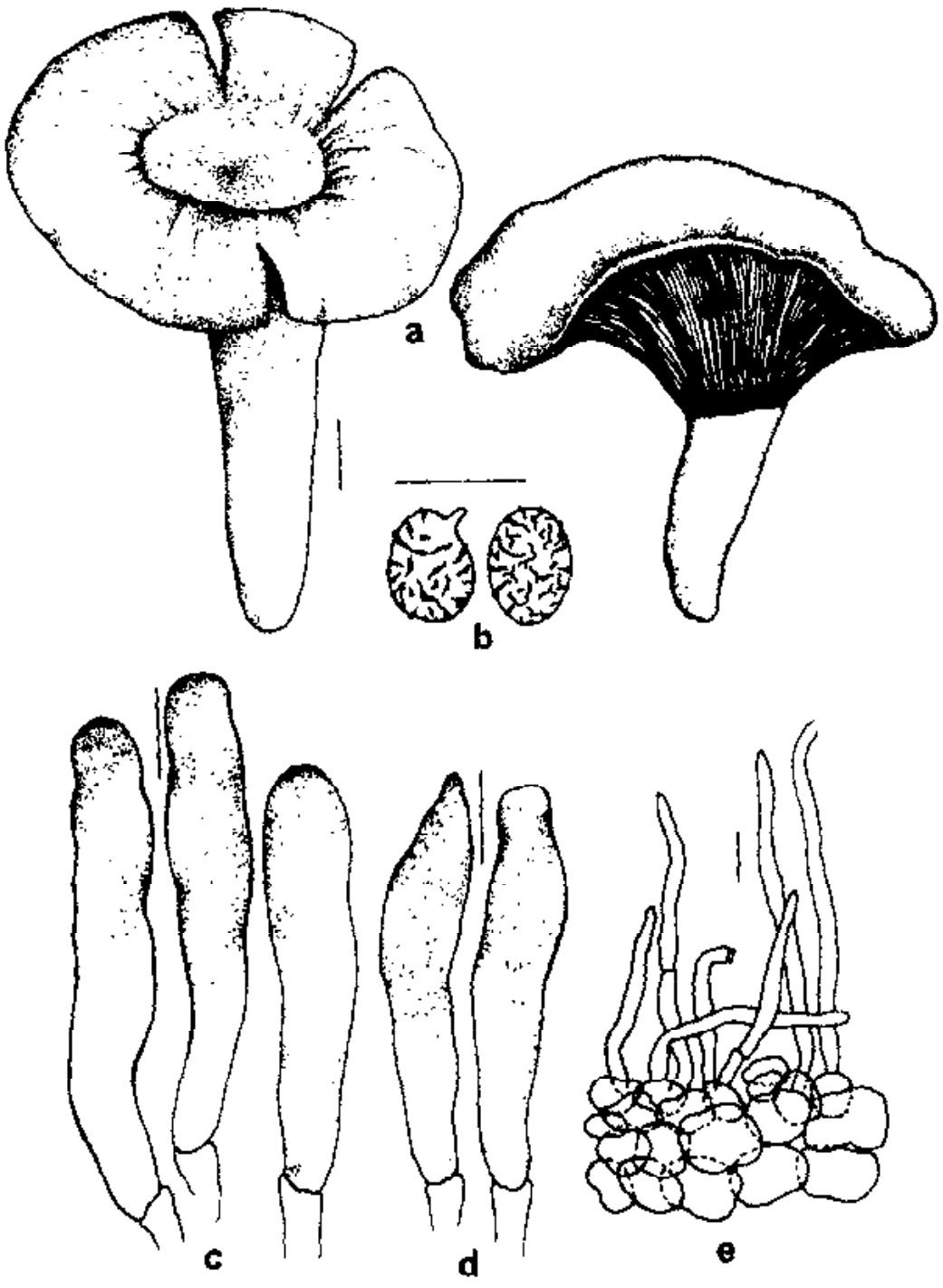


Fig. 11. *Lactarius piperatus* var. *glaucescens*: a. Basidiomes b. Basidiospores c. Pleuromacrocystidia d. Cheilomacrocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

12-18 mm, cylindrical or tapering downwards, concolorous with the pileus. Context solid, white, greenish on exposure. Latex white, slowly olive green on exposure. Taste acrid. Spore print yellowish white.

Basidiospores 6-8 x 5.8-7.2 µm, subglobose to broadly ellipsoid (Q=1.1-1.25); composed of isolated warts and few ridges (less than 0.5 µm high), sometimes forming somewhat broken reticulum. Basidia 35-48 x 7-8 µm, subclavate to cylindric, 4-spored. Pleuromacrocystidia 44-55 x 7-9 µm, emergent up to 30 µm, mostly found towards lamellar edge, cylindrical to subclavate; content refractive. Pleuropseudocystidia up to 6 µm, cylindrical with rounded to acute apices. Gill edge sterile. Cheilomacrocystidia cylindrical to slightly ventricose; content refractive. Pileipellis a hyphoepithelium, two layered; suprapellis hyphal; hyphae erect to suberect, septate, thin walled; subpellis pseudoparenchymatous.

Ecology : Common, grows in ectomycorrhizal association with the species of *Quercus* in temperate deciduous forests.

Specimens examined : Uttaranchal, Pithoragarh, Sandev, September 2003, col. K. Das & J.R. Sharma, KD4005, KD4008.

Notes : Lactarius piperatus var. *glaucescens* differs from the typical variant (Hesler & Smith 1979) by having latex which turns olive green and erect hyphae in pilear suprapellis.

Plate 7: a. *Lactarius dwaliensis* b. *L. piperatus* var. *piperatus* c. *L. piperatus* var. *glaucescens*.

Subgenus **Lactifluus** (Burl.) Hesler & A.H. Sm.
North American Species of *Lactarius* 58, 1979; emend. Verbeken. Mycotaxon **66**: 370, 1998. *Lactaria* subsection *Lactifluae* Bull., Mem. Torrey Bot. Club **4**: 89, 1908.

Pileus dry, matted to velvety, with or without papilla, orange yellow to reddish brown; margin decurved to incurved; stipe mostly concolorous; basidiospores globose to ellipsoid, ornamentation amyloid of isolated warts or sometimes forming complete to incomplete reticulum; pleuromacrocystidia present or absent; cheilomacrocystidia capitate, cylindric to fusoid; pileipellis a lampropalisade; hymenophoral trama cellular. Nine taxa in India; six taxa in Kumaon Himalaya.

KEY TO THE SPECIES

1a. Pleuromacrocystidia present 2

b. Pleuromacrocystidia absent 4

2a. Basidiospores 8.1-11.5 x 7.4-11 µm; pileus never with papilla ..... **L. corrugis**

b. Basidiospores 6.4-10 x 5.8-8.9 µm; pileus sometimes with an acute papilla 3

3a. Pileus almost smooth often papillate; pileipellis orange yellow to brown in all stages of basidiome development ..... **L. volemus**

b. Pileus subvelvety to velvety without papilla; pileipellis buff to ochraceous in all the stages of basidiome development ..... **L. volemus** var. **flavus**

4a. Hymenial cystidia (cystidioid elements) mostly capitate to subcapitate ..... **L. capitatus**

b. Hymenial cystidia subcylindric to cylindric, flexuous, fusoid or ventricose but never capitate 5

5a. Odour strongly alkaline; latex sticky, unchanging ..... **L. hygrophoroides** var. **odoratus**

b. Odour indistinctive; latex nonsticky, changing slowly to brown droplets on exposure ..... **L. hygrophoroides** var. **lavendulaceus**

Lactarius capitatus K.Das, J.R. Sharma & Montoya

Mycotaxon **90**: 286, 2004. Pl. 8, 10; fig. 12

Pileus 50-80 mm diam, planoconvex to slightly depressed when mature; pileipellis dry, matted pruinose to velvety, sometimes minutely areolate towards center at maturity, medium reddish to grayish-orange, grayish-red, medium to brownish-orange, often dark red at the edge; margin incurved to decurved, wavy, often crenate. Lamellae decurrent, close at first sight but subdistant when excluding the lamellulae (5-6 per cm), light orange to orange-yellow, light to medium reddish-brown after bruising; lamellulae in five different lengths. Stipe 33-63 x 10-18 mm, dry, matted, cylindric or slightly tapered towards base, often longitudinally grooved, dry, matted, concolorous to pileus. Context solid, pale to light orange-yellow or ochraceous, turning slowly brownish. Latex at first whey like, later white to pale buff, droplets turning very slowly to pinkish, finally dark reddish-brown to brown, staining the white paper medium brown. Odour spicy to fishy. Spore print white.

Basidiospores (6.4) 7-8.8 (9.6) x (5.6) 6.4-7.8 (8) µm (Q = 1.03-1.11), globose to subglobose, ornamentation amyloid, 0.6-0.8 µm high, composed mostly of conical isolated warts, at times connected or somewhat aligned; under SEM the ornamentation appears of subcylindric warts, broadened towards base, apex rounded, isolated or aligned and even interconnected at base level, at times with rounded, sinuous or truncate ridges; with suprahylar plage. Basidia 34-44 x 8-10 µm, subclavate to clavate, 4-spored; sterigma up to 7.5 µm long. Hymenial cystidioid elements abundant, mostly capitate, sometimes subcylindric, septate, wall 0.8-1.6 µm thick, with hyaline or slightly yellowish and dense contents; at lamellae surfaces 38.4-92 x 5.6-8 µm, terminal segments 12-24 x 5.6-8.8 µm; at lamellae margins 33-70 x 4.6-7.5 µm, abundant, often septate, terminal segments 14.4-28 x 4.8-8.8 µm. Pseudocystidia abundant, subcylindric, 4-6.4 µm broad. Pileipellis a trichodermis of two layers, up to 225 µm thick; elements of suprapellis 20-135 x 5.5-13 µm, filamentous, capitate or subcapitate to cylindric, mostly hyaline or with dense yellowish contents, often septate, wall 0.8-1.6 µm thick; subpellis pseudoparenchymatous; cells 7-34 x 6-24 µm, wall 0.8-1.6 (-2.4) µm thick. Hymenophoral trama mostly cellular, sphaerocytes 8-28 µm diam, hyphae 4-4.8 µm thick, laticifers 8-11.2 mm diam, subhymenium thick and cellular. Stipitipellis two layered; elements of suprapellis 18-125 x 4-12 µm, capitate or subcapitate to fusiform, often s eptate, thick walled; wall up to 1 µm broad; subpellis pseudoparenchymatous of subisodiametric cells, 10-20 x 6-14 µm.

Ecology : Rare, grows under *Quercus leucotrichophora* and *Rhododendron arboreum* in temperate deciduous forests.

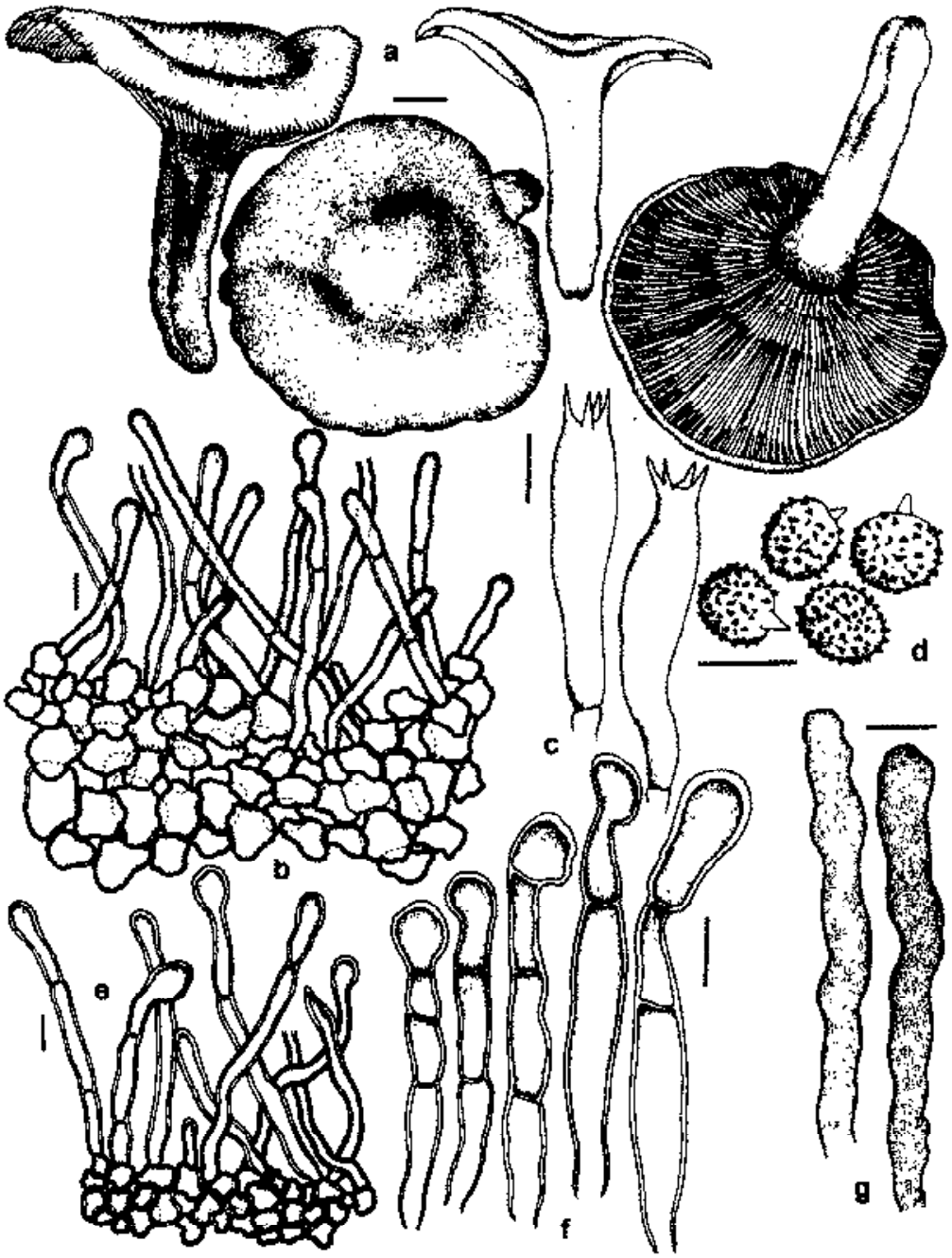


Fig. 12. *Lactarius capitatus*: a. Basidiomes b. Cross section of pileipellis c. Basidia d. Basidiospores e. Cross section of stipitipellis f. Marginal cystidioid elements g. Pleuropseudocystidia. Bars: a = 10 mm; b-g = 10 µm.

Specimens examined : Uttaranchal, Bageshwar, Loharkhet top, September 15, 2003, **col.** K. Das & J.R. Sharma, KD7001, KD7004; *ibid.*, September 26, 2003, **col.** K. Das & J.R. Sharma, KD7095.

Notes : Lactarius capitatus is distinguished in the field by having the pileus and stipe surfaces matted, pruinose to velvety, reddish to brownish-orange, the lamellae and context are pale to light orange-yellow or ochraceous, latex droplets turning slowly to pink and finally dark reddish-brown to brown, and mild spicy odor in the fresh material. Moreover, the verrucose basidiospores and presence of typical capitate to subcapitate thick walled cystidioid elements in the hymenium and suprapellis of both pileus and stipe make the species very distinct.

Lactarius capitatus is closely related to *L. luteolus*. The latter differs in that the basidiomes lack reddish tinges [being buff, white or whitish-buff (Peck 1896, Hesler & Smith 1979)]. Moreover, *L. luteolus* presents white latex droplets staining brown, and as observed in the holotype it has elliptic basidiospores (Q=1.3) and thin walled or slightly thick walled (0.8 µm thick) marginal cystidioid elements.

Lactarius nonpiscis Verbeken shares with the present taxon capitate, septate and thick walled elements of the suprapellis, stipitipellis and hymenial marginal cells, as well as verrucose basidiospores (Verbeken *et al.* 2000). However, *L. nonpiscis* differs by having smaller basidiomata [pileus 13-26 mm diam, stipe 20-40 x 3-7 (-10) mm], strongly wrinkled pileipellis with small veins, more ellipsoid basidiospores (Q = 1.31-1.36) and higher basidiospore ornamentation (up to 1.5 mm).

Lactarius corrugis Peck

Ann. Rep. N.Y. State Mus. **32**: 31, 1880; Atri & Saini, Geob. N. Rep. **5**(1986) 102; Bhatt & Lakhanpal, Ind. Phytopath. **43**(1990) 159; Saini & Atri, Ind. Phytopath. **46**(1993) 362; Das & Sharma, Phytotax. **4**(2004)4. Pl. 9; fig. 13

Pileus 60-105 mm diam., planoconvex to depressed or subinfunduliform when mature; pileipellis dry, subvelvety to velvety, rugate to areolate, sometimes rimose, yellowish pink, medium reddish orange, gray reddish orange, dark reddish orange to light reddish brown; margin incurved to inrolled. Lamellae adnate to subdecurrent, entire, close (excluding lamellulae), ochraceous-white, light orange-yellow to brilliant orange yellow, turning brown after bruising, lamellulae numerous. Stipe 38-80 x 12-22 mm, central, subcylindric, slightly tapered towards base, tomentose to subvelvety, brownish orange to light reddish brown. Context ochraceous yellow, brown on exposure. Latex white, slowly cream on exposure. Odor indistinct. Spore print white.

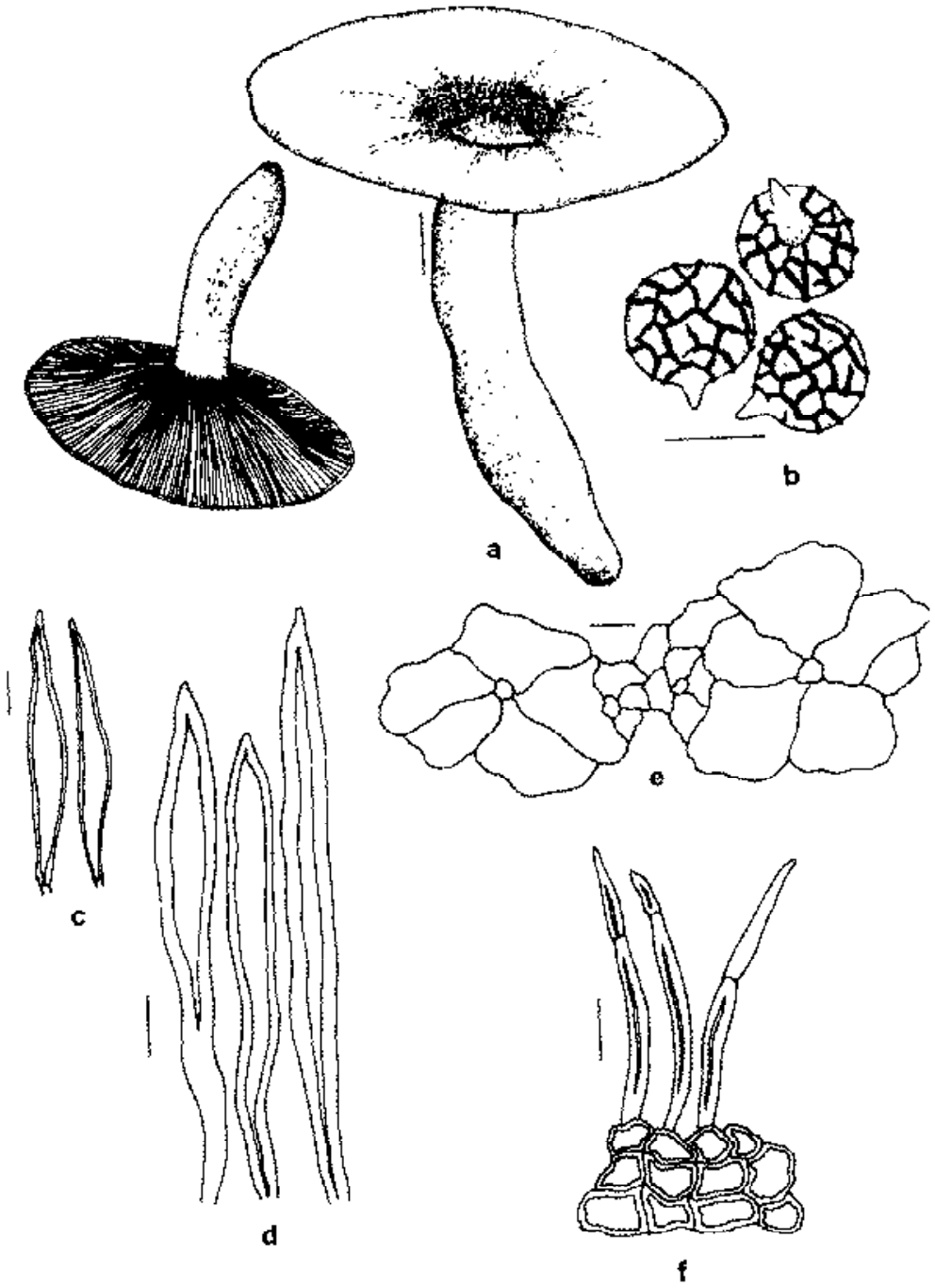


Fig. 13. *Lactarius corrugis*: a. Basidiomes b. Basidiospores c. Cheilocystidia d. Pleuromacrocystidia e. Sphaerocytes f. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

Spores 8.1-11.5 x 7.4-11 µm, globose to subglobose (Q= 1-1.13); ornamentation amyloid, up to 0.8 µm, composed of ridges forming complete reticulum. Basidia 40-54 x 8.3-9.6 µm, clavate, 4-spored; sterigmata up to 7.5 µm long. Pleuromacrocystidia 53.1-118 x 6.6-9.96 µm, abundant, fusiform to fusiform-sinuate, very thick walled; wall up to 4 µm broad. Cheilomacrocystidia 49-61 x 6.6-7.5 µm, subfusiform, very thick walled; wall up to 3 µm broad. Hymenophoral trama cellular. Pileipellis a trichoepithelium up to 120 µm thick; elements of suprapellis 55-77 x 3.9-5 µm, subcylindric, fusiform to lanceolate, septate, thick walled; subpellis composed of pseudoparenchymatous thick walled cells. Pilear trama with abundant sphaerocytes (up to 23 µm diam).

Ecology : Common, grows under *Quercus leucotrichophora* in temperate deciduous forests.

Specimens examined : Uttaranchal, Pithoragarh, Maitly top, September 28, 2001, **col.** K. Das & J.R. Sharma, KD4022; Uttaranchal, Pithoragarh, Dafia Dhura, September 29, 2001, **col.** K. Das & J.R. Sharma, KD4045; Uttaranchal, Champawat, Mayawati, September 29, 2002, **col.** K. Das & J.R. Sharma, KD4598.

Notes : The species is easily characterized by its fairly thick walled pleuromacrocystidia and velvety brownish pileus which usually cracks at center and becomes areolate. The white latex changes slowly to cream on exposure.

L. corrugis shares many characters with *L. volemus* (Fr.: Fr.) Fr. However, the present species is separated by smaller spores and pileocystidia. Moreover, unlike the present taxon, the pileus is lighter and often found with a papilla in *L. volemus*.

Lactarius hygrophoroides Berk. & Curt.

Ann. Mag. Nat. Hist. 3rd ser. 4: 293, 1859. var. **lavendulaceus** Hesler & Smith, North American Species of Lactarius. 176, 1979; Bhatt *et al.*, Ind. Phytopath. **52**(1999) 238; Das & Sharma, Phytotax. 4(2004)4.

Pl. 8; fig. 14

Pileus 50-90 mm diam., convex to planoconvex with depressed center or infunduliform when mature; pileipellis dry, slightly velvety, azonate, light to medium orange yellow, light orange; margin inrolled when young, gradually plane at maturity, regular. Lamellae broadly adnate to subdecurrent, distant (excluding lamellulae), entire, cream yellow to pale yellow, lamellulae present. Stipe 25-45 x 10-20 mm, mostly central, sometimes eccentric, cylindric or slightly tapered towards base, glabrous, concolorous with the pileus. Context solid, white, unchanging. Latex white, changing slowly to brown, nonsticky,

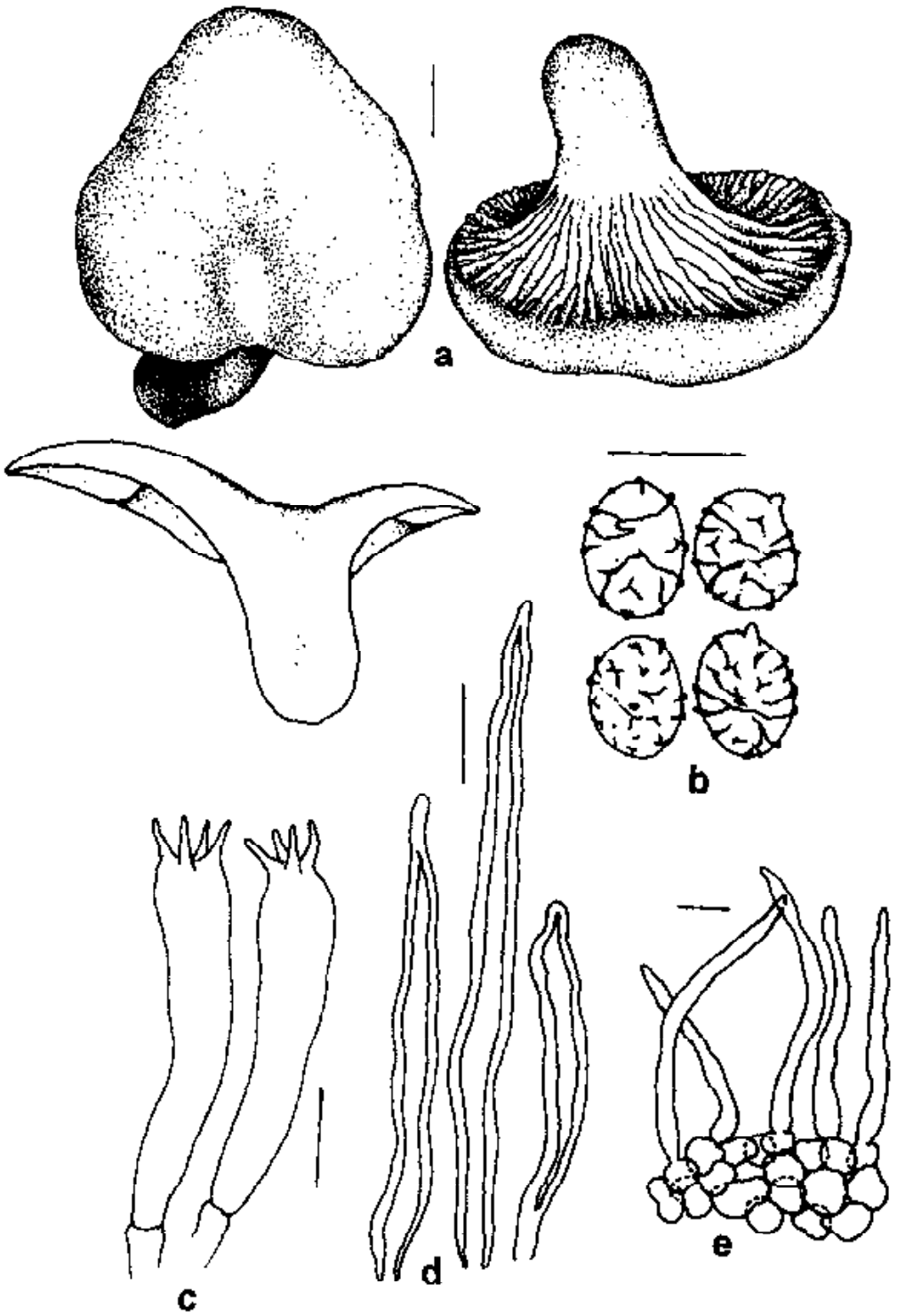


Fig. 14. *Lactarius hygrophoroides* var. *lavendulaceus*: a. Basidiomes b. Basidiospores c. Basidia d. Elements of suprapellis e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

staining lamellae pinkish at first then vinaceous buff after sometime. Odour indistinct. Spore print yellowish white.

Basidiospores 7.2-9 x 5-7 µm, broadly ellipsoid (Q = 1.2-1.4); ornamentation amyloid, up to 0.5 µm, composed of isolated warts and ridges forming partial reticulum. Basidia 35-52 x 8-11 µm, clavate, 4-spored. Pleuromacrocystidia absent. Pleuropseudocystidia up to 7 µm broad, irregularly cylindric. Cheilomacrocystidia 24-38 x 4-6.5 µm, cylindric to subclavate, scattered. Pileipellis a trichoepithelium to lampro epithelium, up to 100 µm thick, composed of two distinct layers; elements of suprapellis 33-67 x 2.5-8.5 µm, lanceolate, ventricose, subcylindric to cylindric, with rounded to acute apices, slightly thick walled (wall up to 1.2 µm thick); subpellis composed of pseudoparenchymatous isodiametric rounded cells; cell diameter up to 22 µm. Stipitipellis made up of two layers as pileipellis, elements of suprapellis are thicker than that of pileipellis. Stipe context heteromerous with abundant spherocytes.

Ecology : Common, grows under *Quercus leucotrichophora and Pinus roxburghii* in subtropical to temperate deciduous and coniferous forests.

Specimens examined : Uttaranchal, Bageshwar, Kausani, August 10, 2001, **col.** K. Das, KD916, KD926; Uttaranchal, Pithoragarh, near Maitly, October1, 2001, **col.** K. Das & J. R. Sharma, KD4037; Uttaranchal, Nainital, ramgarh, August 20, 2002, **col.** K. Das, KD2139; Uttaranchal, Bageshwar, Loharkhet top, September 25, 1999, **col.** K. Das & J.R. Sharma, KD1088.

Notes : The distinct yellowish to orange basidiomes with indistinctive odour separate this taxon from other variants under this species.

Lactarius hygrophoroides Berk. & Curt.

Ann. Mag. Nat. Hist. 3rd ser. **4**: 293, 1859. var. **odoratus**, Hesler & Smith, North American Species of Lactarius. 173, 1979; Bhatt *et al.*, Ind. Phytopath. **52** (1999) 239; Das & Sharma, Phytotax. **4**(2004)4. Pl. 8; fig. 15

Pileus 55-85 mm diam., convex to planoconvex with depressed center; pileipellis dry, velvety, azonate, grayish reddish orange, soft reddish brown; margin decurved to incurved when young, gradually plane at maturity, regular. Lamellae broadly adnate to subdecurrent, distant (excluding lamellulae), entire, pale orangish yellow, lamellulae present. Stipe 30-60 x 9-18 mm, central, cylindric or slightly tapered towards base, glabrous, concolorous with the pileus. Context solid, white, unchanging. Latex white, unchanging, staining lamellae pinkish grey on exposure, sticky. Odour strongly alkaline. Spore print yellowish white.

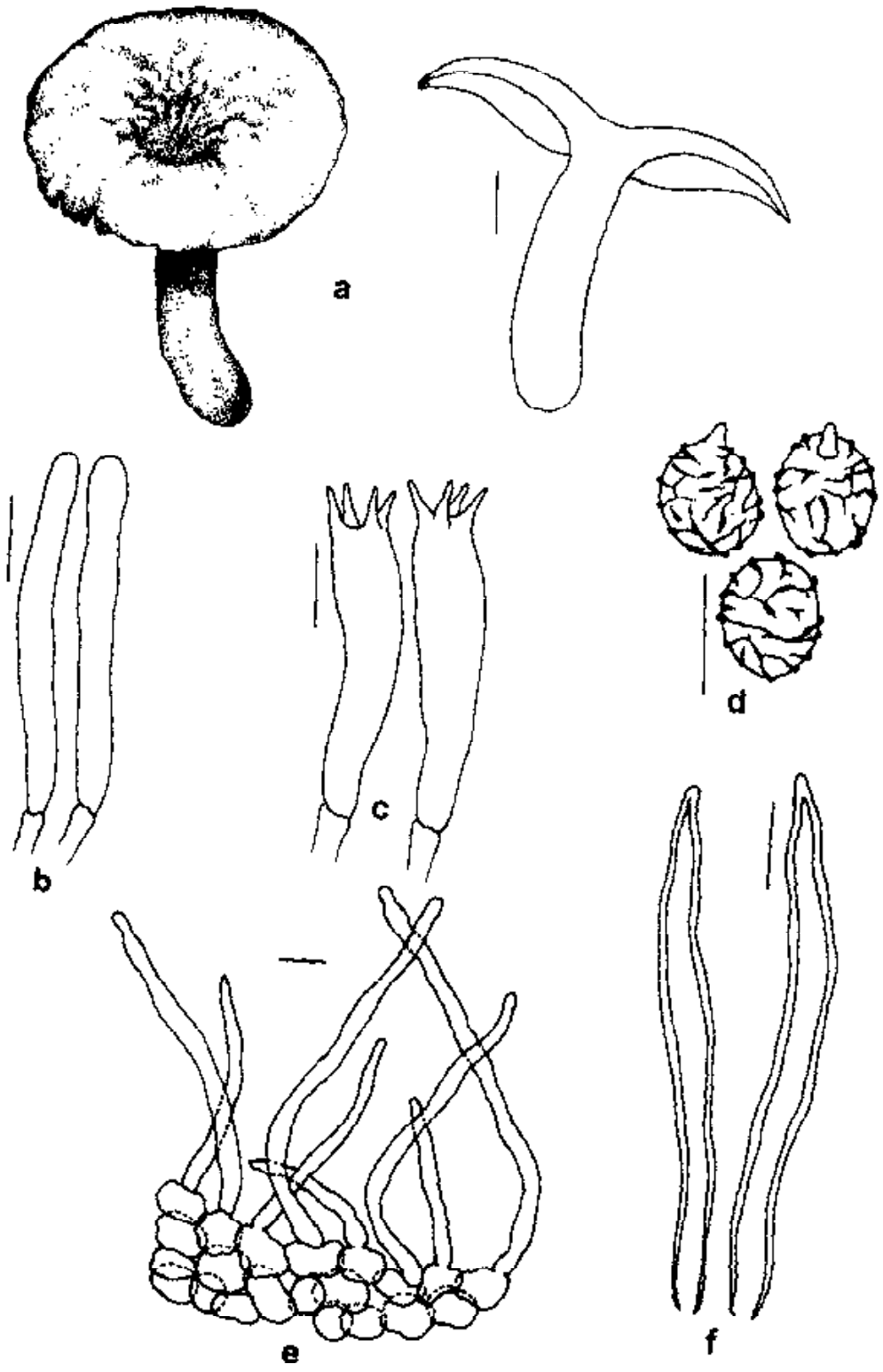


Fig. 15. *Lactarius hygrophoroides* var. *odoratus*: a. Basidiomes b. Cheilocystidia c. Basidia d. Basidiospores e. Cross section of pileipellis f. Elements of suprapellis. Bars: a = 10 mm; b-f = 10 µm.

Basidiospores 7-9 x 5.8-7.5 µm, broadly ellipsoid to ellipsoid (Q = 1.17-1.4); ornamentation amyloid, up to 0.5 µm, composed of isolated warts and ridges forming partial reticulum. Basidia 28-54 x 6-10 µm, clavate, 4-spored. Pleuromacrocystidia absent. Pleuropseudocystidia abundant up to 8 µm broad, irregularly cylindric. Cheilomacrocystidia 24-45 x 3-5.8 cylindric to subcylindric, scattered. Pileipellis a trichoepithelium to lamproepithelium, up to 130 µm thick, composed of two distinct layers; elements of suprapellis 30-90 x 3-8 µm, mostly subcylindric to cylindric, with rounded to acute apex, slightly thick walled (wall up to 1.3 µm thick); subpellis composed of pseudoparenchymatous isodiametric rounded cells; cell diameter up to 28 µm. Stipitipellis made up of two layers as pileipellis. Stipe context heteromerous with abundant spherocytes.

Ecology : Common, grows under *Quercus leucotrichophora* in temperate mixed forests.

Specimens examined : Uttaranchal, Champawat, Mayawati, August 15, 2002, **col.** K. Das, KD2113; Uttaranchal, Nainital, Ramgarh, August 20, 2002, **col.** K. Das, KD2144.

Notes : The darker basidiomes with strong alkaline odor in *Lactarius hygrophoroides* var. *odoratus* separate it from the closely related variant *Lactarius hygrophoroides* var. *lavendulaceus*.

Lactarius volemus (Fr.) Fr.

Epicr. Syst. Mycol. p. 344, 1848. *Agaricus volemus* Fr., Syst. Mycol. 1: 69, 1821; Saini & Atri., Soc. Ind. Natn. Sci. Acad. **48**(1982) 455; Atri & Saini, Geob. N. Rep. **5**(1986) 102; Saini & Atri, Geo. N. Rep. **3**(1984) 5; Rawla, Ind. Sci. Cong. Proc. (1994) 32; Das & Sharma, Phytotax. **4**(2004)6. Pl. 9; fig. 16

Pileus 37-80 mm diam., planoconvex, planoconcave or infundiliform when mature with or without papilla; pileipellis dry, glabrous, slightly areolate towards center, light to medium orange yellow, medium or deep to brownish orange, light reddish brown; margin incurved when young, mostly regular. Lamellae broadly adnate to subdecurrent, rather close (excluding lamellulae), entire, sometimes forked, ochraceous-white to light orange yellow, brownish orange or light reddish brown to brown after bruising, lamellulae numerous. Stipe 58-65 x 8-16 mm, central, cylindric or slightly tapered towards base, glabrous, concolorous with the pileus or slightly darker towards base. Context solid, ochraceous yellow, brown on exposure. Latex white, unchanging. Odour strong fish like. Spore print white.

Basidiospores 7-10 x 6.6-8.9 µm, globose to subglobose (Q = 1-1.15); ornamentation amyloid, up to 0.7 µm, composed of ridges forming almost

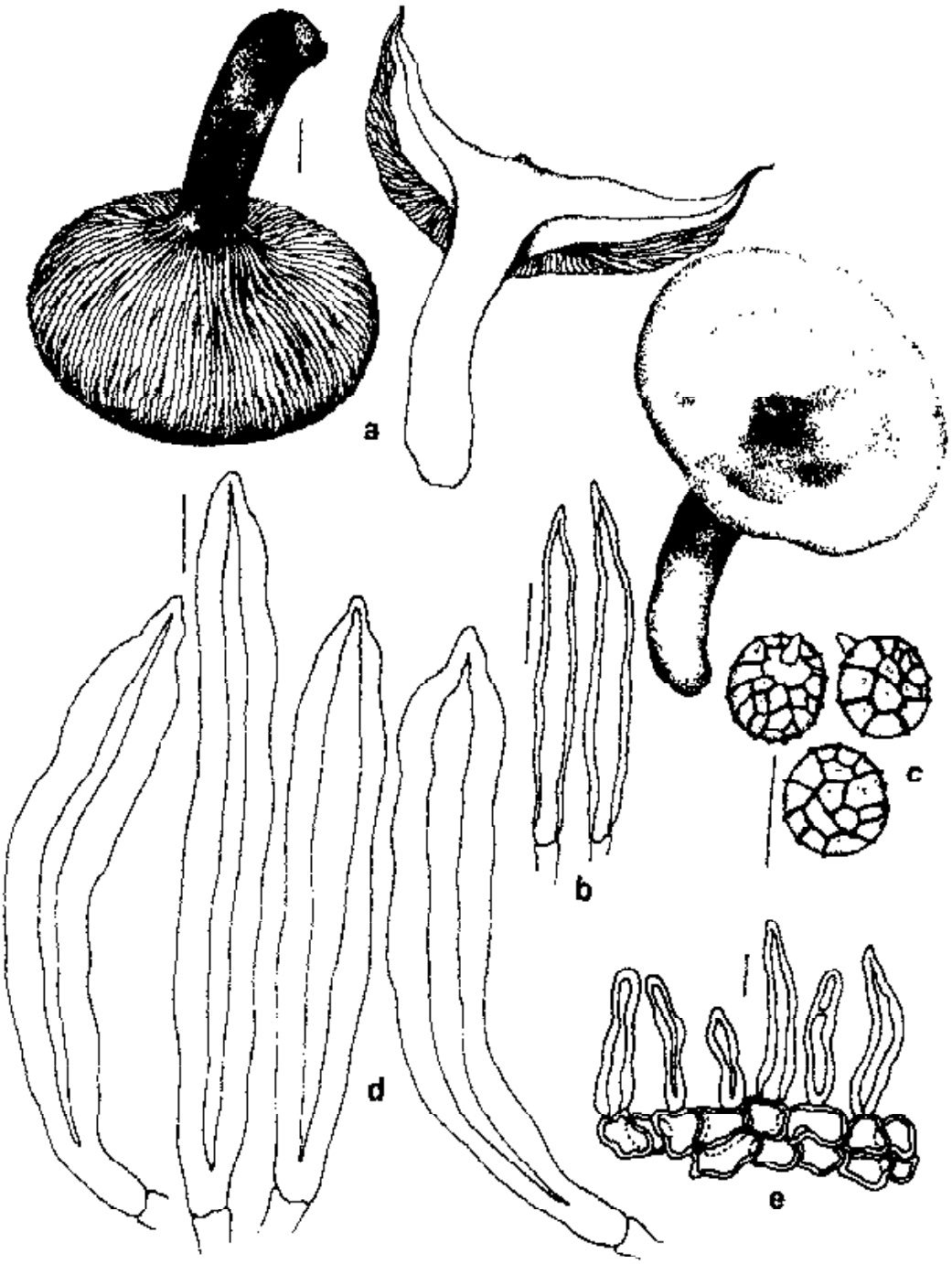


Fig. 16. *Lactarius volemus* var. *volemus*: a. Basidiomes b. Cheilocystidia c. Basidiospores d. Pleuromacrocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e ≈ 10 µm.

complete reculum. Basidia 59-70 x 9-12 µm, cylindric to subclavate, 2 to 4-spored. Pleuromacrocystidia 68-87 x 8-12.5 µm, emerging up to 35 µm, numerous, fusiform to subfusiform-acuminate, very thick walled; wall up to 4.5 µm broad. Cheilomacrocystidia 36-48 x 4-7 µm, fusiform, very thick walled; wall up to 3 µm broad. Hymeophoral trama cellular with abundant sphaerocytes. Pileipellis a trichoepithelium up to 125 µm thick; elements of suprapellis 17-53 x 3.5-8.2 µm, cylindric to subcylindric, lanceolate, sometimes septate, thick walled (wall up to 2.5 µm broad); subpellis composed of pseudoparenchymatous thick walled cells. Pilear trama with abundant lactiferous hyphae (up to 13 µm broad). Stipitipellis of two layers as pileipellis.

Ecology : Common, grows under *Quercus semecarpifolia, Q. dilatata and Rhododendron arboreum* in temperate deciduous forests.

Specimens examined : Uttaranchal, Bageshwar, Dhakuri, September 26, 1999, **col.** K. Das & J.R. Sharma, KD1090; *ibid.*, September, 2003, **col.** K. Das & J.R. Sharma, KD7060; Uttaranchal, Nainital, Mukteshwar, August 18, 2002, **col.** K. Das, KD2123; Uttaranchal, Pithoragarh, Sandev, September 27, 2001, **col.** K. Das & J.R. Sharma, KD4014; Uttaranchal, Champawat, Mayawati, September 29, 2002, **col.** K. Das & J.R. Sharma, KD4581.

Notes : The yellowish orange to brown, glabrous basidiomes with or without papilla, yellowish white lamellae becoming brown after bruising and distinct fishy odor characterize the present species in the field. Moreover, very thick walled pleurocystidia, globose to subglobose spores with almost complete reticulation are also very characteristic. *Lactarius corrugis* with which this species resembles, has more velvety pileus without papilla and larger spores.

Lactarius volemus (Fr.) Fr.

Epicr. Syst. Mycol. 344, 1848. var. **flavus** Hesler & Smith, North American Species of Lactarius. p. 165, 1979; *Agaricus volemus* Fr., Syst. Mycol. **1**: 69, 1821; Atri & Saini, Geob. N. Rep. **5**(1986) 101; Saini & Atri, Ind. Phytopath. **46**(1993) 363; Das & Sharma, Phytotax. **4**(2004)6.

Pl. 9; fig. 17

Pileus 30-55 mm diam., planoconvex, applanate or planoconcave with slightly depressed center; pileipellis dry, subvelvety to velvety, often cracked, pale yellow, buff yellow, pale to light orange yellow or light yellowish brown; margin decurved, mostly regular, sometimes splitted. Lamellae emarginate to subdecurrent, rather close (excluding lamellulae), entire, sometimes forked, yellowish white to pale yellow, light brown to pale reddish brown after bruising, lamellulae numerous. Stipe 45-70 x 9-12 mm, central, cylindric or slightly tapered towards base, glabrous, concolorous with the pileus. Context

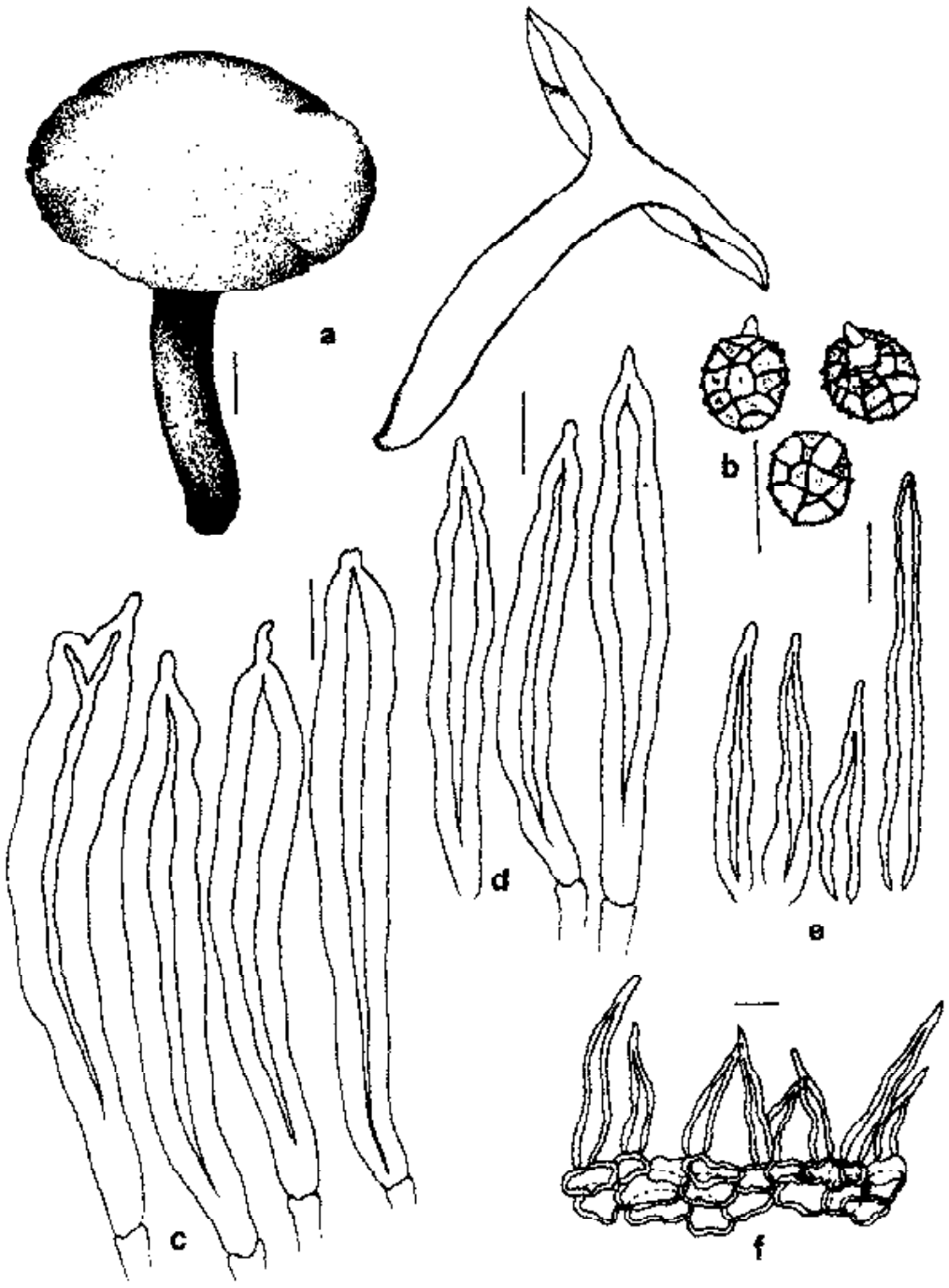


Fig. 17. *Lactarius volemus* var. *flavus*: a. Basidiomes b. Basidiospores c. Pleuromacrocystidia d. Cheilomacrocystidia e. Elements of suprapellis f. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

solid, yellowish white, gradually brown on exposure. Latex white, unchanging. Odour strong fish-like. Spore print white.

Basidiospores 6.4-8.3 x 5.8-8 µm, globose to subglobose (Q = 1-1.13); ornamentation amyloid, up to 0.7 µm, composed of ridges forming incomplete to almost complete reticulum. Basidia 38-55 x 6-10.4 µm, clavate, 4-spored. Pleuromacrocystidia 61-95 x 6-12 µm, numerous, ventricose fusiform to fusoid, very thick walled; wall up to 4 µm broad. Cheilomacrocystidia 33-74 x 4.5-7 µm, fusiform to subfusiform, very thick walled; wall up to 3.2 µm broad. Hymeophoral trama cellular with abundant sphaerocytes. Pileipellis a trichoepithelium up to 85 µm thick; elements of suprapellis 18-40 x 4-8 µm, cylindric to subfusoid or lanceolate, sometimes septate, thick walled (wall up to 2.2 µm thick); subpellis composed of pseudoparenchymatous thick walled cells. Pilear trama with abundant lactiferous hyphae, up to 15.5 µm broad. Stipitipellis made up of two layers as pileipellis.

Ecology : Common, grows under *Quercus leucotrichophora* and *Pinus roxburghii* in subtropical to temperate, mixed or coniferous forests.

Specimens examined : Uttaranchal, Nainital, Mukteshwar, August 19, 2002, **col.** K. Das, KD2143; Uttaranchal, Pithoragarh, Maitly, September 30, 2001, **col.** K. Das & J.R. Sharma, KD4022; Uttaranchal, Almora, near Binsar, August 9, 2001, **col.** K. Das, KD971.

Notes : Present taxon is distinguished from *L. volemus* var. *volemus* by its yellowish to buff, velvety, smaller basidiomes and slightly smaller basidiospores.

Plate 8: a. *Lactarius hygrophoroides* var. *odoratus* b & c. *L. hygrophoroides* var. *lavendulaceus* d. *L. capitatus*.

Plate 9: a. *Lactarius volemus* var. *flavus* b & c. *L. corrugis* d. *L. volemus* var. *volemus*.

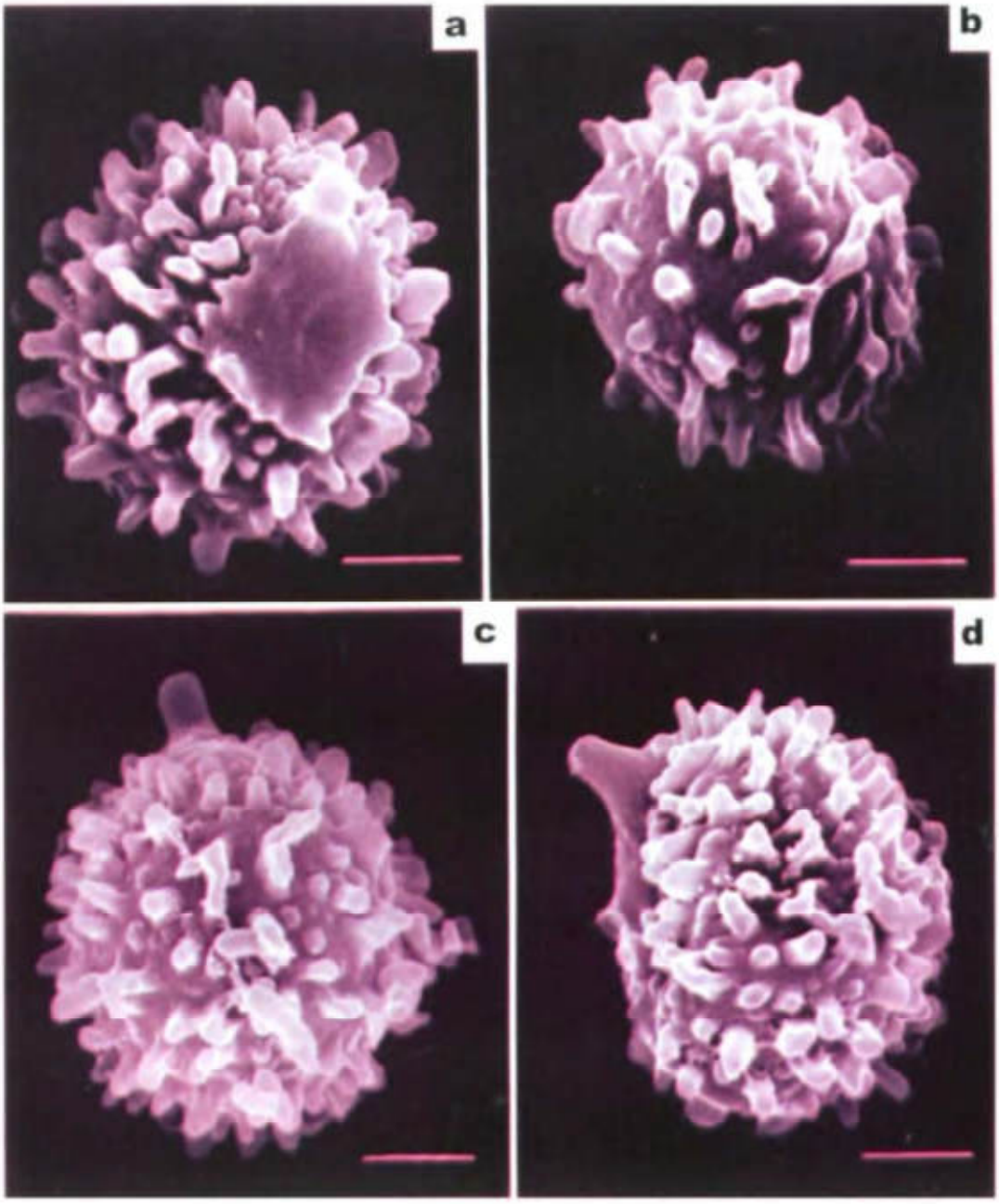


Plate 10: a. Scanning Electron Micrographs of basidiospores: 1-4. *Lactarius capitatus* (*Mycotaxon* **90:** 289). Bars = 10 ìm.

Subgenus **Piperites** (Fr.) Kauffman
The Agaricaceae of Michigan p. 88, 1918; *Lactarius* (Tribus) *Piperites* Fr., Epic. Syst. Mycol. p. 333, 1838; *Lactarius* section *Piperites* (Fr.) Quel., Champ. Jura et Vosges p. 194, 1872.

Pileus viscid, slimy or dry, smooth to hairy, azonate to zonate, buff, orange yellow to greenish blue; margin inrolled to plane; lamellae subdecurrent to decurrent; stipe mostly concolorous; latex white, yellow, orange, reddish brown or blue; basidiospores ornamentation amyloid, in parallel or reticulate fashion; pleuromacrocystidia present or absent; cheilomacrocystidia present or absent; pileipellis an ixocutis to trichoderm. Thirty two taxa in India; thirteen in Kumaon Himalaya.

KEY TO THE SPECIES

1a. Latex watery or white 2

b. Latex orange, very red or deep to dark reddish brown or deep greenish blue to blue 9

2a. Latex watery (transparent) ..... **L. dhakurianus**

b. Latex white 3

3a. Pileus dry; pileipellis a trichoderm ..... **L. daflanus**

b. Pileus viscid; pileipellis an ixocutis to ixotrichoderm 4

4a. Pileus grayish; spore ornamentation of zebroid pattern ..... **L. maitlyensis**

b. Pileus white to yellow; spore ornamentation as partially complete to incomplete reticulum 5

5a. Pileus yellowish white to pinkish buff, azonate ..... **L. controversus**

b. Pileus azonate to zonate, yellow, grayish yellow, orange yellow with a silvery lustre 6

6a. Latex unchanging 7

b. Latex yellow on exposure 8

7a. Pileus distinctly zonate ..... **L. zonarius**

b. Pileus azonate ..... **L. alnicola**

8a. Hairs at pileus margin very sticky; stipe pitted or scrobiculate ..... **L. abbotanus**

b. Hairs at pileus margin not sticky; stipe not scrobiculate ..... **L. mayawatianus**

9a. Latex deep greenish blue ..... **L. subindigo**

b. Latex orange, red to dark red or reddish brown 10

10a. Latex orange to orange yellow ..... **L. deliciosus**

b. Latex red to reddish brown 11

11a. Latex red; basidiomes grow in association with *Pinus* ..... **L. rubrifluus**

b. Latex reddish brown; basidiomes grow in association with *Abies* 12

12a. Basidiomes distinctly reddish brown after bruising; pileus margin sulcate; lamellae and lamellulae relatively distant ..... **L. subpurpureus**

b. Basidiomes distinctly bluish green after bruising; pileus margin regular; lamellae and lamellulae relatively crowded ..... **L. paradoxus**

Lactarius abbotanus K. Das & J.R. Sharma

Mycotaxon **88**: 378, 2003. Pl. 13; fig. 18

Pileus 64-83 mm diam., convex with depressed center, becoming deeply depressed to funnel shaped with age; cuticle glutinous, sticky, azonate, increasingly hairy towards margin, dark to deep orange yellow when young, brilliant yellow to orange yellow at maturity; margin decurved to inrolled, hairy, hairs long, up to 7 mm, slimy, sticky. Lamellae broadly adnate, distant (4 per 10 mm), yellowish white, lamellulae in two rows. Stipe 38-45 x 14-18 mm, cylindrical or with broader base, hollow, yellowish white to pale yellow becoming soft orange yellow after bruising, distinctly scrobiculate or pitted, pits medium to soft orange yellow, base hairy. Context pale yellow, brilliant yellow on exposure. Latex white, immediately brilliant to yellow on exposure. Spore print not found.

Basidiospores 8.3-10.5 x 7.4-8.0 µm (Q = 1.06-1.34), subglobose to ellipsoid, amyloid, ornamentation up to 1 µm high, composed of uneven ridges with acute edges forming partially complete reticulation, often spiny, connected with fine lines. Basidia 32-43 x 5-7 µm, subclavate, 4-spored. Pleuromacrocystidia 55-74 x 7-11.5 µm, abundant, fusiform to conical, projected up to 48 µm

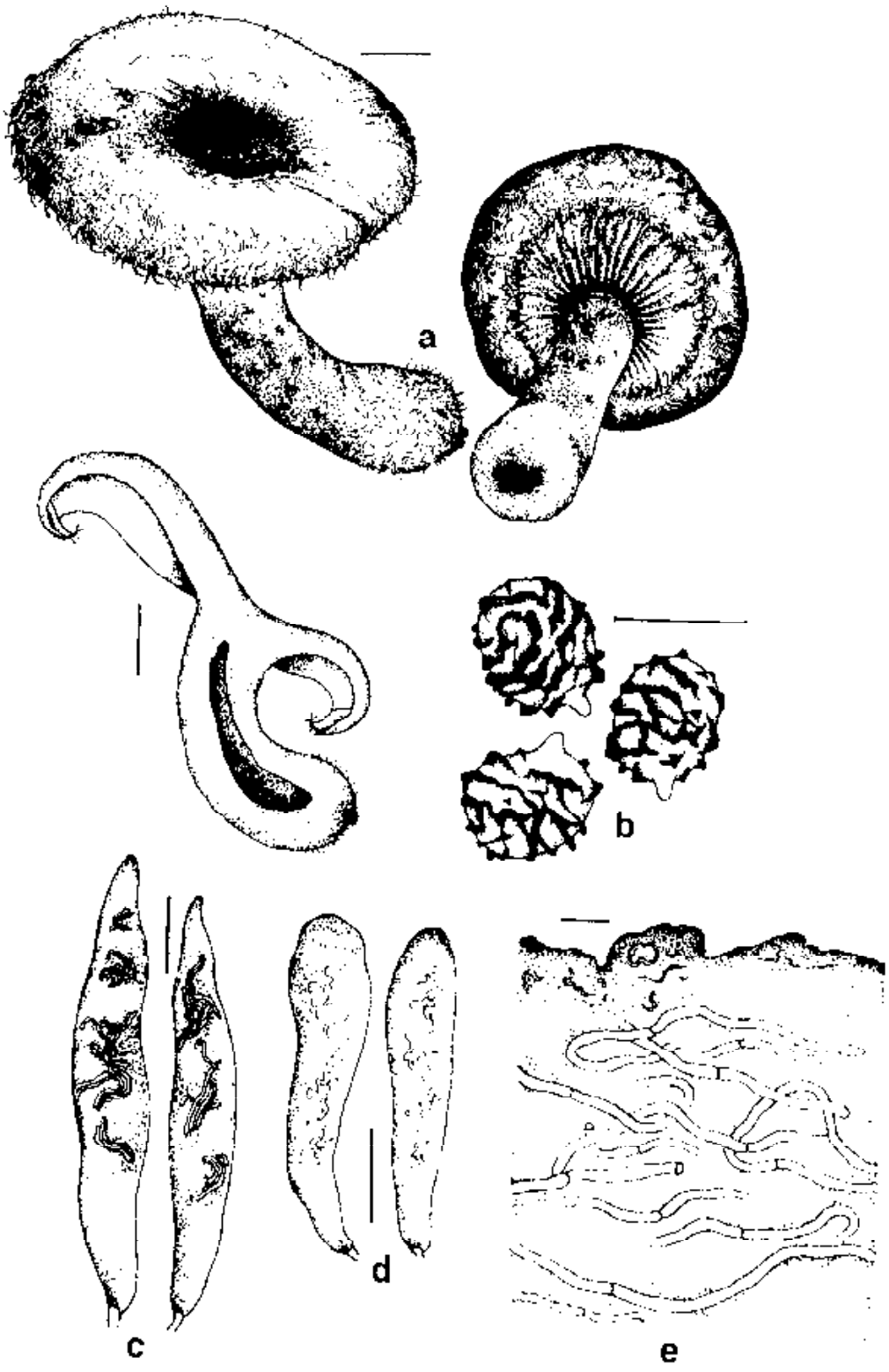


Fig. 18. *Lactarius abbotanus*: a. Basidiomes b. Basidiospores c. Pleurocystidia d. Cheilocystidia e. Pileipellis. Bars: a = 10 mm; b-e = 10 µm.

beyond hymenial layer. Cheilomacrocystidia 39-47 x 7-8 µm, clavate to subclavate. Paracystidia 26-30 x 8.5-9.5 µm, densely crowded, clavate. Subhymenium narrow, up to 10 µm thick, cellular. Pileipellis an ixocutis, about 500 µm thick, composed of densely interwoven thin walled hyphae, hyphae 2.5-4 µm broad. Lactiferous hyphae abundant in pilear trama,up to 8 µm broad.

Ecology : Rare, grows in close association with *Quercus leucotrichophora* in temperate deciduous forests.

Specimens examined : Uttaranchal, Champawat, Abbot Mt., September 23, 2002, **col.** K. Das & J.R. Sharma, KD4524; Uttaranchal, Champawat, Furti, September 27, 2002, **col.** K. Das & J.R. Sharma, KD4529.

Notes : Lactarius abbotanus can easily be recognized in the field by the azonate, glutinous pileus with glutinous marginal hairs, distant lamellae, chalky scrobiculate or pitted stipe and white latex turning brilliant yellow immediately on exposure. Abundant pleuromacrocystidia and fairly thick pileipellis also make this taxon distinct.

The above mentioned characters place this taxon into subgenus *Piperites* (Fr.) Kauff., section *Piperites* Fr. and subsection *Scrobiculati* Hesler & A.H. Sm. It is closely allied with *L. citriolens* Pouzar, *L. delicatus* Burl. and *L. aquizonatus* Kytöv. But unlike the present species, *L. citriolens* (Heilmann-Clausen *et al.* 1998) has dry marginal hairs, medium crowded lamellae, stipe without scrobicules or pits and smaller spores (6.3-9.1 x 4.7-6.4 µm). Distinctly zonate, glabrescent pileus, faintly to non-scrobiculate stipe and smaller spores (7-9.5 x 6-7 µm) separate *L. delicatus* (Hesler & Smith 1979) from the present taxon. In *L. aquizonatus* (Heilmann-Clausen *et al.* 1998), the pileus is distinctly zonate, gills crowded and spores are smaller (6-8.5 x 4-6 µm).

Lactarius alnicola A.H. Smith.

Brittonia **12**: 319, 1960; Atri & Saini, Geob. N. Rep. **5**(1986) 103; Kavaka **16**(1988) 17; Das & Sharma, Phytotax. **4**(2004)4. Pl. 12; fig. 19

Pileus 45-90 mm diam., convex-depressed, broadly infundibuliform at maturity; pileipellis viscid to glutinous, matted fibrillose, obscurely spotted, pale yellow to light yellow, gradually orangish after bruising; spots medium yellowish orange. Lamellae decurrent, distant (3-4 per cm), forked, often interveined, yellowish white to cream, lamellulae numerous. Stipe 40-50 x 15-22 mm, cylindric, fibrillose in places, scrobiculate, yellowish white, white above, gradually orangish towards base after bruising. Context hard, hollow, pale to light orangish yellow. Odour mild. Taste acrid. Latex white unchanging. Spore print yellowish white to very pale yellow.

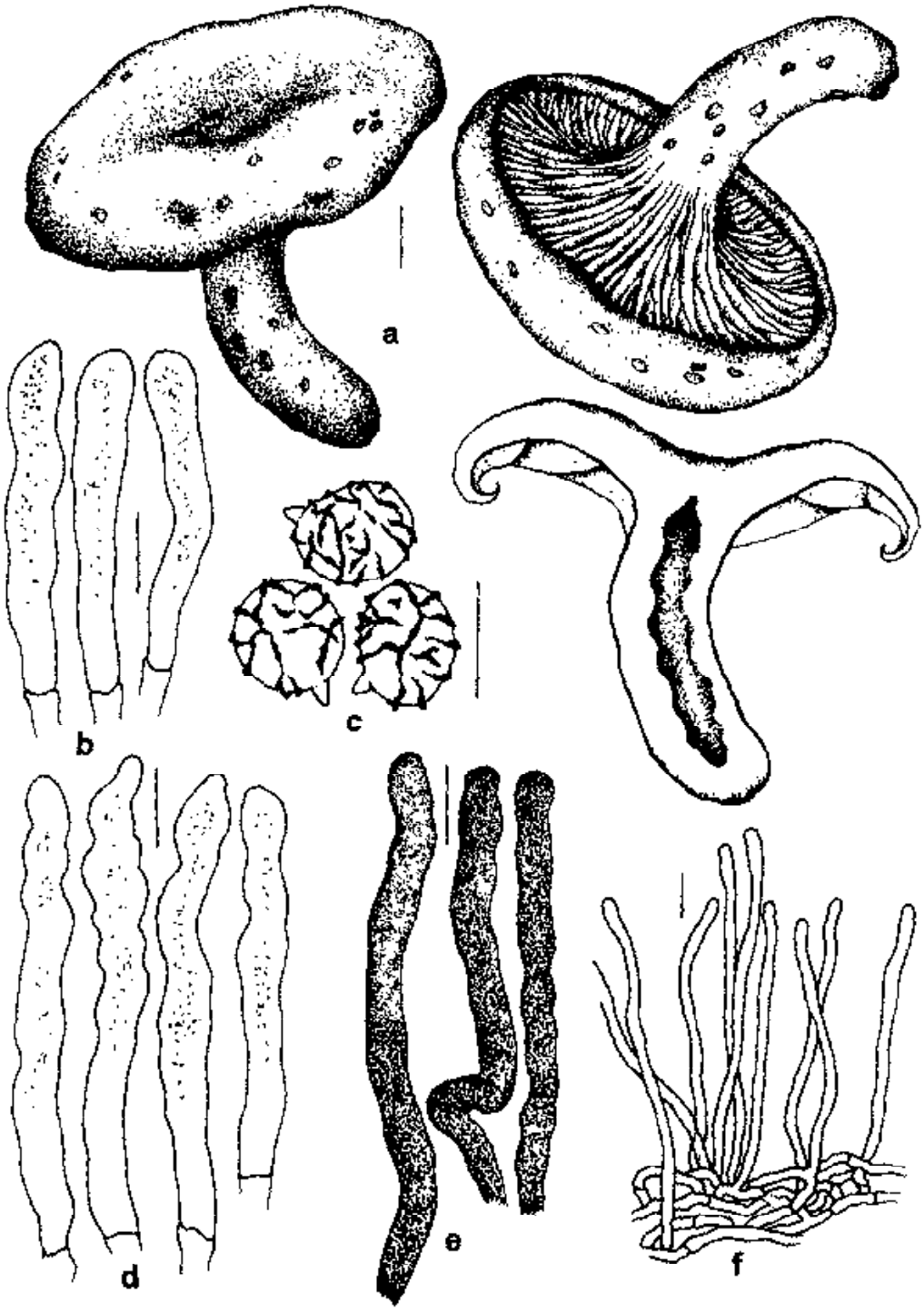


Fig. 19. *Lactarius alnicola*: a. Basidiomes b. Cheilocystidia c. Basidiospores d. Pleuromacrocystidia e. Pleuropseudocystidia f. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

Basidiospores 8.6-10.2 x 7.5-9.2 µm, globose to broadly ellipsoid (Q = 1.01-1.27); ornamentation amyloid, up to 1.4 µm high, composed of warts and ridges forming partially complete reticulation. Basidia 35-45 x 8-11 µm, clavate, 4-spored. Pleuromacrocystidia 45-70 x 5-8 µm, almost fusiform with wavy walls near apex. Pleuropseudocystidia 5-7 µm broad, cylindrical. Lamellae edge sterile. Cheilomacrocystidia 30-40 x 6-10 µm, clavate. Hymenophoral trama composed of interwoven hyphae and lactifers. Pileipellis an ixocutis to ixotrichoderm, 250-300 µm thick, composed of repent to ascending hyphae (up to 4 µm broad). Stipipellis composed mostly of repent hyphae.

Ecology : Rare, grows in ectomycorrhizal association with the species of *Abies* in the temperate mixed forests.

Specimens examined : Uttaranchal, Bageswar, Dhakuri, September, 1999, col. K. Das & J.R. Sharma, KD1036, KD1045.

Notes : The species can be distinguished by buff to yellowish basidiomes, scrobiculate stipe, matted fribillose pileus with naked margin and white unchanging latex. *Lactarius alnicola* is close to *L. scrobiculatus* but the latter has smaller spores (Heilman-Clausen, 1998).

Lactarius controversus (Fr.) Fr.

Epicr. Syst. Mycol. p. 335. 1838; *Agaricus controversus* Fr., Syst. Mycol. **1**: 62, 1821; Watling & Gregory, N. Hedwigia **32**(1980) 536; Abraham *et al*, Kavaka **9**(1981)38; Rawla, Bio. Ind. (2002) 226; Das & Sharma, Phytotax. **4** (2004)4. Fig. 20

Pileus 70-110 mm, convex to planoconvex with depressed center, infundibuliform at maturity; pileipellis viscid, azonate, yellowish white, pinkish white, pale yellowish pink or buff; margin inrolled, decurved at maturity. Lamellae adnate to slightly decurrent, rather crowded (8-9 per cm), light pinkish yellow; lamellulae in different series. Stipe 30-45 x 15-20 mm, cylindric or slightly tapering downwards, yellowish to pinkish buff. Cojtext white, stuffed, hollow at maturity. Latex white, unchanging. Taste slowly acrid. Spore print pinkish buff.

Basidiospores 6-7.7 x 5-5.8 µm, broadly ellipsoid to ellipsoid (Q = 1.17-1.45); ornamentation amyloid, up to 0.5 µm high, composed of ridges and few warts forming partially complete reticulation. Basidia 45-55 x 7-10 µm, cylindric to subclavate, 4-spored. Pleuromacrocystidia 40-54 x 7-10 µm, emergent up to 10 µm, cylindric to fusiform with mucronate to moniliform apices, often with irregular subapical constrictions. Pleuropseudocystidia up to 5 µm broad, cylindrical with rounded apices. Lamellae edge sterile. Cheilomacrocystidia 30-40 x 4-6 µm, fusiform with mucronate apices. Paracystidia

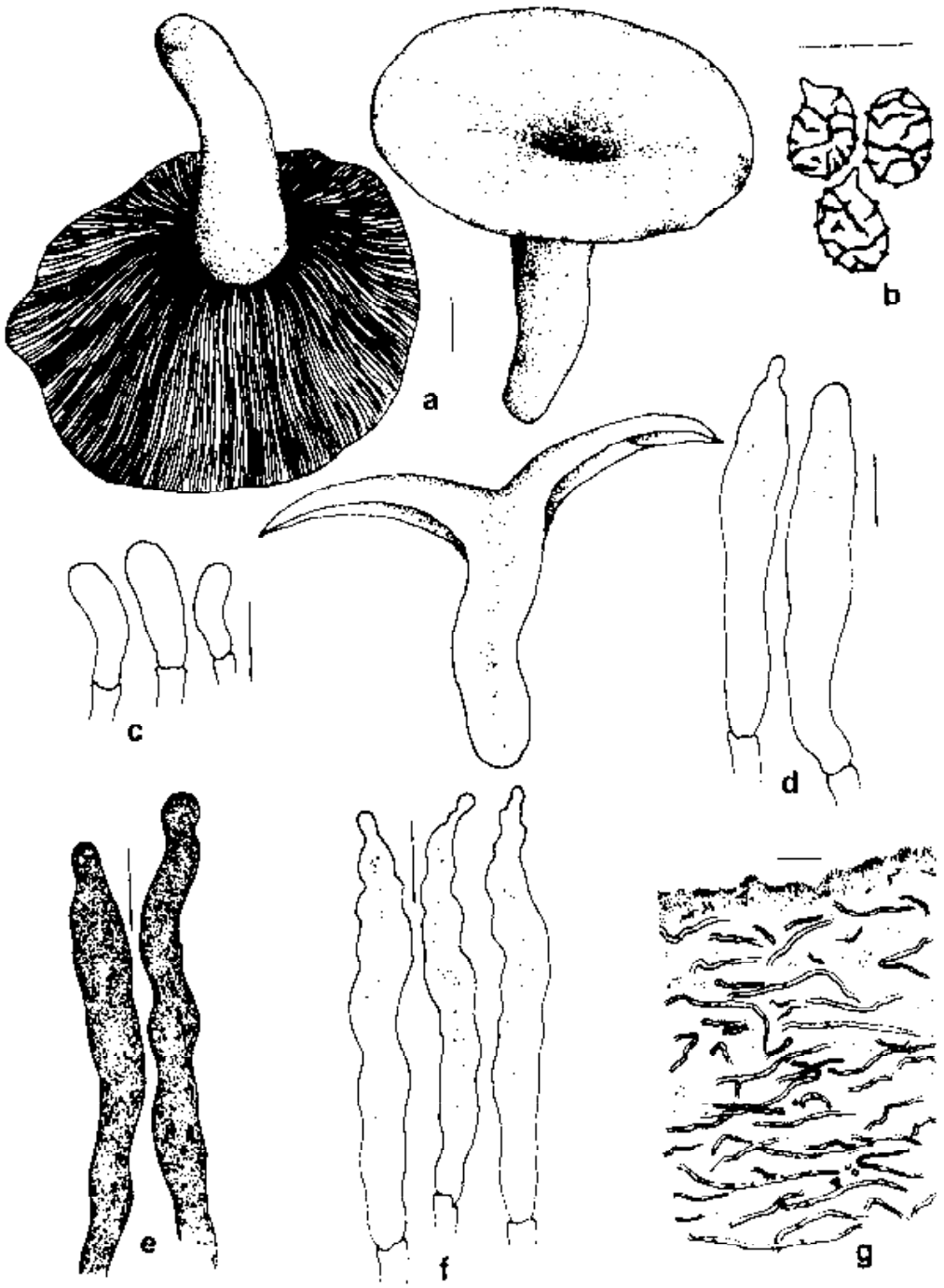


Fig. 20. *Lactarius controversus*: a. Basidiomes b. Basidiospores c. Paracystidia d. Cheilocystidia e. Pleuropseudocystidia f. Pleuromacrocystidia g. Pileipellis. Bars: a = 10 mm; b-g = 10 µm.

14-20 x 5-8 µm, cylindric to subclavate. Pileipellis an ixocutis, up to 380 µm, composed of parallel to subparallel hyphae (up to 3 µm broad).

Ecology : Rare, grows ectomycorrhiza with the species of *Quercus* and *Rhododendron* in the temperate mixed forests.

Specimens examined : Uttaranchal, Champawat, Mayawati, September, 2002, **col.** K. Das & J.R. Sharma, KD4555; Uttaranchal, Almora, Mornoula, October, 2002, **col.** K. Das & J.R. Sharma, KD4573.

Notes : Morphologically, *L. controversus* resembles *L. piperatus* but the latter has no tinge of pink in the basidiomes and has the white latex which turns cream to yellow on exposure.

Lactarius dafianus K. Das, J.R. Sharma & Verbeken

Mycotaxon **88**: 338, 2003 Pl. 13; fig. 21

Pileus 65-75 mm diam., convex, applanate with depressed center when mature; pileipellis slightly moist, medium to dark reddish orange becoming deep reddish purple or blackish at center, zonate; zones more distinct towards periphery. Lamellae rather dense (5 per cm), emarginate to subdecurrent, forked, lamellulae in several rows, light yellowish pink. Stipe 25-32 x 8-11 mm, cylindric, slightly tapering towards base, medium reddish to rusty brown; context hollow, pale to pale orange yellow. Latex watery white, unchanging. Spore print white.

Basidiospores 7.7-9.5 x 5.9-6.7 µm (Q = 1.20-1.42), broadly ellipsoid to ellipsoid; ornamentation amyloid, up to 1 µm high, composed of rather spiny warts and ridges, often aligned or connected, never forming a complete reticulum, at most a very incomplete reticulate pattern, but isolated warts and ridges mostly quite abundant; plage not or very slightly distally amyloid. Basidia 35-45 x 10-12 µm, subcylindric to subclavate, 4-spored. Pleuromacrocystidia 55-84 x 6-11 µm, abundant, fusiform with mucronate to moniliform apices, with needle-like contents, originating rather deep in the hymenium. Lamellae edge with scattered basidia and cheilomacrocystidia. Cheilomacrocystidia 54-70 x 5-10 µm, lanceolate to fusiform, contents as in pleuromacrocystidia. Hymenophoral trama composed of hyphae and abundant sphaerocytes, lactifers up to 8 µm broad. Pileipellis a loosely interwoven trichoderm, up to 80 µm thick; terminal elements 30-60 x 3-6 µm, cylindric.

Ecology : Rare, grows in close association with *Rhododendron arboreum* in temperate deciduous forests.

Species examined : Uttaranchal, Pithoragarh, Dafia Dhura, October 3, 2001, **col.** K. Das & J.R. Sharma, KD4059; Uttaranchal, Pithoragarh, Kannar, October 4, 2001, **col.** K. Das & J.R. Sharma, KD4088.

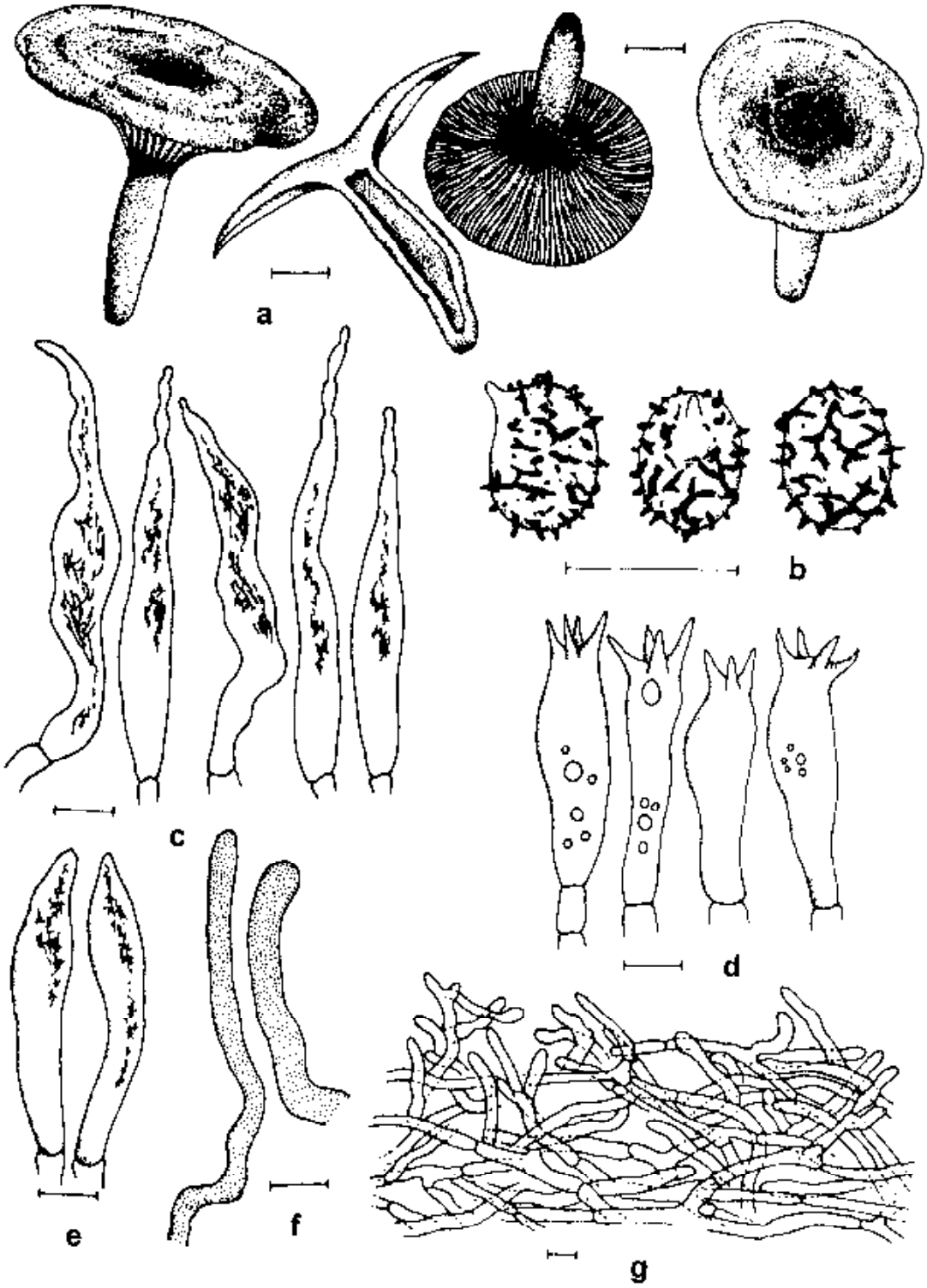


Fig. 21. *Lactarius dafianus*: a. Basidiomes b. Basidiospores c. Pleuromacrocystidia d. Basidia e. Cheilomacrocystidia f. Pleuropseudocystidia g. Pileipellis. Bars: a = 10 mm; b-g = 10 µm.

Notes : The dry pileus, unchanging latex, non-scrobiculate stipe, trichoderm pattern of pileipellis and incomplete reticulate arrangement of warts and ridges on basidiospores place this species under the subgenus *Piperites* (Fr.) Kauffman, section *Colorati* (Bat.) Hesler & A.H. Sm. *Lactarius dafianus* resembles *L. rufus* (Scop.: Fr.) Fr., but the latter differs by the azonate pileus with a distinct umbo. Furthermore, in *L. rufus*, spore print is "cream buff to pale pinkish buff" in colour and spores are larger [8.5-10.5 (12) x 6-7.5 (-8) µm] (Hesler & Smith 1979).

Lactarius deliciosus (Fr.) Gray

Nat. Arr. Brit. Pls. **1**: 624, 1821. *Agaricus deliciosus* Fr., Syst. Mycol. **1**: 67, 1821; Berk., Hook. J. Bot. 4(1852) 134; Saini & Atri, Soc. Ind. Natn. Sci. Acad. **48**(1982) 456; Geob. N. Rep. **3**(1984) 5; Atri & Saini, Geob. N. Rep. **10**(1991) 107; Rawla, Bio. Ind. (2002) 228; Das & Sharma, Phytotax. **4**(2004)4. Pl. 11; fig. 22

Pileus 40-100 mm diam., convex with depressed center, planoconvex to broadly infundibuliform at maturity; pileipellis viscid distinctly zonate with broad and narrow concentric zones, soft to very orange darker at the zonation, whitish between two concentric rings, grayish green after bruising; margin inrolled, gradually plane at maturity, wavy. Lamellae decurrent, distant (3-4 per cm), soft orange to orange yellow, slowly grayish green after bruising; lamellulae in different series. Stipe 35-70 x 8-22 mm, cylindric to clavate, concolorus with pileus, grayish green after bruising. Context hollow, light yellowish orange. Latex very orange yellow to soft orange, staining lamellae grayish green after sometime. Odour fruity. Taste mild.

Basidiospores 8-10.5 (11) x 6-7.6 µm, broadly ellipsoid to ellipsoid (Q = 1.17-1.6); ornamentation amyloid, up to 0.5 µm high, composed of mainly ridges forming incomplete reticulation. Basidia 40-55 x 9-12 µm, cylindric to subclavate, 4-spored. Pleuromacrocystidia 50-72 x 7-10 µm, uncommon, subfusiform with mucronate to moniliform apices. Lamellae edge sterile. Cheilomacrocystidia same as pleuromacrocystidia. Paracystidia 18-28 x 7-10 µm, abundant, mostly clavate. Pileipellis an ixocutis, up to 100 µm thick, composed of branched septate hyphae; hyphae up to 6 µm broad.

Ecology : Common, grows in close association with the species of *Quercus*, *Rhododendron* and *Abies* in the temperate mixed forests.

Specimens examined : Uttaranchal, Bageswar, Dhakuri, September, 1999, **col.** K. Das & J.R. Sharma, KD1007, KD1013, KD1019; *ibid.*, September, 2003, **col.** K. Das & J.R. Sharma, KD7013, KD7016, KD7040, KD7042, KD7043.

Notes : Lactarius deliciosus is distinguished easily in the field by viscid zonate orange pileus which changes to grayish green after bruising,

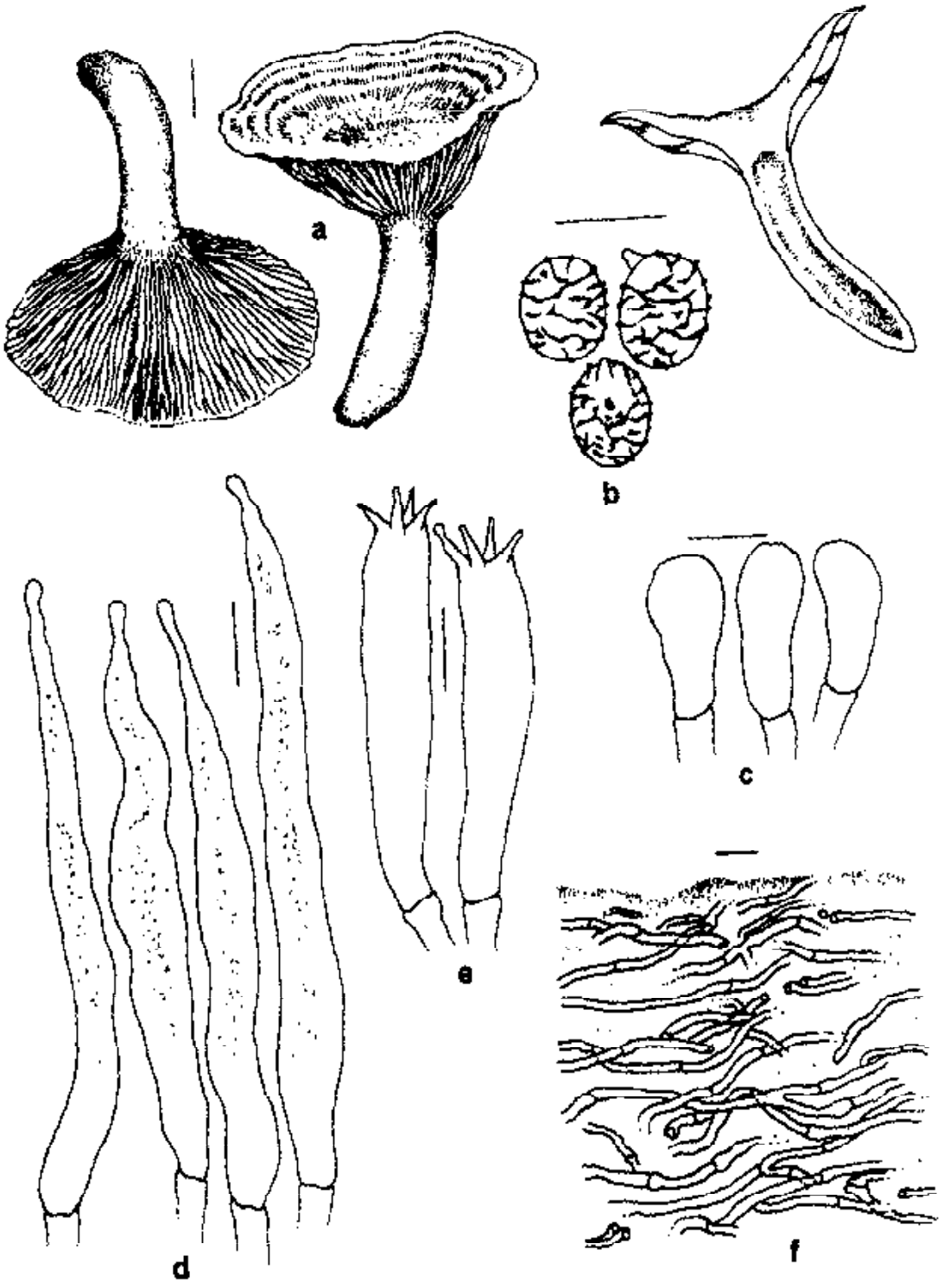


Fig. 22. *Lactarius deliciosus*: a. Basidiomes b. Basidiospores c. Paracystidia d. Pleuromacrocystidia e. Basidia f. Pileipellis. Bars: a = 10 mm; b-f = 10 µm.

carrot orange unchanging latex, zonate pileus, fruity odor. *Lactarius sanguifluus* which resembles with *Lactarius deliciosus*, can be separated by brownish red latex (Heilmann-Clausen *et al.* 1998).

Lactarius dhakurianus K. Das, Basso & J.R. Sharma

Mycotaxon **91**: 3, 2005. Fig. 23

Pileus 60-90 mm diam., convex, planoconvex with slightly depressed center at maturity; pileipellis slightly slimy, unpolished, smooth, irregularly granulose all over, light to medium orange yellow, brilliant orange yellow or ochraceous; margin incurved to decurved, regular, sometimes splitted. Lamellae broadly adnate to adnexed, distant (2-3 per cm), concolorous with the pileus, often with brownish spots at maturity; lamellulae of similar length. Stipe 50-65 x 16-23 mm, cylindric or tapering towards base, upper part concolorous with pileus, paler towards base, often with irregular brown spots towards base. Context solid, yellowish white to pale yellow, slowly becoming slightly brownish. Latex transparent, watery, unchanging. Odour aromatic. Taste acrid. Spore print yellow white.

Basidiospores 5.7-8 x 4.2-6.3 µm, subglobose to ellipsoid (Q = 1.28); ornamentation less than 0.5 µm, amyloid, composed of numerous irregular warts, not or rarely connected by fine lines; plage inamyloid, distinct. Basidia 28-50 x 6-9 µm, subcylindric to clavate, 2 to 4-spored; sterigmata up to 5 µm long. Pleuromacrocystidia absent. Pleuropseudocystidia 4-7 µm broad, irregularly cylindric with rounded apices, contents dense. Paracystidia 35-50 x 6-8 µm, cylindric to clavate. Lamellae edge fertile. Cheilomacrocystidia absent. Cheilopseudocystidia up to 6 µm broad, cylindrical. Paracystidia subclavate to clavate. Subhymenial layer up to 28 µm thick, cellular. Hymenophoral trama cellular with sphaerocytes and few hyphae; cells up to 40 µm diam. Pileipellis an ixocutis, composed mostly of repent parallel and interwoven hyaline hyphae submerged under a very thin gluten layer; hyphae up to 3.5 µm broad. Stipitipellis a cutis, composed of parallel hyphae; hyphae up to 5.5 µm broad.

Ecology : Rare, grows in association with species of *Rhododendron* and *Quercus* in deciduous temperate forests.

Specimens examined : Uttaranchal, Bageswar, Dhakuri top, September 19, 2003, **col.** K. Das & J.R. Sharma, KD7025; *ibid.*, September 29, 1999, **col.** K. Das & J.R. Sharma, KD1008.

Notes : Lactarius dhakurianus was found only at the survey sites in the forests surrounding Dhakuri. It can easily be distinguished in the field by the orange yellow to yellow ochre pileus, distant lamellae with a single

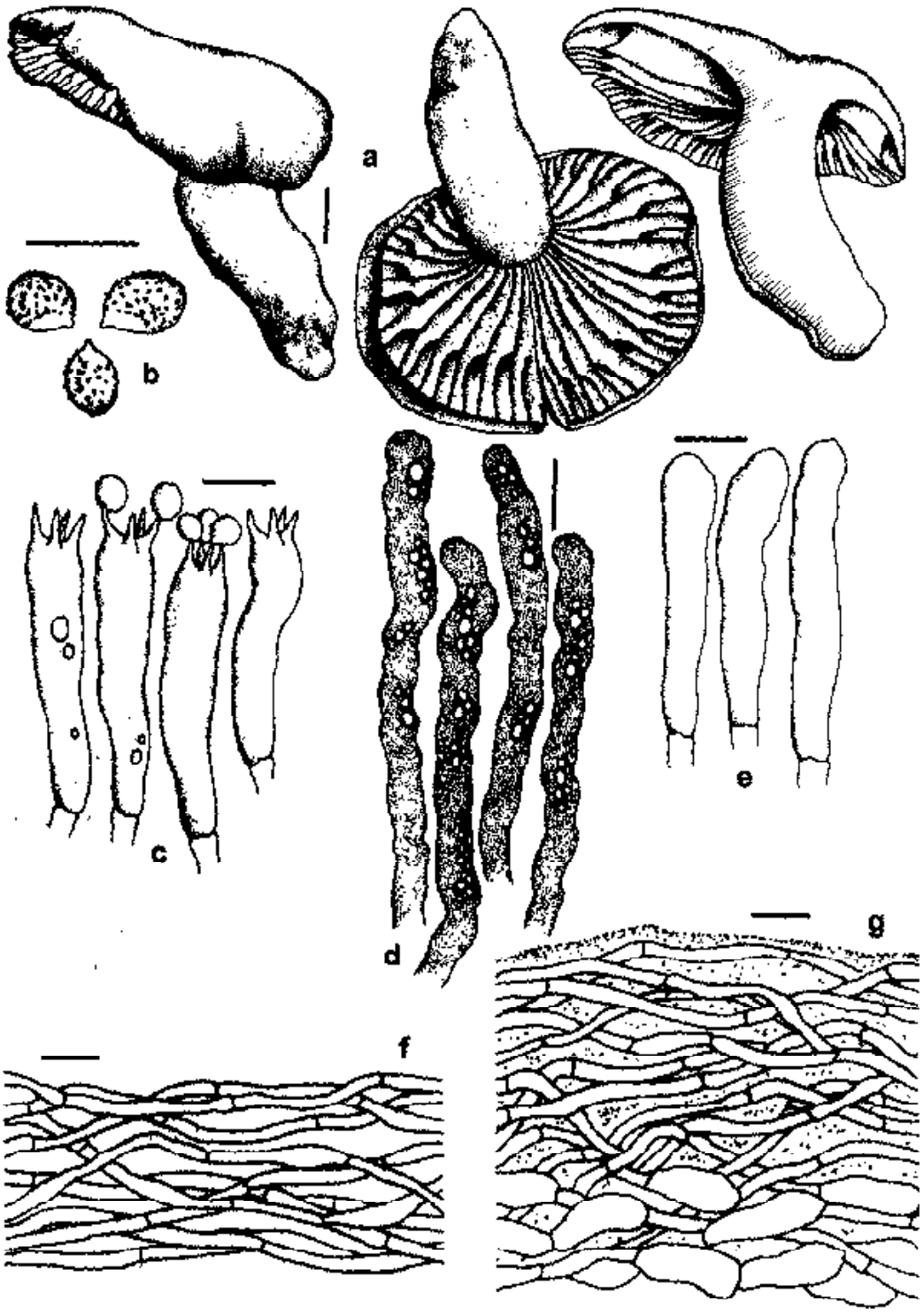


Fig. 23. *Lactarius dhakurianus*: a. Basidiomes b. Basidiospores c. Basidia d. Pleuropseudocystidia e. Paracystidia f. Cross section of stipitipellis g. Cross section of pileipellis. Bars: a = 10 mm; b-g = 10 µm.

row of lamellulae and watery (transparent) unchanging latex. Microscopically, the absence of hymenial macrocystidia is also very characteristic.

Lactarius dhakurianus resembles Indian species *L. himalayana* Rawla & Sarwal and the American species *L. villozonatus* G.F. Atk. However, the pale yellow pileus, the crowded lamellae with 1-3 rows of lamellulae, the pruinose stipe and the different spore ornamentation with warts "mostly joined by thinnish ridges to form a partial network with few meshes" and cutis arrangement of pileipellis separate *L. himalayana* (Rawla & Sarwal 1983) from the present taxon. Similarly, the zonate villose pileus, subdistant lamellae, the reticulate pattern of basidiospore ornamentation and the presence of pleuromacrocystidia are the characters which separate *L. villozonatus* (Hesler & Smith 1979, Burlingham 1932) from *L. dhakurianus*.

Moreover, the present species also shares some features with *L. aureifolius* Verbeken and *L. aurantifolius* Verbeken, both African species. *L. aureifolius* (Verbeken & Walleyn 1999), however, differs in the presence of white latex, lamellae with 3-5 rows of lamellulae, basidiospores with suprahilar plage and with a central amyloid spot. *L. aurantifolius* (Verbeken 1996) has white latex, white fimbriate lamellae edge and larger basidiospores (7.4-9.6 x 5.9-7.3 µm).

Lactarius maitlyensis K.Das, J.R. Sharma & Verbeken

Mycotaxon **88**: 336, 2003. Pl. 13; fig. 24

Pileus 40-70 mm diam., convex, applanate with slightly depressed center at maturity; pileipellis viscid, faintly zonate to azonate, greyish to deep grey-reddish brown with pale yellow areas and darker center; margin decurved, somewhat wavy. Lamellae adnate to emarginate, subdistant to rather dense (4-5 per cm), with two rows of lamellulae, yellowish white to pale yellow. Stipe 38-50 x 7-10 mm, subcylindric or tapered towards base, yellowish white, grey-yellowish brown towards base. Context firm, yellowish white becoming dingy slowly. Latex white, becoming light greenish yellow on exposure. Spore print yellowish white.

Basidiospores 6.5-8 x 5.7-6.7 µm (Q = 1.02-1.21), globose to broadly ellipsoid; ornamentation amyloid, up to 1.5 µm high, composed of ridges and warts in a distinct zebra-like pattern; ridges often with a somewhat knotty aspect; plage not or very slightly distally amyloid. Basidia 35-50 x 10-13 (-14) µm, clavate, 4-spored, with rather long sterigmata (up to 11 µm). Pleuromacrocystidia 50-90 x 9-14 µm, abundant, emergent up to 35 µm, irregularly subclavate to fusiform, apices subacute to often very long and narrow, with needle-like contents. Pleuropseudocystidia moderately abundant, cylindric, but often with very irregular, knotty apices, 3-4 µm

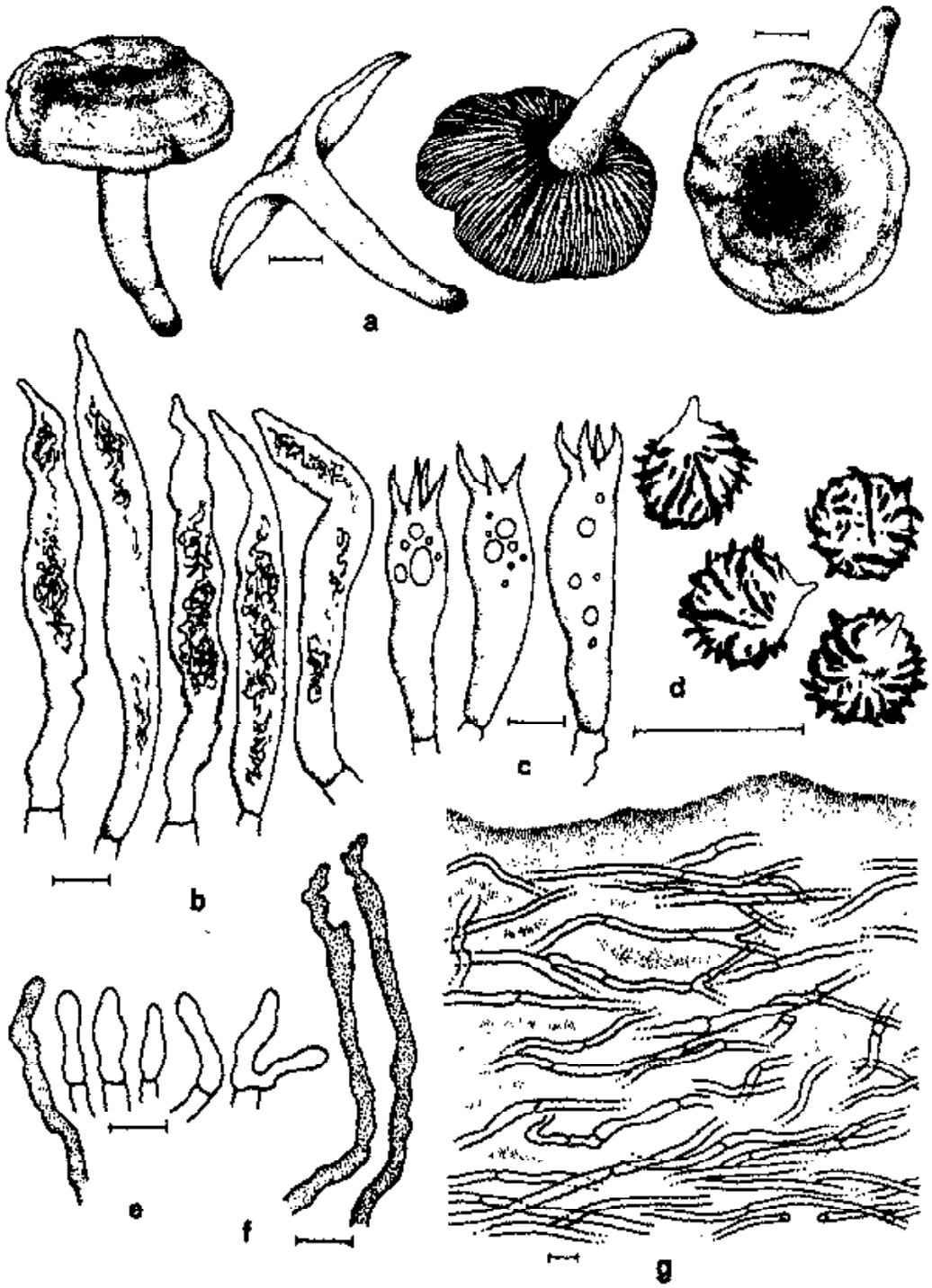


Fig. 24. *Lactarius maitlyensis*: a. Basidiomes b. Pleuromacrocystidia c. Basidia d. Basidiospores e. Marginal cells f. Pleuropseudocystidia g. Cross section of pileipellis. Bars: a = 10 mm; b-g = 10 μm.

broad. Lamellae edge sterile; marginal cells 25-40 x 4-7 µm, subclavate to fusoid or cylindric. Cheilomacrocystidia absent. Cheilopseudocystidia 25-40 x 4-7 µm, subclavate to fusoid. Hymenophoral trama cellular with sphaerocytes and hyphae, lactifers abundant, up to 10 µm thick. Pileipellis an ixocutis, up to 150 µm thick, composed of thin, 3-4 µm broad, hyaline hyphae.

Ecology : Rare, grows in ectomycorrhizal association with *Quercus leucotrichophora* in the subtropical to temperate mixed forests.

Specimens examined : Uttaranchal, Pithoragarh, Maitly, October 20, 2001, **col.** K. Das & J.R. Sharma, KD4030; Uttaranchal, Pithoragarh, Maitly top, October 3, 2001, **col.** K. Das & J.R. Sharma, KD4034.

Notes : Lactarius maitlyensis is characterized morphologically by a faintly zonate to azonate greyish brown pileus, white latex, changing to lemon yellow on exposure. Microscopically, zebroid spores, irregularly subclavate to fusiform macrocystidia with needle-like contents and a pileipellis of ixocutis arrangement are also very characteristic.

Lactarius maitlyensis belongs to subgenus *Piperites* (Fr.) Kauffman, section *Glutinosi* Quél., subsection *Pyrogalini* Singer and resembles *L. pyrogalus* (Bull.: Fr.) Fr. and *L. flexuosus* (Pers. : Fr.) Gray, both European species. Distinctly zonate pileus, smaller spores (5.2-7.7 x 4.5-6.2 µm), and pleurocystidia with acute to mucronate apices without needle-like contents (Heilmann-Clausen *et al.* 1998) separate *L. pyrogalus* from the present taxon. Similarly, larger (30-110 mm) basidiocarps, unchanging white latex, larger spores (6-8.6 x 5-6.9 µm) and regularly shaped pleurocystidia without needle-like contents (Heilmann-Clausen *et al.* 1998), are the characters which separate *L. flexuosus* from *L. maitlyensis*.

The present species also shares some features with *Lactarius xanthogalus* Verbeken & E. Horak and *L. cristulatus* Montoya & Bandala, both having spores with zebroid ornamentation patterns. *Lactarius xanthogalus* even has white latex, which immediately changes to sulphur yellow on exposure and subglobose to broadly ellipsoid spores (Q = 1.16-1.23 in average) (Verbeken & Horak 2000). *L. xanthogalus*, however, differs in colour of basidiocarp, which is "orange-yellow, evenly orange, with age gradually changing to paler concolourous, cream-coloured or whitish" and the larger spores (8.8-9.8 x 7.5-7.9 µm) in average (Verbeken & Horak 2000). *Lactarius cristulatus* has basidiocarps which are grey in colour, although these tend to present olivaceous tinges, the latex is invariable and the spores are definitely more ellipsoid "... 'Q' = 1.26-1.38..." (Montoya & Bandala 2003).

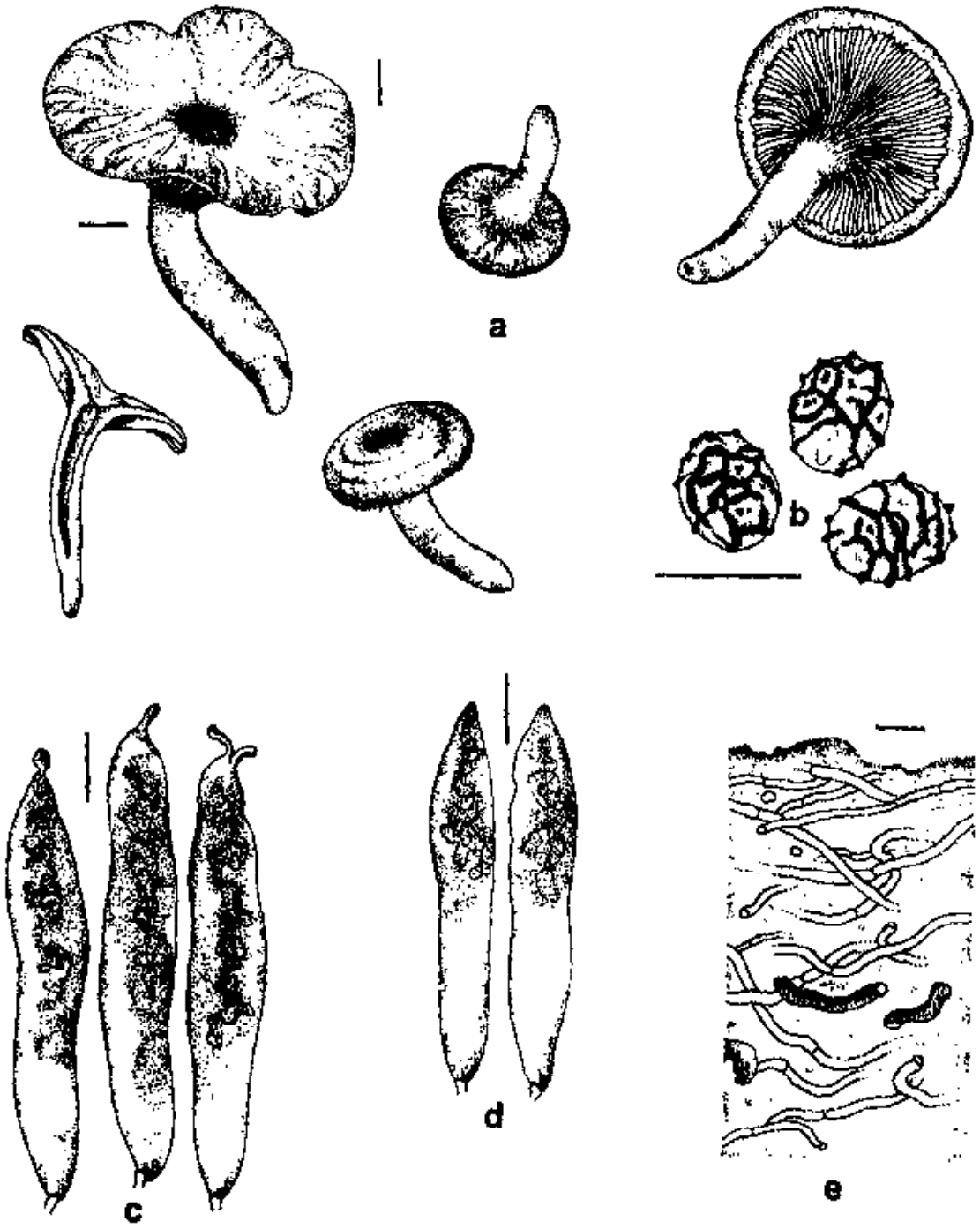


Fig. 25. *Lactarius mayawatianus*: a. Basidiomes b. Basidiospores c. Pleurocystidia d. Cheilocystidia e. Pileipellis. Bars: a = 10 mm; b-e = 10 µm.

Lactarius mayawatianus K. Das & J.R. Sharma

Mycotaxon **88**: 380, 2003. Pl. 13; fig. 25

Pileus 40-75 mm diam., at first convex with depressed center, later umbilicate with center deeply depressed, often cracked at maturity; cuticle smooth at center, increasingly hairy towards margin, hairs sometimes confluent to form adpressed triangular scales, viscid, faintly zonate when young, azonate with age, brilliant to light orange yellow, paler at maturity; margin inrolled, hairy when young, forming a roll of cottony tissue almost covering the gap between the edge of margin and the stipe, hairs deep yellowish brown when mature, margin gradually expanding and tomentose to smooth when mature; context yellowish white. Lamellae medium crowded (7-9 per cm), decurrent, yellowish white, lamellulae in many rows. Stipe 40-92 x 9-16 mm, cylindrical or narrower towards base, hollow, non-scrobiculate. Latex white, pale greenish yellow (lemon yellow) on exposure. Spore print pale yellow.

Spores 7.5-9.0 x 5.8-7.0 µm (Q = 1.22-1.38), broadly ellipsoid to ellipsoid, amyloid, ornamentation up to 0.7 µm high, composed mainly of ridges with acute edges forming an incomplete reticulation, few isolated warts present. Basidia 33-41 x 6.5-8.5 µm, subclavate, 4-spored. Pleuromacrocystidia 53-76 x 9.5-12 µm, fusiform to lanceolate, apex mucronate or sometimes with forked apical appendices, projecting up to 36 µm beyond hymenial layer. Cheilomacrocystidia cylindrical to fusiform with acute apices, 44-63 x 8-10 µm. Subhymenial layer up to 10 µm thick, cellular. Pileipellis an ixocutis, up to 76 µm thick, mostly composed of parallel hyphae, hyphae thin walled, 2.5-3.5 µm broad. Lactiferous hyphae up to 8.5 µm broad, abundant in pilear trama.

Ecology : Rare, grows in ectomycorrhizal association with *Rhododendron arboreum* Sm. in temperate deciduous to mixed forests.

Specimens examined : Uttaranchal, Champawat, Mayawati, September 28, 2002, **col.** K. Das & J.R. Sharma, KD4549; Uttaranchal, Champawat, Furti, September 29, 2002, **col.** K. Das & J.R. Sharma, KD4551; Uttaranchal, Almora, Mornoula, October 6, 2002, **col.** K. Das & J.R. Sharma, KD4582.

Notes : It is readily recognized by the presence of a roll of cottony tissue at young age, which disappears slowly and the pilear margin becomes glabrescent to smooth at maturity, brownish adpressed pilear hairs, crowded lamellae with numerous lamellulae and a non-scrobiculate stipe.

Morphologically, *L. mayawatianus* seems to be closely related to *L. gossypinus* Hesler & A.H. Sm. and *L. scrobiculatus* (Scop.:Fr.) Fr.

But *L. gossypinus* (Hesler & Smith 1979) can, however, be separated from *L. mayawatianus* by zonate pileus, lamellae with pinkish tinge, watery, unchanging latex, white spore deposit and lower spore ornamentation (up to 0.2 µm high). The basidiomes of *L. scrobiculatus* (Heilmann-Clausen *et al.* 1998) are larger (60-200 mm), intensely yellow with distinctly honey coloured zones, and the above all scrobiculate stipe has irregularly shaped brown pits. Microscopically, the warts and ridges on spores are up to 1 µm high, and the fusoid pleuromacrocystidia are absent or uncommon.

Lactarius paradoxus Beardslee & Burl.

Mycologia **32**: 584, 1940; Atri & Saini, Geob. N. Rep. **5**(1980) 102; Rawla, Bio. Ind. (2002) 232; Das & Sharma, Phytotax. **4**(2004)5. Pl. 12; fig. 26

Pileus 45-75 mm diam., convex with depressed center, slightly infundibuliform at maturity; pileipelis viscid, indistinctly zonate, greenish yellow, dark yellow, medium to dark orange yellow with silvery lusture, pale green, light to medium bluish green or deep to dark bluish green after maturity or bruising: margin inrolled to incurved when young, slightly decurved at maturity. Lamellae subdecurrent to decurrent, subdistant (5-6 per cm); medium orange yellow, dark yellowish pink or medium reddish orange, changing deep bluish green, dark yellowish green, dark green to dark bluish green after bruising or maturity; lamellulae numerous. Stipe 40-62 x 10-20 mm, cylindric to clavate, mostly concolorus with pileus. Context hollow. Latex copius, dark reddish brown (vinaceous brown), staining the lamellae distinctly greenish on exposure. Odour indistinct. Taste mild. Spore print yellowish white to pale yellow.

Basidiospores 8-9.3 x 6-7.2 µm, subglobose to ellipsoid (Q = 1.14-1.58), ornamentation amyloid, up to 0.5 µm high, composed of broken reticulum. Basidia 40-51 x 10-12 µm, subclavate to clavate, 4-spored, sterigmata up to 9 µm long. Pleuromacrocystidia absent. Pleuropseudocystidia, up to 6 µm broad, abundant, contents dense. Cheilomacrocystidia 40-50 x 3-5 µm, cylindrical with acute to rounded apices. Pileipellis an ixocutis, up to 100 µm thick.

Ecology : Rare, grows ectomycorrhizally with the species of *Quercus*, *Rhododendron* and *Abies* in the temperate deciduous to mixed forests.

Specimens examined : Uttaranchal, Bageswar, Dhakuri, October 1999, **col.** K. Das & J.R. Sharma, KD1052; Uttaranchal, Pithoragarh, Dafia Dhura, October, 2001, **col.** K. Das & J.R. Sharma, KD4060, KD4068.

Notes : Lactarius paradoxus is quite close to *L. rubrifluus* and *L. subpurpureus*. But both *L. rubrifluus* and *L. subpurpureus* have distinctly distant arrangement of lamellae and lamellulae. Moreover, latex of *L. rubrifluus* is dark to deep red.

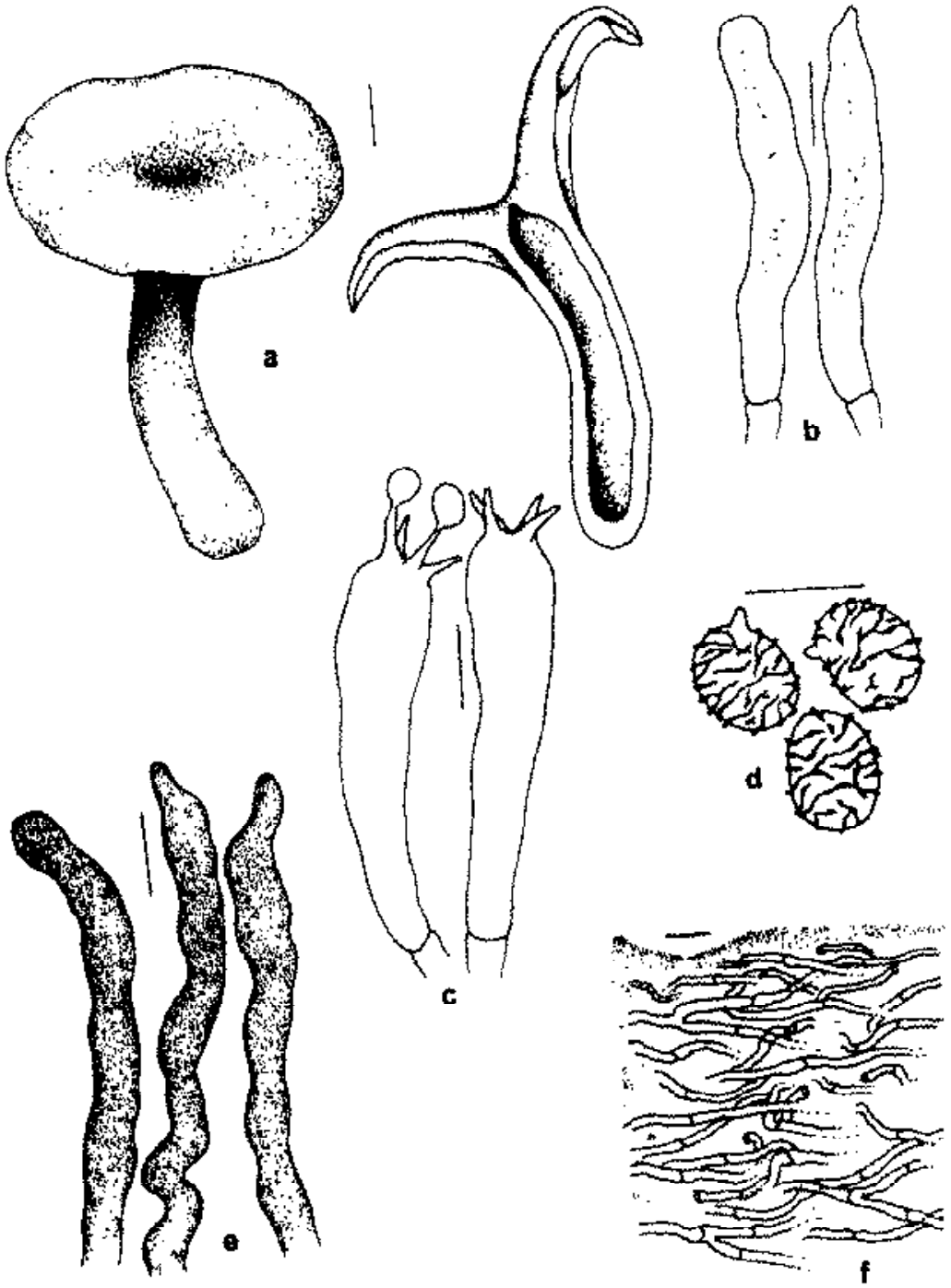


Fig. 26. *Lactarius paradoxus*: a. Basidiomes b. Cheilocystidia c. Basidia d. Basidiospores e. Pleuropseudocystidia f. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

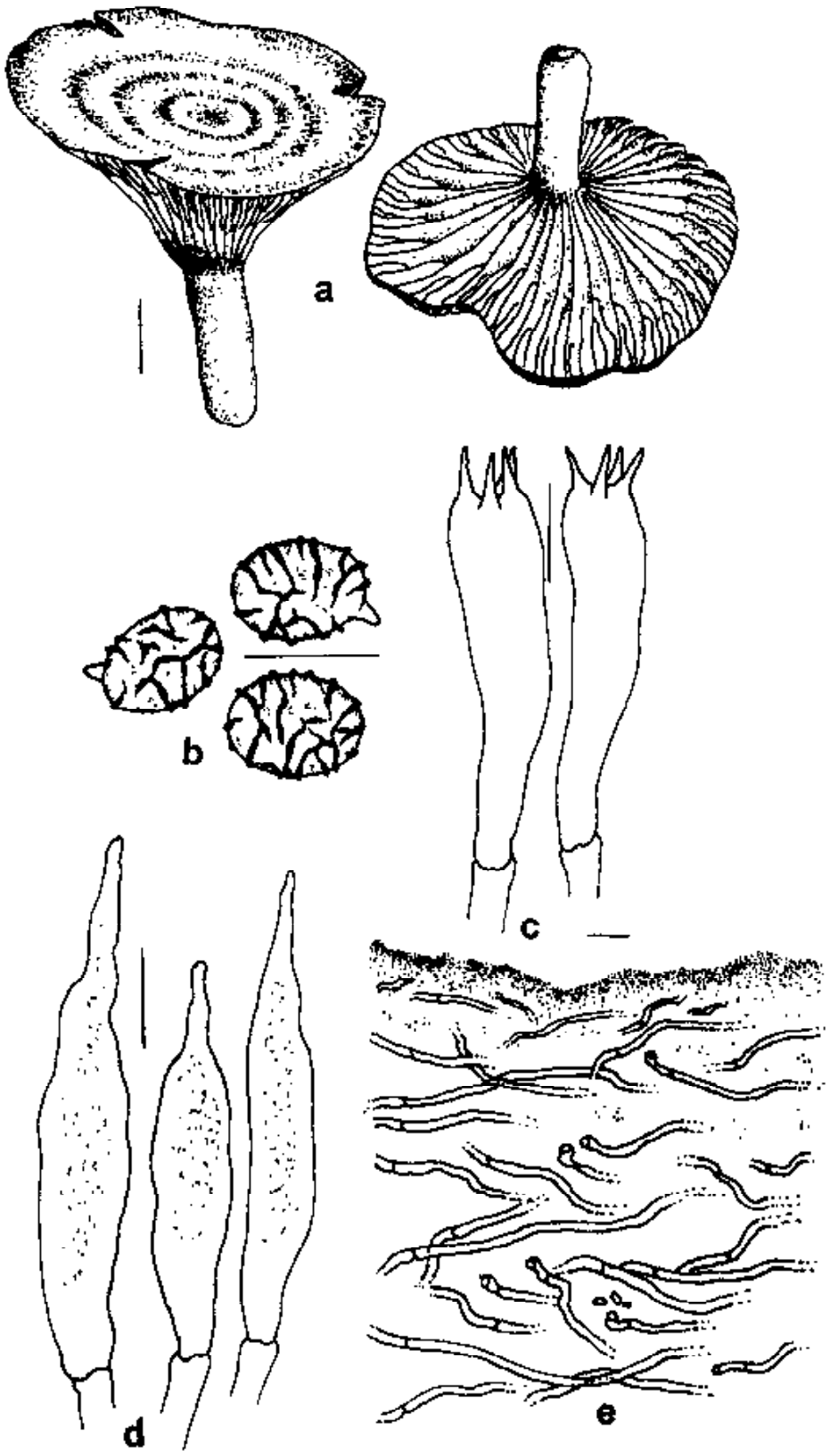


Fig. 27. *Lactarius rubrifluus*: a. Basidiomes b. Basidiospores c. Basidia d. Pleuromacrocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

Lactarius rubrifluus Gillet

Bull. Soc. Linn. Normandie Ser. II, **4**: 255, 1870; Sharma & Das, Phytotax. **2**(2002) 14; Das & Sharma, Phytotax. **4**(2004)5. Pl. 11; fig. 27

Pileus 30-55 mm diam., applanate to depressed; pileipellis smooth, viscid, zonate, dingy orange, brownish orange to light brown, reddish orange to very red soon after bruising, dark bluish green to deep green after sometime; margin somewhat incurved, irregularly elevated to loabed, reddish. Lamellae subdecurrent to decurrent, distant (*ca* 4 per cm), forked, light reddish orange, deep greenish blue where bruised; lamellulae present. Stipe 17-30 x 5-10 mm, central, equal, medium orange yellow to reddish orange, sometimes with deep yellowish green to deep bluish green patches. Latex dark to deep red, unchanging. Spore print not obtained.

Basidiospores 8-10 x 5.7-6.6 µm, amyloid, broadly ellipsoid (Q = 1.25-1.40); ornamentation amyloid, up to 1 µm high, composed of incomplete to complete reticulum. Basidia 40-50 x 8-10 µm, clavate, 4-spored. Pleuromacrocystidia 41.5-53.2 x 9-12 µm, ventricose. Cheilomacrocystidia not found. Subhymenial layer up to 19 µm, cellular. Hymenophoral trama interwoven; hyphae up to 3.5 µm broad, lactifers numerous up to 5 µm broad. Sphaerocytes abundant in pileus trama, up to 22 µm diam. Pileipellis an ixocutis, about 60-70 µm thick, composed of somewhat parallel septate hyphae.

Ecology : Rare, grows in ectomycorrhizal association with the species of *Pinus* in the subtropical to temperate coniferous forests.

Specimens examined : Uttaranchal, Almora, August, 2001, **col.** K. Das, KD902; Uttaranchal, Bageswar, Kausani, August, 2001, **col.** K. Das, KD922.

Notes : Lactarius rubrifluus is distinguished by light brown pileus, zoned with reddish margin, light reddish orange, distant lamellae, bruising deep greenish blue. The red to deep red and unchanging latex is also quite distinct in the field. In the exudation of coloured latex, the present species appears closely related to *L. sanguifluus* (Paulet) Fr., reported earlier by Lakhanpal, *et al.* (1987). But in *L. sanguifluus* the dark to deep reddish brown latex turns greenish on exposure and the lamellae are also closer as compared to the present species.

Further, *L. rubrifluus* is also easily separated from *L. paradoxus* Beardslee & Burlingham and *L. subpurpureus* Peck by dark red latex.

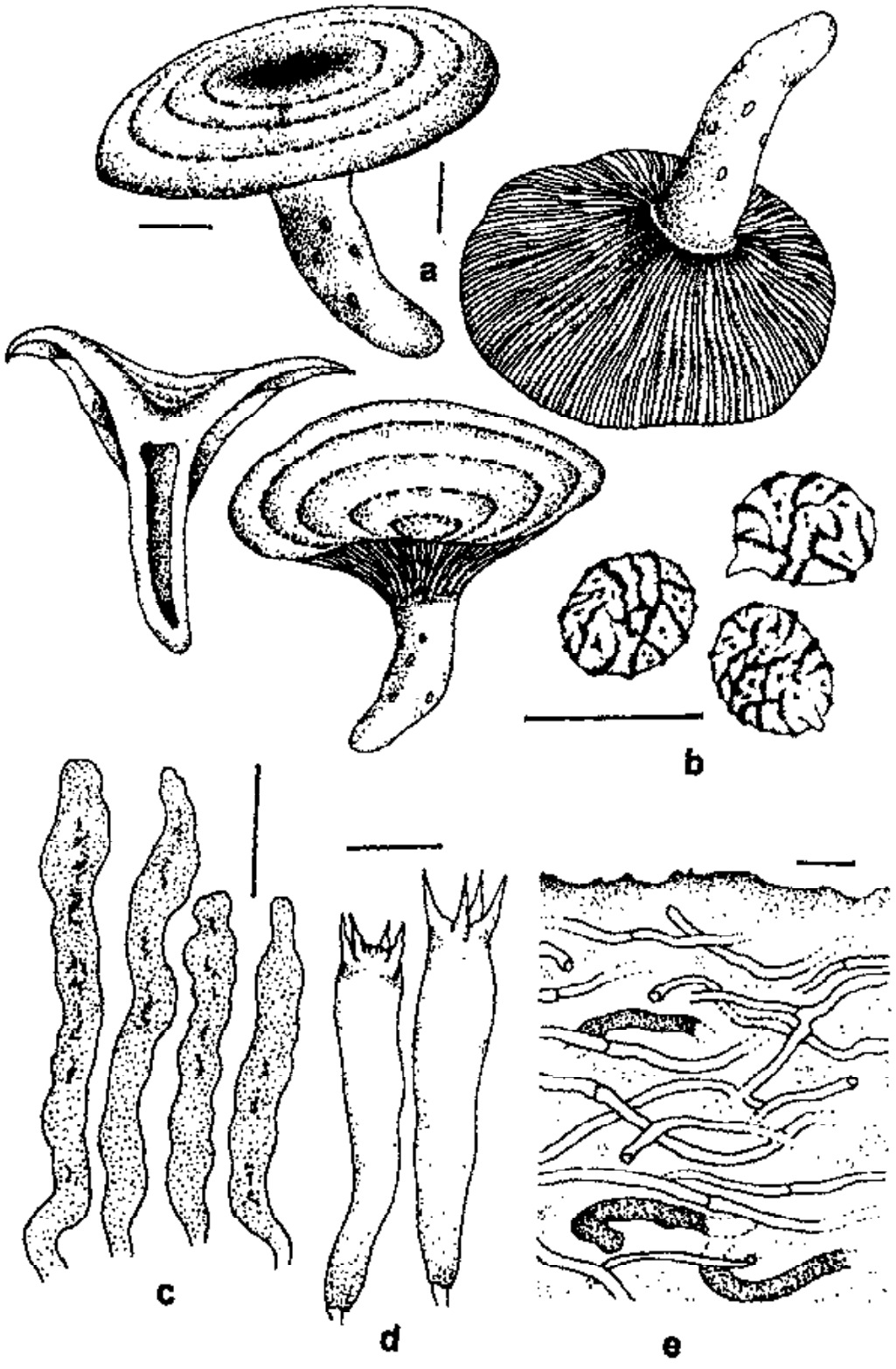


Fig. 28. *Lactarius subindigo*: a. Basidiomes b. Basidiospores c. Pleuropseudocystidia d. Basidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

Lactarius subindigo Verbeken & E. Horak

Aust. Syst. Bot. **13**: 651, 2000; Sharma & Das, Mycotaxon **88**(2003) 382; Das & Sharma, Phytotax. **4**(2004)5. Pl. 11; fig. 28

Pileus 55-70 mm diam., at first convex with depressed center, later umbilicate when mature; cuticle viscid when moist, zonate, medium greenish to medium blue with silvery lustre, sometimes medium yellow with age; margin strongly incurved when young, plane when mature. Lamellae decurrent, crowded (10-14 per 10 mm), lamellulae in several rows, light to medium greenish blue, deep to very deep greenish blue after bruising. Stipe 25-40 x 6-10 mm, cylindrical or gradually tapered towards base, concolorous with pileus, scrobiculate, hollow. Context brittle, light greenish to light blue. Latex dark to deep greenish blue, unchanging. Spore print yellowish white.

Spores 7-8.5 x 5.5-7.2 µm (Q = 1.18-1.38), broadly ellipsoid to ellipsoid, amyloid, ornamentation up to 0.5 µm high, composed of blunt ridges forming partial to incomplete reticulation, isolated warts abundant. Basidia 40-64 x 7-8.5 µm, subclavate, 4-spored. Pleuromacrocystidia and Cheilomacrocystidia both absent. Pseudocystidia abundant, shape irregular, 30-55 x 3-5 µm. Subhymenial layer 12-14 µm thick, cellular. Pileipellis an ixocutis, 50-80 µm thick, composed of interwoven hyphae, hyphae up to 3 µm broad. Lactiferous hyphae abundant in pilear trama, up to 7 µm broad.

Ecology : Common, grows ectomycorrhizally with *Quercus leucotrichophora* in the temperate deciduous and mixed coniferous forests.

Specimens examined : India, Uttaranchal, Champawat, Abbot Mount, 2200m, on ground, September 24, 2002, **col.** K. Das & J.R. Sharma, KD4525; Uttaranchal, Champawat, Mayawati, September 30, 2002, **col.** K. Das & J.R. Sharma, KD4550; Uttaranchal, Almora, Mornoula, October 6, 2002, **col.** K. Das & J.R. Sharma, KD4584.

Notes : Lactarius subindigo belongs to section *Dapetes* Fr. and is quite common in Kumaon Himalaya. It can be identified by overall indigo blue basidiocarps becoming yellow with age and zonate medium blue pilear surface with a silvery lustre, bluish latex and scrobiculate, hollow stipe.

This species is distinguished from the closely related *L. indigo* (Schwein.) Fr. by the absence of true pleurocystidia, cheilocystidia and smaller spores (*ca* 7-9.5 x 6-7.5 µm in *L. indigo*) with wider and more rounded ridges (Verbeken & Horak 2000). The overall bluish appearance, *L. subindigo* may also share with *L. quieticolor*. But the pale yellowish pink to light orange lamellae, orange latex turning reddish brown on exposure and true cystidia clearly separate *L. quieticolor* from *L. subindigo*.

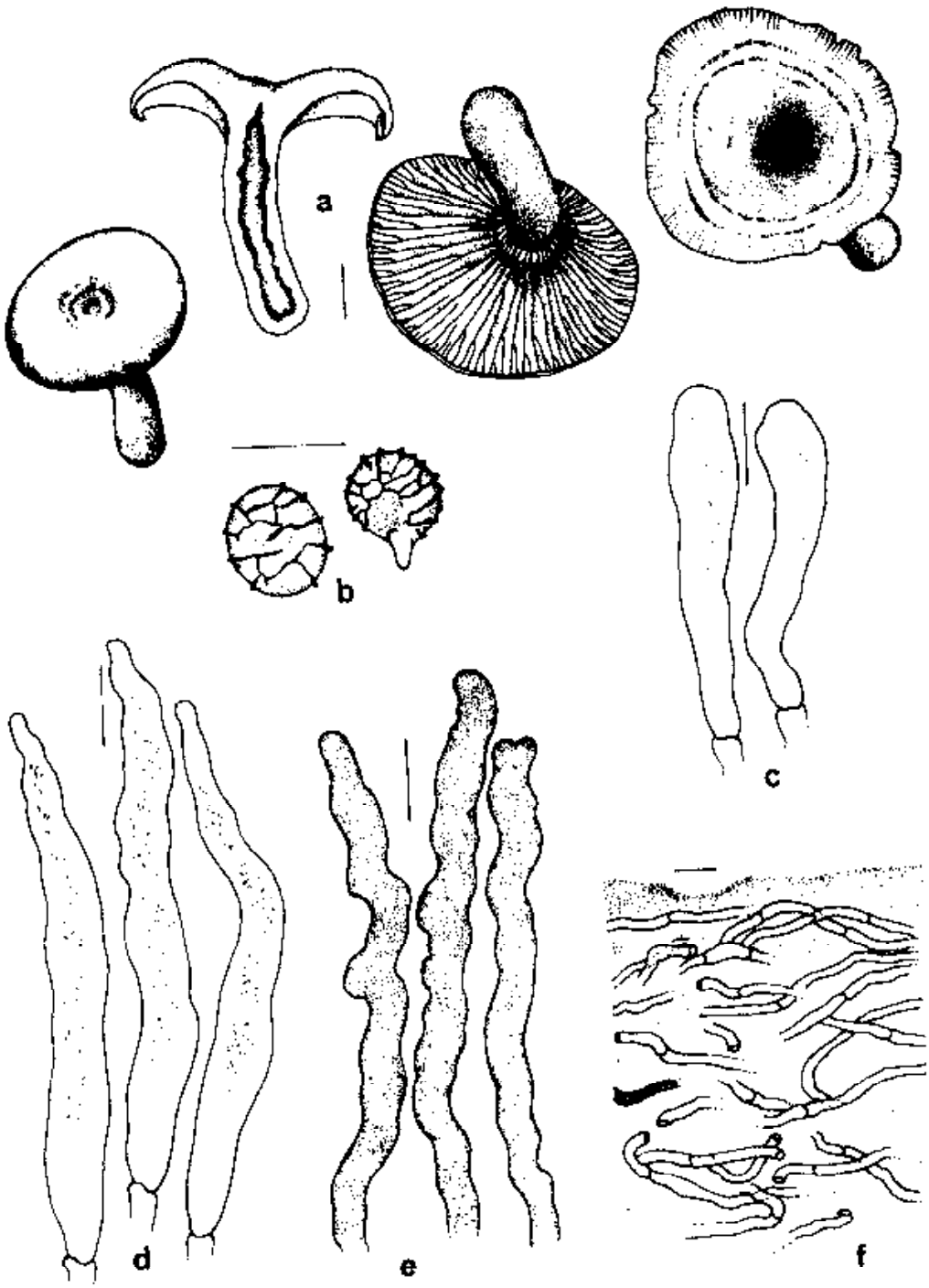


Fig. 29. *Lactarius subpurpureus*: a. Basidiomes b. Basidiospores c. Cheilocystidia d. Pleuromacrocystidia e. Pleuropseudocystidia f. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

Lactarius subpurpureus Peck

Ann. Rep. N.Y. State Mus. **29**: 43, 1878; Watling & Gregory, N. Hedwigia **32**(1980) 537; Saini & Atri, J. Ind. Bot. Soc. **69**(1990) 475; Atri & Saini, Geob. N. Rep. **5**(1986) 102; Das & Sharma, Phytotax. **4**(2004)5.

Pl. 12; fig. 29

Pileus 47-110 mm diam, convex with depressed center, gradually planoconvex to infundibuliform at maturity; pileipellis viscid, zonate, yellowish gray, gray yellowish brown, pale to medium yellowish pink, pinkish gray, dark to very deep red at the margin and at the concentric zones, ochraceous with silvery lustre when mature, often light to medium bluish green at the center; margin curved when young, plane at maturity, sulcate. Lamellae subdecurrent to decurrent, distant (3-4 per cm) thick, pinkish yellow, few forked near the stipe; very dark to deep red after bruising on exposure; lamellulae present. Stipe 41-50 x 12-24 mm, equal to subclavate, silvery white ring at the juncture of lamellae and stipe, dark yellowish pink, light redish brown, often with a silvery lustre at maturity. Latex dark reddish brown (vinaceous brown). Spore print pale ochraceous.

Spores 8-10.5 x 6-8.2 µm, broadly ellipsoid to ellipsoid [Q = (1.12) 1.18-1.5], ornamentation amyloid, up to 0.5 µm, composed of ridges forming incomplete reticulation. Basidia 30-55 x 8-11 µm, clavate, 4-spored; basidioles frequent. Pleuromacrocystidia 50-75 x 6-9 µm, emergent up to 26 µm, fusoid to subcylindric with acute apices, hyaline. Pleuropseudocystidia irregularly cylindric. Lamellae edge fertile. Cheilomacrocystidia 28-38 x 6-8 µm, clavate, hyaline. Pileipellis an ixocutis, up to 220 µm, composed of almost parallel hyphae. Hymenophoral trama heteromerous.

Ecology : Rare, grows ectomycorrhizally with the species of *Abies* in the temperate mixed coniferous forests.

Specimens examined : Uttaranchal, Bageswar, Dhakuri, September, 1999, **col.** K. Das & J.R. Sharma, KD1026, KD1046, KD1042, KD1050; Uttaranchal, Bageswar, Dhakuri, September, 2003, **col.** K. Das & J.R. Sharma, KD7086.

Notes : Lactarius subpurpureus is distinguished by the distant lamellae, zonate sulcate pileus and dark reddish brown latex. It resembles *L. paradoxus* but can be separated from the latter by the distinctly zonate pileus with sulcate margin, comparatively distant arrangement of lamellae and lamellulae.

Lactarius zonarius (Bull.) Fr.

Epicr. Syst. Mycol. 336, 1838. *Agaricus zonarius* Bull.; Saini & Atri, Ind. Phytopath. **35**(1982) 267; Atri & Saini, Kavaka **16**(1988) 17; Das & Sharma, Phytotax. **4**(2004)6. 1782, Pl. 104.

Pl. 12; fig. 30

Pileus 44-110 mm diam., convex with depressed center, deeply depressed to infundibuliform at maturity; Pileipellis viscid, glabrous, distinctly zonate,

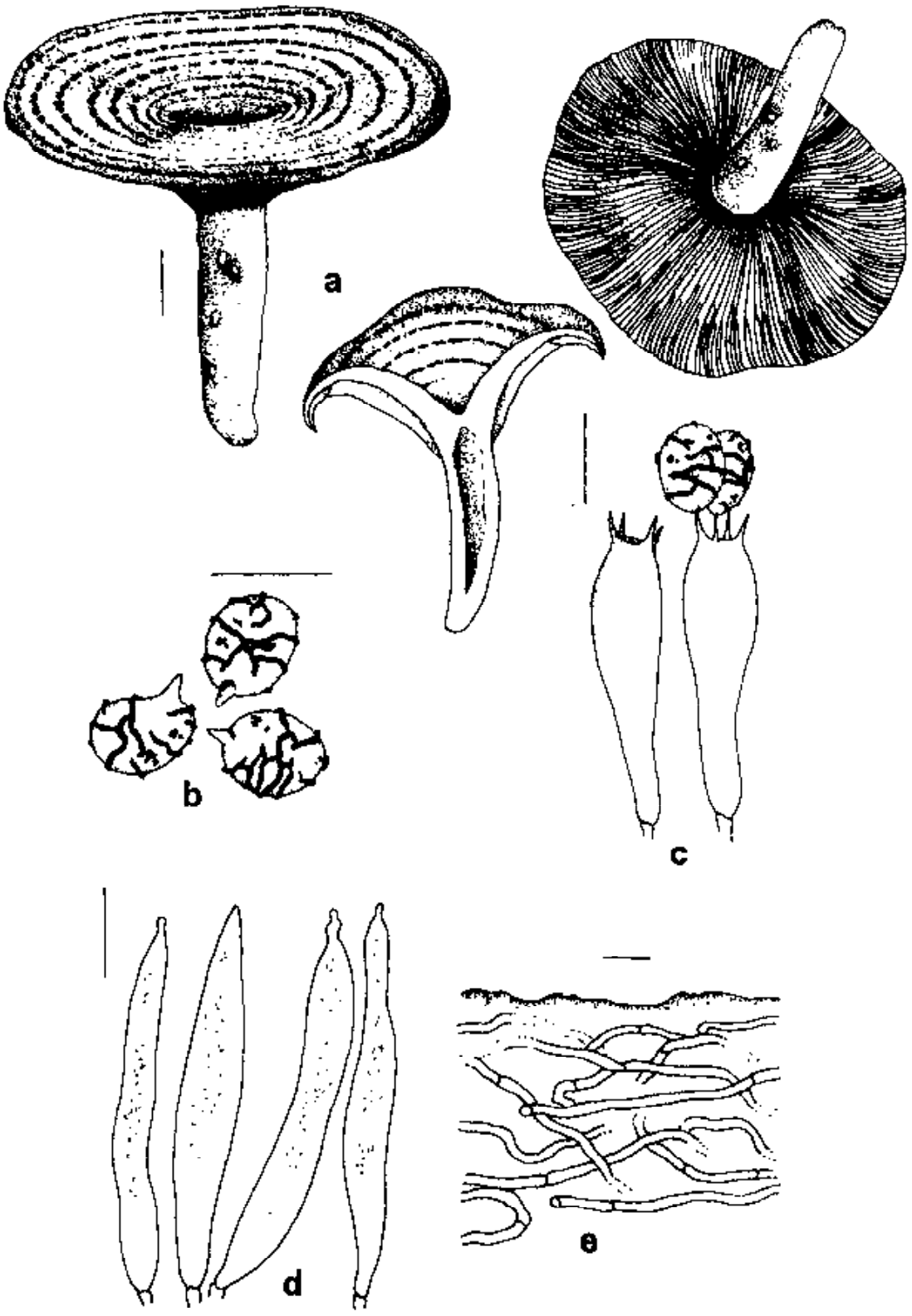


Fig. 30. *Lactarius zonarius*: a. Basidiomes b. Basidiospores c. Basidia d. Pleuromacrocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

ochraceous to orange yellow; margin incurved, tomentose when young, slightly uplifted and quickly naked at maturity. Lamellae subdecurrent to decurrent, close (7-10 per cm), sometimes forked near stipe, yellowish white, ochraceous where injured, lamellulae present. Stipe 23-50 x 7-18 mm, central, cylindric or tapering at base, scrobiculate, concolorus with pileus. Context yellowish white to pale ochraceous, hollow. Latex white unchanging. Odour fruity. Taste acrid. Spore print yellowish white.

Basidiospores 7-9.2 x 5.2-7.5 µm, subglobose to broadly ellipsoid (Q = 1.11-1.28); ornamentation amyloid, up to 1 µm high, composed of warts and ridges never forming reticulation. Basidia 34-50 x 7-10 µm, subclavate, 4-spored. Pleuromacrocystidia 35-60 x 5.5-7.5 µm, emergent up to 14 µm, fusiform to moniliform. Pleuropseudocystidia up to 5.5 µm broad, medium abundant, irregularly cylindrical with rounded apices. Lamellae edge sterile. Cheilomacrocystidia 23-39 x 3.3-6.4 µm, fusiform. Pileipellis an ixocutis, up to 150 µm thick; hyphae up to 5 µm broad.

Ecology : Abundant, grows ectomycorrhizally with the species of *Quercus*, *Rhododendron* in the temperate deciduous forests.

Specimens examined : Uttaranchal, Nainital, Gagar, August, 2002, **col.** K. Das, KD2136 ; Nainital, Mukteswar, August, 2002, **col.** K. Das, KD2118; Uttaranchal, Almora, Mornoula, October, 2002, KD4562, KD4571; Uttaranchal, Champawat, Mayawati, September 2002, **col.** K. Das & J.R. Sharma, KD4546; Uttaranchal, Bageswar, Loharkhet top, **col.** K. Das & J.R. Sharma, KD7080.

Notes : Lactarius zonarius appears one of the common *Lactarius* in Kumaon Himalaya and can be easily distinguished in the field by viscid zonate ochraceous to yellow orange pileus, which is unchanging after bruising, scrobiculate concolorus stipe, white unchanging latex and fruity odor. *Lactarius evosmus* Kühner & Romagn. are very close to *L. zonarius*. But *L. evosmus* has paler and less distinct zonate pileus, lamellae which change to pink and non scrobiculate stipe (Heilmann-Clausen *et al.* 1998). Microscopically *L. evosmus* has pleuromacrocystidia which are never emergent.

Plate 11: a. *Lactarius zonarius* b. *L. subindigo* c, d & e. *L. rubrifluus* f. *L. deliciosus.*

Plate 12: a. *Lactarius alnicola* b. *L. paradoxus* c. *L. subpurpureus*.

Plate 13: a. *Lactarius dafianus* b. *L. maitlyensis* c & d. *L. abbotanus* e. *L. mayawatianus.*

Subgenus **Plinthogali** (Burl.) Hesler & A.H. Smith
North American Species of *Lactarius* 99, 1979; emend. Verbeken, Persoonia **17**: 378, 2000.
Lactaria group Plinthogalae Burl., Mem. Torrey Club **14**: 83, 1908.

Pileus grayish yellow to brownish black; stipe mostly concolorous; basidiopore ornamentations amyloid as light to heavy bands and ridges, with or without reticulum; pleuromacrocystidia and cheilomacrocystidia present or absent; cystidia mostly with brown intracellular pigmentation; pileipellis a palisade to trichopalisade; hymenophoral trama cellular. Twelve taxa in India; five in Kumaon Himalaya.

KEY TO THE SPECIES

1a. Spore ornamentation up to 2.7 µm high, never forming any reticulation ..... **L. montoyae**

b. Spore ornamentation not more than 2 µm high, forming incomplete to almost complete reticulation 2

2a. Lamellae edge always concolorous 3

b. Lamellae edge not concolorous 4

3a. Stipe 35-50 mm long; pleuromacrocystidia absent; pileipellis trichoepithelium ..... **L. picinus**

b. Stipe 50-100 mm long; pleuromacrocystidia present; pileipellis trichopalisade to hymeniderm ..... **L. lignyotus**

4a. Pileipellis radially wrinkled; lamellulae in 3-4 rows; spore ornamentation up to 2 µm high; pleuromacrocystidia present .....

..... **L. lignyotus** var. **canadensis**

b. Pileipellis not wrinkled; lamellulae only in 2 rows; spore ornamentation only up to 0.7 µm high; pleuromacrocystidia absent .....

..... **L. gerardii** var. **subrubescens**

Lactarius gerardii Peck

Bull. Buffalo Soc. Nat. Sci. **1**: 57, 1873. var. **subrubescens** (Smith & Hesler) Hesler & Smith, North American Species of Lactarius: 114, 1979; *Lactarius subrubescens* Smith & Hesler, Brittonia **14**: 384, 1962; Das & Sharma, Ann. For. **13**(1005) 6; Phytotax. **4**(2004) 4.

Pl. 14; fig. 31

Basidiocarp caespitose to gregarious. Pileus 27-74 mm diam., convex to planoconvex with a very small umbo, becoming applanate to uplifted

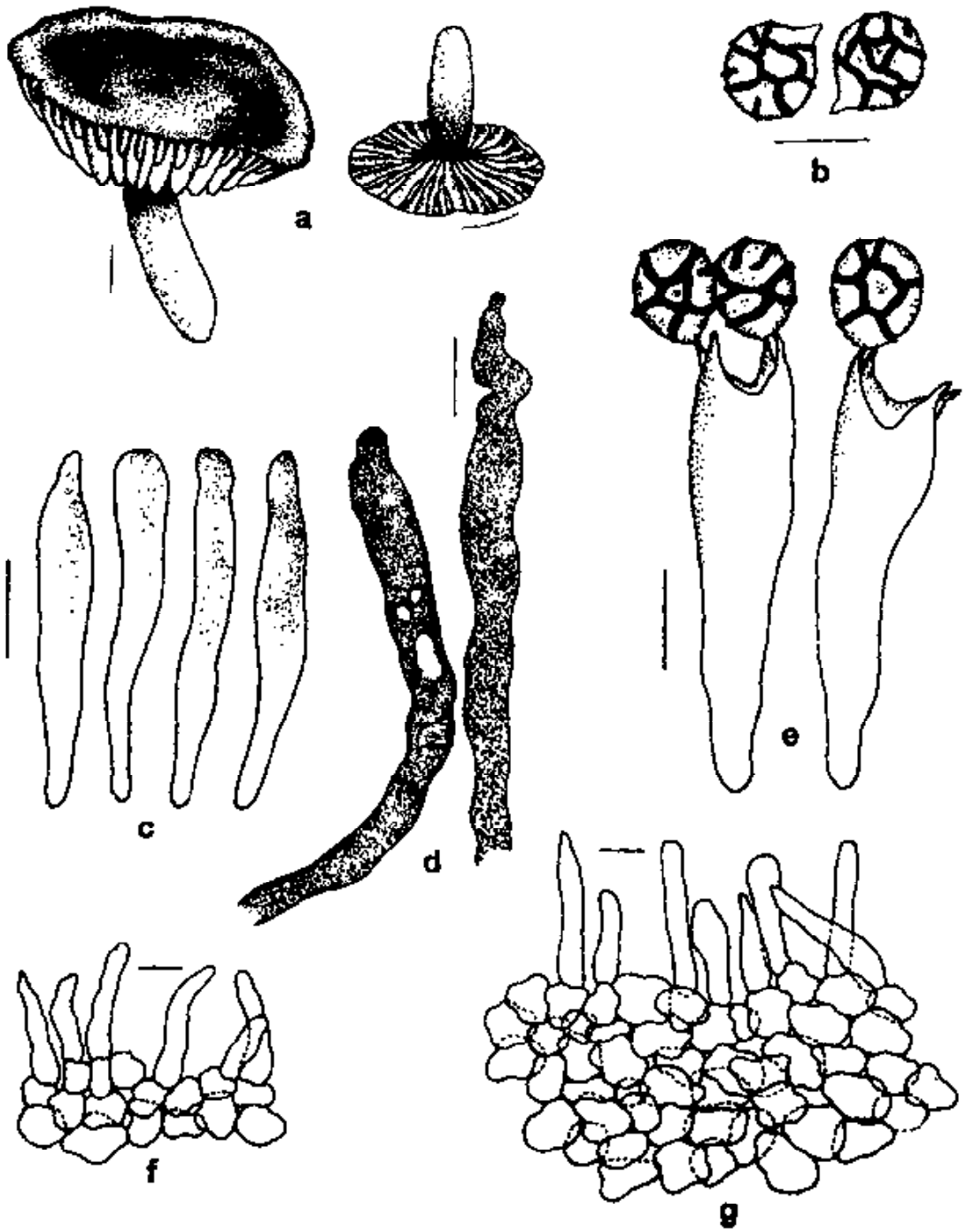


Fig. 31. *Lactarius gerardii* var. *subrubescens*: a. Basidiomes b. Basidiospores c. Cheilomacrocystidia d. Pleuropseudocystidia e. Basidia f. Cross section of stipitipellis g. Cross section of pileipellis. Bars: a = 10 mm; b-g = 10 µm.

without any umbo; cuticle dry, subvelvety, azonate, light to dark greyish yellow or light orange yellow with tinge of dark yellowish brown, somewhat cracked radially when mature; margin more greyer, slightly decurved becoming upturned in age, wavy. Lamellae subdecurrent to decurrent, entire, subdistant (2-4 per cm) with 2 rows of lamellulae, pale cream, medium pink on bruising. Stipe 20-45 x 8-15 mm, cylindric or narrow at either or both ends, velvety, concolorous with the pileus, often darker at apex. Context white, light pink after bruising. Latex white, unchanging. Spore print yellowish white.

Spore 7.5-11 x 7-10 µm, globose to broadly ellipsoid, inamyloid, ornamentation up to 0.7 µm high forming partial to complete reticulation. Basidia 37-50 x 9-12 µm, clavate, 4-spored. Pleuromacrocystidia absent. Pleuropseudocystidia up to 6.5 µm broad, abundant, cylindrical. Cheilomacrocystidia abundant, 25 -47 x 4-8 µm, clavate to subcylindric. Subhymenium layer up to 25 µm thick. Pileipellis a palisade, up to 80 µm thick, composed of 4-6 layers of spherical cells; terminal elements up to 7.5 µm broad, fusoid to subfusoid, cylindrical or subclavate, with brown intercellular pigmentation. Stipipellis a palisade to trichopalisade, composed of 3-4 layers of cells; terminal element up to 7 µm broad, fusoid to cylindrical with intercellular pigmentation.

Ecology : Common, grows under *Quercus semecarpifolia* and *Rhododendron arboreum* in the moist temperate forests.

Specimens examined : Uttaranchal, Pithoragarh, Dafiadhura, October 8, 2001, **col.** K. Das & J.R. Sharma, KD4062, KD4073; *ibid.*, October 9, 2001, **col.** K. Das & J.R. Sharma, KD4094; Uttaranchal, Bageswar, Dhakuri, October 5, 1999, **col.** K. Das & J.R. Sharma, KD1092; *ibid.*, September 16, 2003, **col.** K. Das & J.R. Sharma, KD7014.

Notes : Lactarius gerardii var. *subrubescens* is characterized in the field by yellowish brown and subvelvety pilear surface, distant lamellae, changing pink after bruising and white unchanging latex. Microscopically, the absence of pleuromacrocystidia, presence of clavate cheilocystidia and comparatively larger spores with almost complete reticulation, make this taxon distinct.

Both *Lactarius atro-olivaceus* Hesler & Smith and *L. gerardii* Peck var. *fragicola* (Smith & Hesler) Hesler & Smith, resemble closely with the present taxon, but are separated by their lamellae turning brownish after bruising. The spores are smaller (7-9 x 6-7.5 µm) in the former.

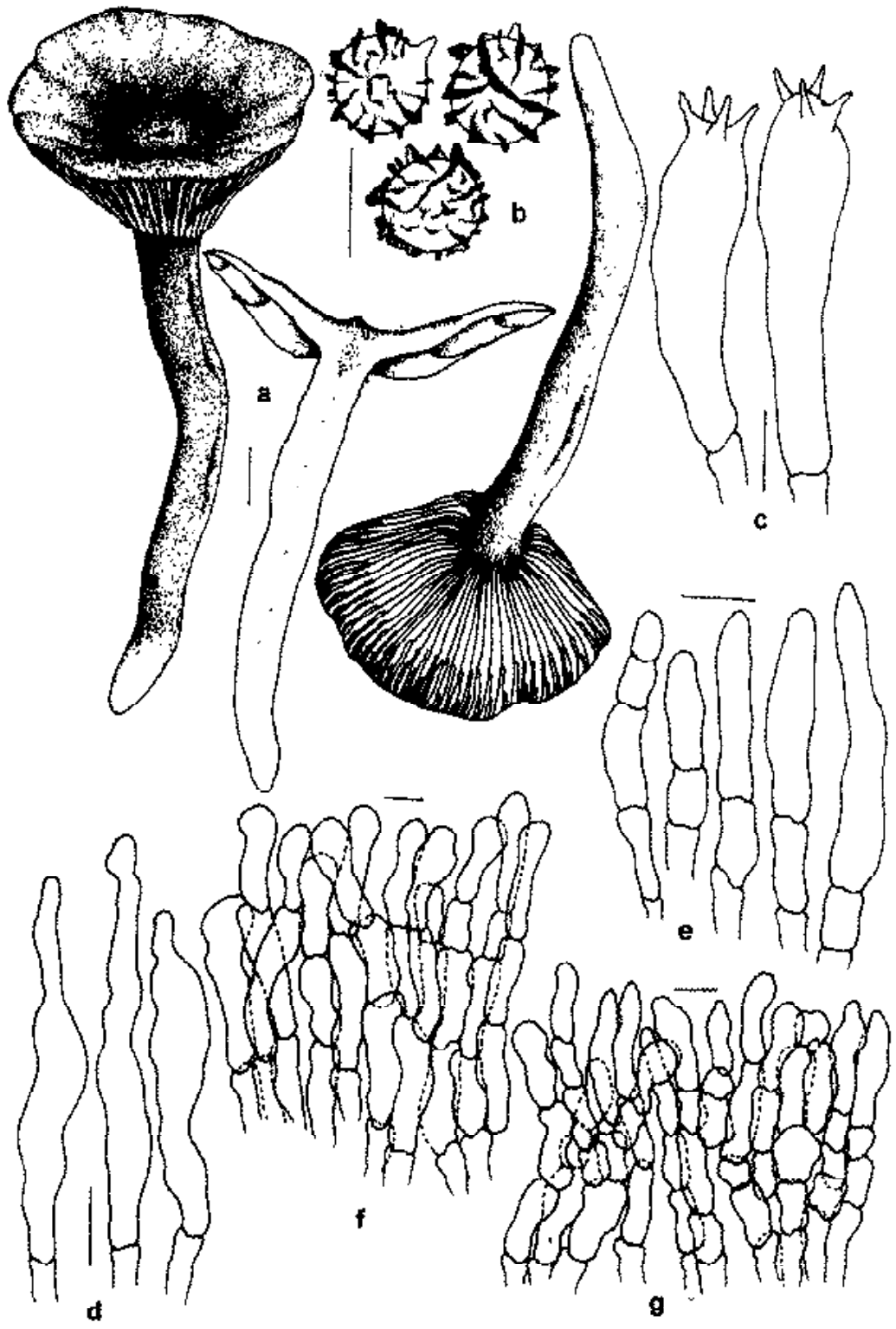


Fig. 32. *Lactarius lignyotus* var. *lignyotus*: a. Basidiomes b. Basidiospores c. Basidia d. Pleuromacrocystidia e. Paracystidia f. Cross section of pileipellis g. Cross section of stipitipellis. Bars: a = 10 mm; b-g = 10 µm.

Lactarius lignyotus Fr.

Monogr. Hymen. Suec. **2**: 177. 1863; Das & Sharma, Ann. For. **13**(2005)1. Fig. 32

Basidiocarp solitary to gregarious. Pileus 35-70 mm diam., convex to planoconvex with decurved margin; center depressed to infundibuliform when mature and with a papilla; pileipellis often wrinkled, pruinose to felty, dry, dark grayish brown to brownish black. Lamellae broadly adnate to subdecurrent, subdistant to distant (4-5 per cm), cream to pale ochre, light to deep yellowish pink after bruising; edge councilors; lamellulae in different rows. Stipe 50-100 x 7-11 mm, felty, dry, cylindric or tapering towards base, sometimes grooved longitudinally, mostly concolorous with the pileus, pale yellow to pale orange yellow at base. Context stuffed, yellowish white, changing to yellowish pink. Latex white, unchanging. Odour indistinct. Taste mild. Spore deposit pale yellow to ochre.

Basidiospores 8.5-10 x 7.7-9.2 µm, globose to broadly ellipsoid (Q = 1.02-1.17); ornamentation amyloid, up to 2 µm high, composed of irregular ridges with spiny extremes, forming an incomplete reticulation. Basidia 45-55 x 9-13 µm, subclavate to clavate, 4-spored; sterigma up to 6 µm long. Pleuromacrocystidia 40-65 x 6-9 µm, irregular. Pleuropseudocystidia up to 7 µm broad, cylindrical. Paracystidia 20- 50 x 4-6 µm. Cheilomacrocystidia 15-34 x 4-6 µm, cylindrical to subclavate. Pileipellis trichopalisade to hymeniderm; terminal elements of suprepellis 30-60 x 8-16 µm, clavate, cylindrical or fusoid, thin walled, with brown intracellular pigmentation; subpellis composed of mostly cylindrical cells. Stipitipellis a trichopallisade; terminal elements of suprapellis 25-45 x 8-13 µm, cylindrical to fusoid, with brown intracellular pigmentation; subpellis composed of globose to elongated cells. Stipe trama with numerous sphaerocytes.

Ecology : Lactarius lignyotus var. *lignyotus* is rare and forms ectomycorrhizal association with species of *Picea* and *Abies* in moist coniferous to mixed temperate himalayan (2000-2800 m) forests.

Specimens examined : India. Uttaranchal: Bageshwar, Dhakuri, September, 2003, **col.** K. Das & J.R. Sharma, KD7101; Pithoragarh, Shandev, October 8, 2004, **col.** K. Das & J.R. Sharma, KD12088.

Notes : The grayish colour and felty nature of the pileipellis, spores morphology with high ornamentations, brown intracellular pigmentation in the cells of suprapellis and the anatomy of pileipellis and suprapellis place this taxon in the subgenus *Plinthogali* (Burl.) Hesler & A.H. Smith. *Lactarius lignyotus* var. *lignyotus* can easily be distinguished by its papillate pileus, radially wrinkled pileipellis and mild taste. Besides, the presence

of pleuromacrocystidia make the species distinct among other taxa of this subgenus. The other variety i.e. *L. lignyotus* Fr. var. *canadensis* A.H. Sm. & Hesler reported from India (Das & Sharma 2004) has marginate lamellae and prefers different ectomycorrhizal association.

Lactarius lignyotus Fr.

var. **canadensis** Smith & Hesler, Brittonia **14**: 398, 1962; Das & Sharma, Mycotaxon **89**(2004) 293. Pl. 14; fig. 33

Pileus 40-75 mm diam., convex, becoming depressed center with a papilla; pileipellis wrinkled, somewhat felty, dark gray brown to brownish black; margin decurved, sulcate to irregularly loabed at maturity. Lamellae subdistant to distant (4-5 per cm), sometimes intervenose, cream to pale ochre, pinkish when injured; lamellulae of different sizes; edge brownish black. Stipe 34-50 x 7-9 mm, dry felty, cylindric, mostly concolorous or slightly paler towards base. Context hollow, yellowish white, slowly pinkish at the base after exposure. Latex white unchanging. Odour indistinct. Taste mild. Spore print pale ochre or buff.

Basidiospores 8.5-11 x 8.2-9.7 µm, globose to subglobose (Q = 1.00-1.14, av. 1.01-1.04); ornamentation amyloid, up to 2 µm high, composed mostly of irregular ridges with spiny extremes, forming an incomplete reticulation, plage amyloid. Basidia 35-52 x 11-14 µm, subclavate, 4-spored; sterigma up to 7 µm long. Pleuromacrocystidia 55-64 x 9-11 µm, rare, subfusoid. Pleuropseudocystidia up to 7 µm broad, cylindrical. Lamellae edge sterile. Cheilomacrocystidia 18-54 x 4-11 µm, abundant, clavate, ventricose or cylindric, with brown intercellular pigmentation. Pileipellis a hymenoepithellium, composed of short chains of vesiculose cells; terminal cells cylindrical to clavate, 19-42 x 9-18 µm, thin walled, with brown intercellular pigmentation. Stipitipellis with numerous cystidia. Caulocystidia 16-90 x 6-13.4 µm, cylindrical to clavate with brown intercellular pigmentation; wall up to 1 µm thick. Stipe trama with abundant sphaerocytes.

Ecology : Rare, grows ectomycorrhizally with species of *Quercus* and *Rhododendron* in moist deciduous temperate forests, preferably among mosses.

Specimens examined : Uttaranchal, Bageswar, Dhakuri, September 16, 2003, **col.** K. Das, KD7006; Uttaranchal, Champawat, Mayawati, October 6, 2002, **col.** K. Das & J.R. Sharma, KD5000.

Notes : Lactarius lignyotus var. *canadensis* is recognized by its papillate pileus, radially wrinkled pileipellis, distinctly margined lamellae and mild taste. Moreover, the presence of pleuromacrocystidia make the species distinct among the other taxa in this subgenus.

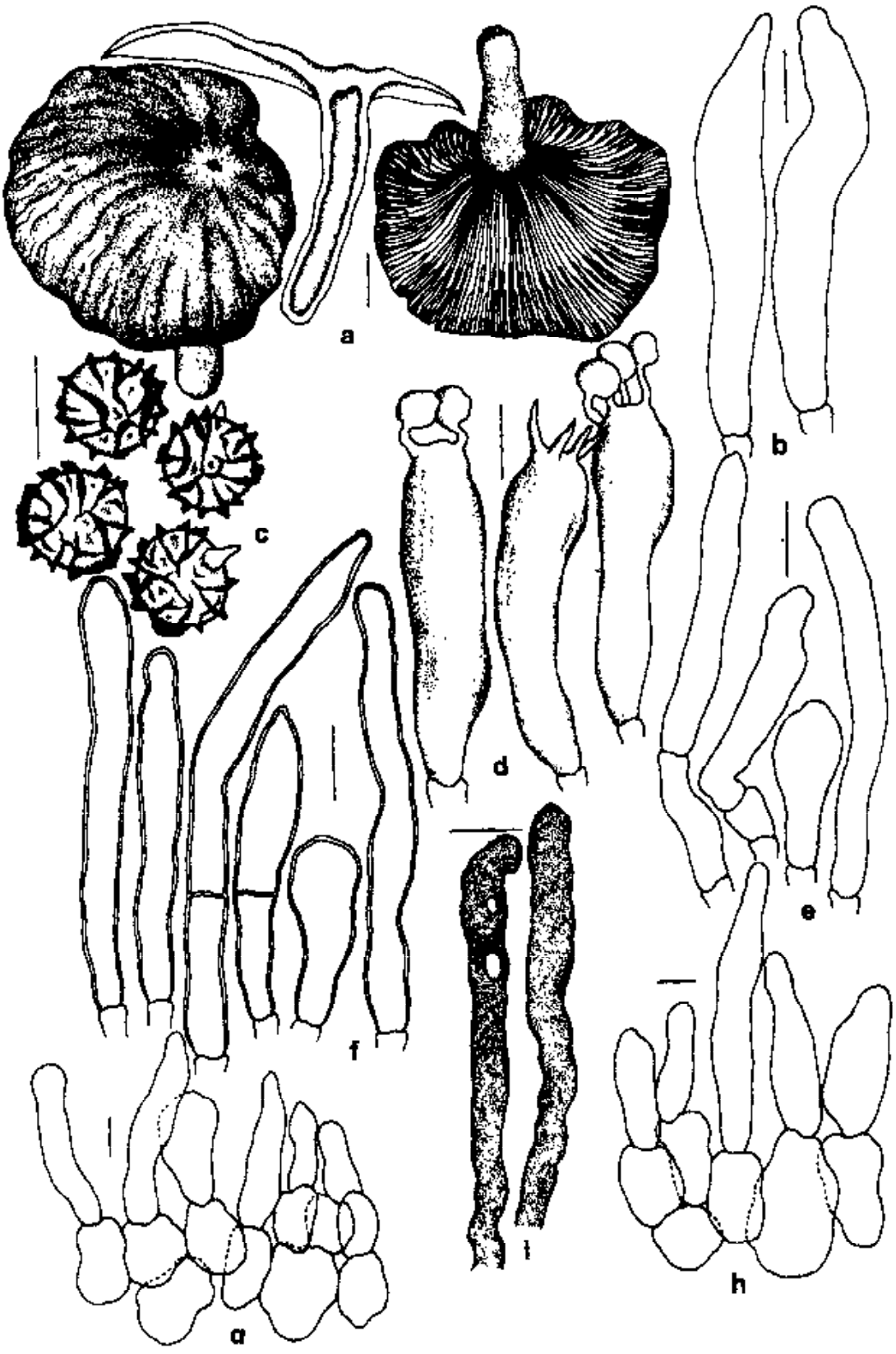


Fig. 33. *Lactarius lignyotus* var. *canadensis*: a. Basidiomes b. Pleuromacrocystidia c. Basidiospores d. Basidia e. Cheilomacrocystidia f. Caulocystidia g & h. Cross section of pileipellis i. Pleuropseudocystidia. Bars: a = 10 mm; b-i = 10 µm.

The smaller spore ornamentation (up to 0.6 µm) and absence of pleuromacrocystidia distinguishes *L. gerardii* Peck var. *subrubescens* (Smith & Hesler) Hesler & Smith from this species. Besides, the present taxon can be separated from the other variants (Hesler & Smith, 1979) by its habitat (among mosses), stipe base which changes pinkish on exposure, margined lamellae and wider caulocystidia.

Lactarius montoyae K. Das & J.R. Sharma

Mycotaxon **89**: 291, 2004. Pl. 14; fig. 34

Pileus 30-60 mm diam., convex, planoconvex to applanate or slightly planoconcave at maturity, center sometimes depressed and with umbo; pileipellis glabrous to pruinose, dry, grayish yellowish to dark grayish yellowish brown, grayish to deep grayish brown; margin slightly decurved or plane, sometimes broadly wavy, often crenate in older specimen. Lamellae adnate or / to subdecurrent, distant (*ca* 4 per cm), edge smooth, concolorous, pale ochre to orange yellow, unchanging when bruised, lamellulae of different sizes. Stipe 25-58 x 7-12 mm, central or slightly eccentric, cylindric or slightly tapering downwards, sometimes slightly longitudinally grooved, glabrous, dry, concolorous, often yellowish white at the base. Context stuffed to hollow, yellowish white. Latex rather sparse, white, unchanging. Odour mild. Spore print pale yellow ochre to orangish yellow.

Basidiospores 7.5-10.0 (10.3) x (7.0) 7.24-9.3 µm, globose to broadly ellipsoid (Q = 1.03-1.15 (1.2), av. 1.06-1.09); ornamentation amyloid, up to 2.7 µm high, composed of ridges arranged in somewhat parallel and / or in a spiral pattern, rarely branched, never reticulate; often shorter ridges occupying the gap between the main ridges; plage amyloid. Basidia 44-60 x 9-12.5 µm, subclavate to clavate, 4-spored; sterigma up to 7.5 µm high. Pleuromacrocystidia absent. Pleuropseudocystidia up to 8.5 µm broad, abundant, mostly cylindrical with rounded apex. Lamellae edge sterile. Cheilomacrocystidia absent. Paracystidia 45-56 x 8-11 µm, subclavate to clavate, sometimes narrower towards apices. Hymenophoral trama mixed, composed of hyphae, sphaerocytes and laticifers. Pileipellis a trichopalisade, up to 110 µm thick; terminal elements of suprapellis cylindrical to ventricose, long slender, 18-65 x 4-9 µm, thinwalled, with brown intracellular pigmentation; subpellis composed of mostly globose cells, up to 27 µm diam. Stipipellis a trichopalisade; terminal elements of suprapellis, cylindrical, slender, 15-50 x 3-7 µm, thin walled, with brown intracellular pigmentation; subpellis of globose cells. Stipe trama with numerous sphaerocytes.

Ecology : Rare, grows in close association with species of *Quercus* and *Rhododendron* in moist deciduous to mixed temperate forests, preferably among mosses.

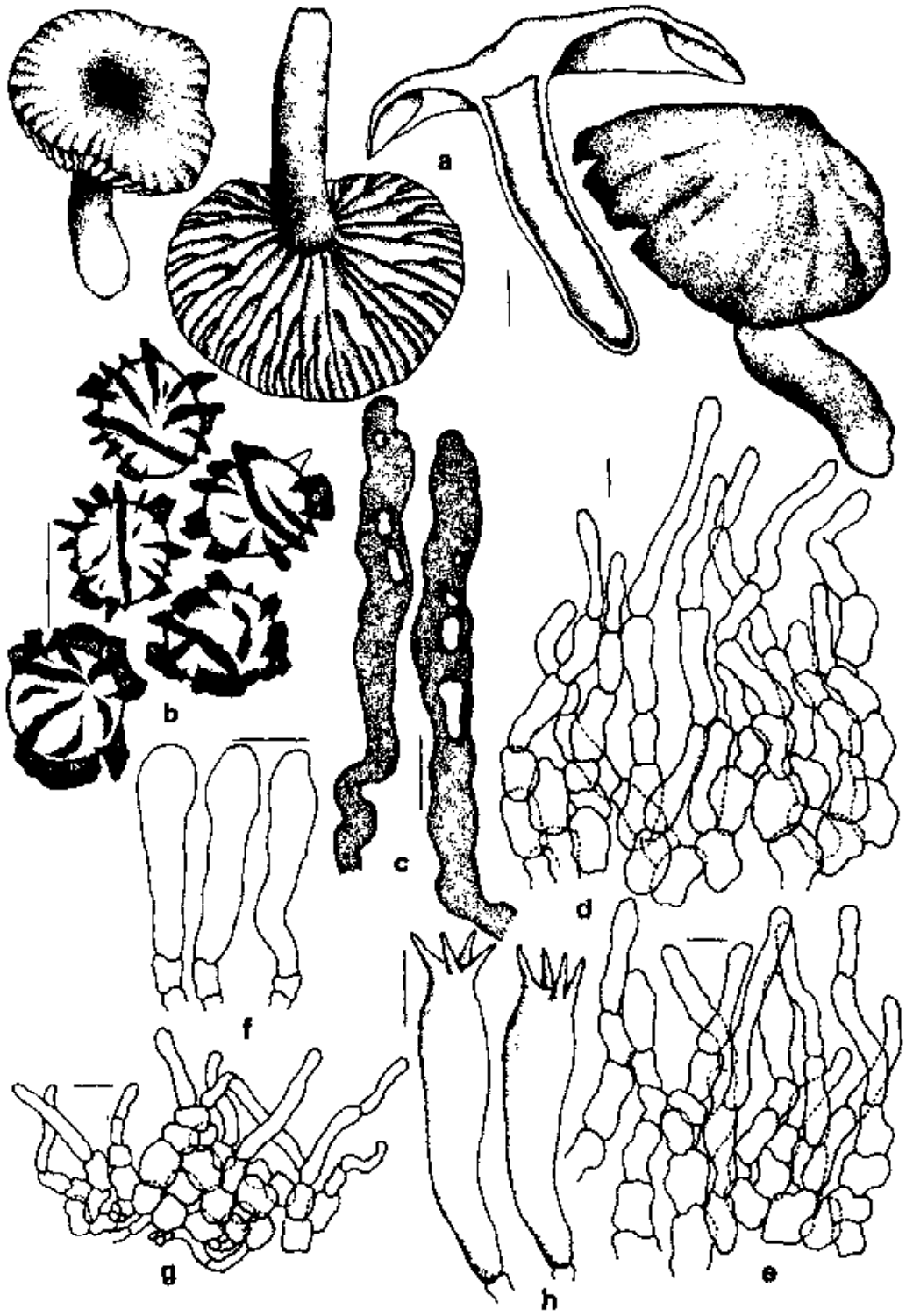


Fig. 34. *Lactarius montoyae*: a. Basidiomes b. Basidiospores c. Pleuropseudocystidia d & e. Cross section of pileipellis f. Paracystidia g. Cross section of stipitipellis h. Basidia. Bars: a = 10 mm; b-h = 10 µm.

Specimens examined : Uttaranchal, Bageswar, Dhakuri, September 29, 1999, **col.** K. Das & J.R. Sharma, KD1065; Uttaranchal, Bageswar, Dhakuri, September 16, 2003, **col.** K. Das, KD7003; Uttaranchal, Bageswar, Dhakuri top, September 25, 2003, **col.** K. Das & J.R. Sharma, KD7080, KD7081.

Notes : Lactarius montoyae was repeatedly collected from the forests surrounding Dhakuri only. Morphologically, it closely resembles *L. romagnesii* Bon. However, the latter differs in having globose to broadly ellipsoid spores with the ornamentations forming a reticulate pattern (Heilmann-Clausen *et al.*, 1998) and the shorter (10-35 x 4-9 µm) terminal elements of suprapellis. *Lactarius montoyae* also comes closer to *L. pterosporus* Romagn. However, the pileus of *L. pterosporus* is strongly wrinkled in the center, "olivaceous buff to dark grayish buff or clay-buff" coloured, crowded lamellae and white latex which turns pale grayish pink when drying (Heilmann-Clausen, 1998).

Lactarius picinus Fr.,

Epicr. Syst. Mycol. p. 343, 1838; Das & Sharma, Ann. For. 9(2001) 284; Phytotax. 4(2004) 5. Fig. 35

Pileus 52-72 mm diam., convex to applanate or slightly depressed; cuticle dry, pruinose, velvety, dark greyish brown, brownish black to black or dark olive brown; margin slightly decurved, often irregular. Lamellae adnate to slightly decurrent, entire, rather crowded (12 per cm) pale ochraceous yellow, dark reddish brown after bruising; edge concolorous with the face. Stipe 35-50 x 10-18 mm, cylindric or slightly narrowed below, greyish brown to black, whitish near base. Context whitish, quickly pale reddish brown after bruising. Latex white, strongly acrid. Spore print not found.

Spores 7.1-9.2 x 6.6-8.5 µm, globose to broadly ellipsoid; ornamentation up to 1.5 µm high, forming almost complete reticulum. Basidia 38-50 x 10-12 µm, cylindric to subclavate, 4-spored. Pleuromacrocystidia absent. Cheilomacrocystidia 30-46 x 3-6 µm, thickwalled, often with dense contents. Paracystidia 15-30 x 5-8 µm, cylindrical to subfusoid. Pileipellis a trichoepithelium, 100-120 µm thick, terminal elements cylindric, 20-48 x 5-7 µm.

Ecology : Rare, grows in ectomycorrhizal association with *Quercus leucotrichophora* in subtropical to temperate, deciduous to mixed forests.

Specimens examined : Uttaranchal, Almora, near Binsar, August, 2001, **col.** K. Das KD602, KD631; Uttaranchal, Nainital, Gagar, August 2001, **col.** K. Das, KD2144.

Notes : The dark grey to blackish, velvety basiodiocarps having whitish to pale ochraceous, crowded lamellae are so characteristic and help in easy recognition of this taxon in the field. Further, the pileipellis being a typical

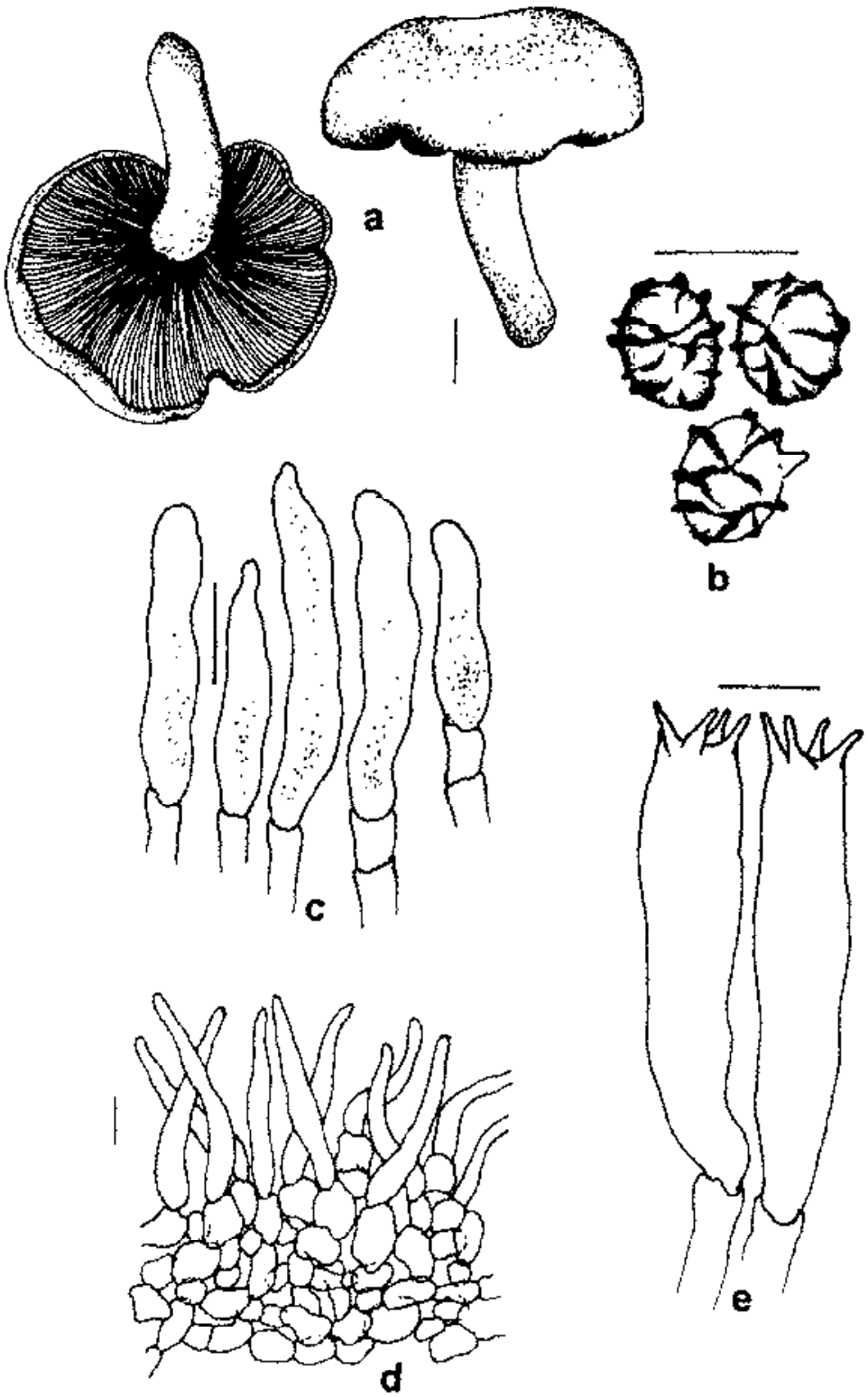


Fig. 35. *Lactarius picinus*: a. Basidiomes b. Basidiospores c. Paracystidia d. Pileipellis e. Basidia. Bars: a = 10 mm; b-e = 10 µm.

trichoepithelium, absence of pleuromacrocystidia, presence of thick-walled cheilomacrocystidia, spores with broad and stout ornamentations also make this species easily recognizable and unique. In the colour and morphology of the basidiocarp, *Lactarius picinus* is close to both *L. fuliginosus* (Fr.: Fr.) Fr. (Heilmann-Clausen *et al.*, 1998) and *L. lignyotus* var. *lignyotus* Fr. (Hesler & Smith, 1979). However, *L. fuliginosus* differs in having greyish brown to clay-buff slightly wrinkled pileus, less crowded gills and spores with comparatively more isolated warts and lower ornamentations. Whereas, the basidiocarps in *L. lignyotus* var. *lignyotus* lack any acrid taste and the spores have heavier ornamentations than the present species.

Plate 14: a. *Lactarius montoyae* b & c. *L. lignyotus* var. *canadensis* d. *L. gerardii* var. *subrubescens*.

Subgenus **Russularia** (Fr.) Kauffman
Agaricaceae of Michigan p. 105, 1918; *Lactarius* (Tribus) *Russularia* Fr., Hymen. Europa. 431, 1874.

Pileus dry or slightly sticky, smooth to rugose wrinkled, with or without umbo or papilla, light yellowish orange to deep reddish brown; lamellae broadly adnate to decurrent; latex white to yellowish white, unchanging, watery to sticky on exposure; basidiospores globose to ellipsoid, ornamentation parallel, incomplete to almost complete reticulum; pileipellis an epithelium to a hyphoepithelium. Seven species in India; four in Kumaon Himalaya.

KEY TO THE SPECIES

1a. Pileipellis typically rugose-wrinkled to veined; hyphoepithelium with trichodermial tufts ..... **L. sanjappae**

b. Pileipellis never veined, hyphoepithelium without trichodermial tufts 2

2a. Latex yellowish white, sticky after exposure; basidiospores with typically zebroid ornamentation ..... **L. verbekenae**

b. Latex white, watery unchanging; basidiospores not with zebroid ornamentation 3

3a. True hymenial cystidia present ..... **L. mukteswaricus**

b. True hymenial cystidia absent ..... **L. serifluus**

Lactarius mukteswaricus K. Das, J.R. Sharma & Montoya

Fungal Diversity **16**: 26, 2004. Pl. 15, 16; fig. 36

Pileus 30-50 mm diam., convex to plane with an umbo, disc gradually depressed, papilla conical, persistent; surface smooth, somewhat leathery, azonate, pale reddish-brown, brownish to deep orange or pale brown, often paler towards margin; margin decurved to inrolled, often wavy. Lamellae subdecurrent to decurrent, close to rather subdistant (*ca* 5-7 per cm at margin), lamellulae of different sizes, orangish-yellow, brownish after bruising. Stipe 30-65 x 5-8 mm, cylindric, concolorous to rather darker towards base, smooth. Context hollow, pale orange to light brown. Latex copious watery to milky white, unchanging. Odour not distinct but spicy when dry. Spore print whitish.

Basidiospores 7.5-9 x 5.8-8 µm, (Q = 1.1-1.22), broadly ellipsoid; ornamentation amyloid, up to 0.6-0.8 (-1.2) µm high, reticulate or forming a partial reticulum, isolated warts present, plage not distinct; under SEM the ornamentation

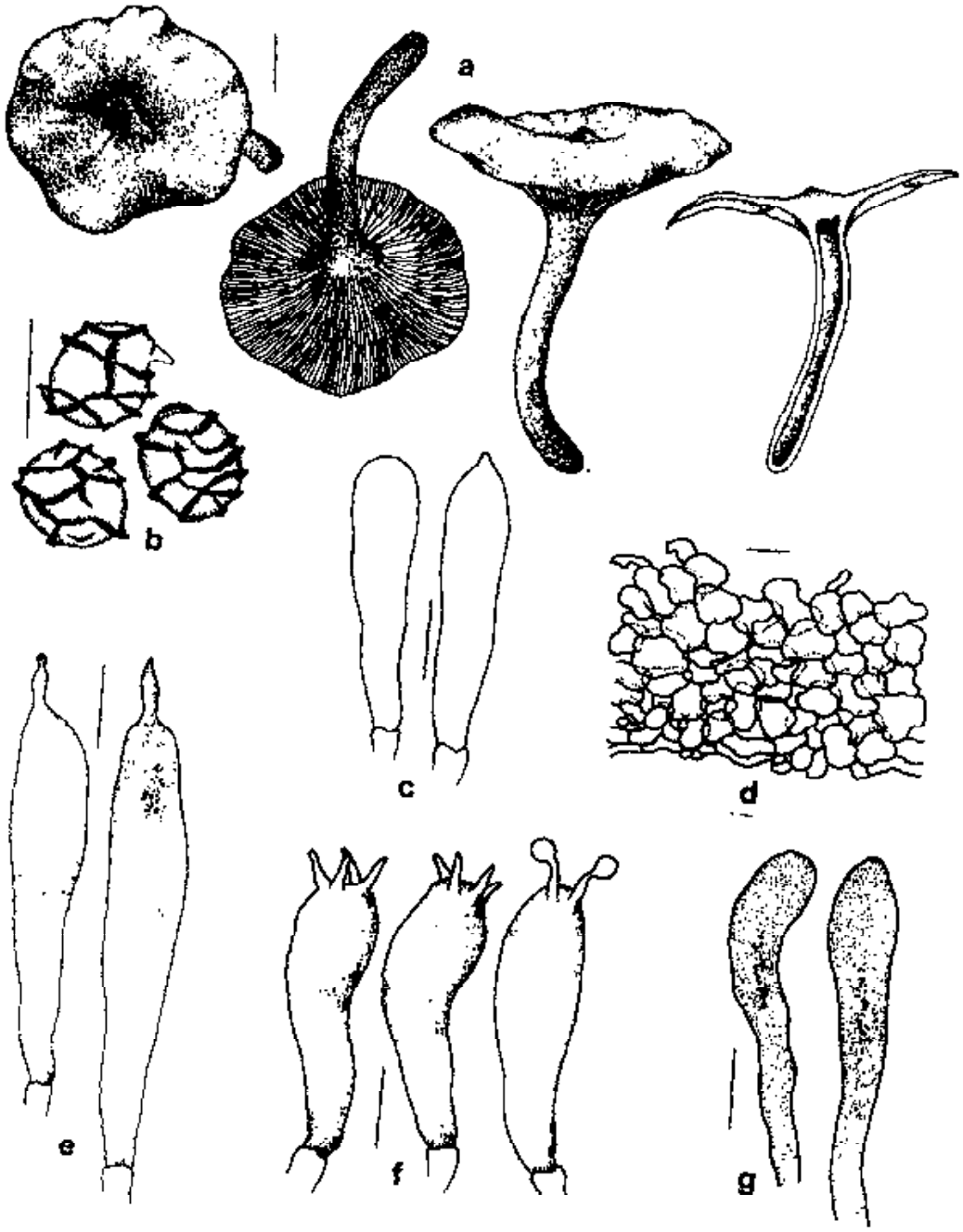


Fig. 36. *Lactarius mukteswaricus*: a. Basidiomes b. Basidiospores c. Cheilomacrocystidia d. Cross section of pileipellis e. Pleuromacrocystidia f. Basidia g. Pleuropseudocystidia. Bars: a = 10 mm; b-g = 10 µm.

is composed of continuous, interconnected ridges, with some free extremes, bands with irregular lobate margin. Basidia 38-50 x 8-12 µm, subclavate to clavate, 2- to 4-spored with long sterigma (up to 8 µm long). Pleuromacrocystidia 50-80 x 7-12 µm, oblong to oblanceolate, acuminate to moniliform at the apex, somewhat emergent (up to 8 µm); with refractive contents. Pleuropseudocystidia subclavate to clavate, up to 8 µm broad, numerous. Lamellar edges fertile, with basidia and few cystidia. Cheilomacrocystidia 30-45 x 6-8 µm, clavate to fusiform, infrequent. Subhymenial layer up to 14 µm, cellular. Hymenophoral trama with sphaerocytes and hyphae, laticifers up to 10 µm broad. Pileipellis a hyphoepithelium, up to 70 µm wide, subpellis composed of subglobose to vesiculose cells, arranged in 5-6 layers, cells 12-22 x 8-15 µm; hyphal elements up to 5 mm broad, scarce.

Ecology : Rare, grows in ectomycorrhizal association with *Quercus leucotrichophora* in temperate deciduous forests.

Specimens examined : Uttaranchal, Nainital, Mukteswar, August 2002, **col.** K. Das, KD2163; *ibid.*, KD2175.

Notes : The present species is distinguished by its papillate and applanate pileus and its rather stocky habit, unchanging watery white latex, basidiomes without any particular odor when fresh, but spicy when dry. Microscopically, the presence of macrocystidia is distinctive. *Lactarius mukteswaricus* is close to *Lactarius camphoratus* (Bull.: Fr.) Fr., but the latter has a spicy odor in fresh condition, crowded lamellae, and a different ornamentation pattern in basidiospores.

Lactarius sanjappae K. Das, J.R. Sharma & Montoya

Fungal Diversity **16**: 24, 2004. Pl. 15, 16; fig. 37

Pileus 30-50 mm diam., plane, soon becoming deeply depressed to funnel shaped, typically without an umbo or papilla; pileipellis mat, dry, azonate, radially rugose-wrinkled to venose, often pitted; veins distinct forming a broken reticulum; pale reddish-brown to pale brown, paler towards margin, veins darker, deep to dark brown; margin incurved, wavy. Lamellae subdecurrent, close (6 per cm near margin), pale orange-yellow to light brown, lamellulae of different sizes. Stipe 40-110 x 5-7 mm, cylindric, concolorous, rather darker towards base. Context solid to stuffed but not hollow, medium orangish-yellow to light brown. Latex copious, watery to milky white, unchanging. Odor mild. Spore print not obtained.

Basidiospores 7.5-8.8 x 6.2-7.6 µm, (Q = 1.15-1.23) broadly ellipsoid; ornamentation amyloid, 0.8-1.2 (-1.8) µm high, a partial to a complete reticulum with isolated ridges and warts, plage not distinct; under SEM reticulum

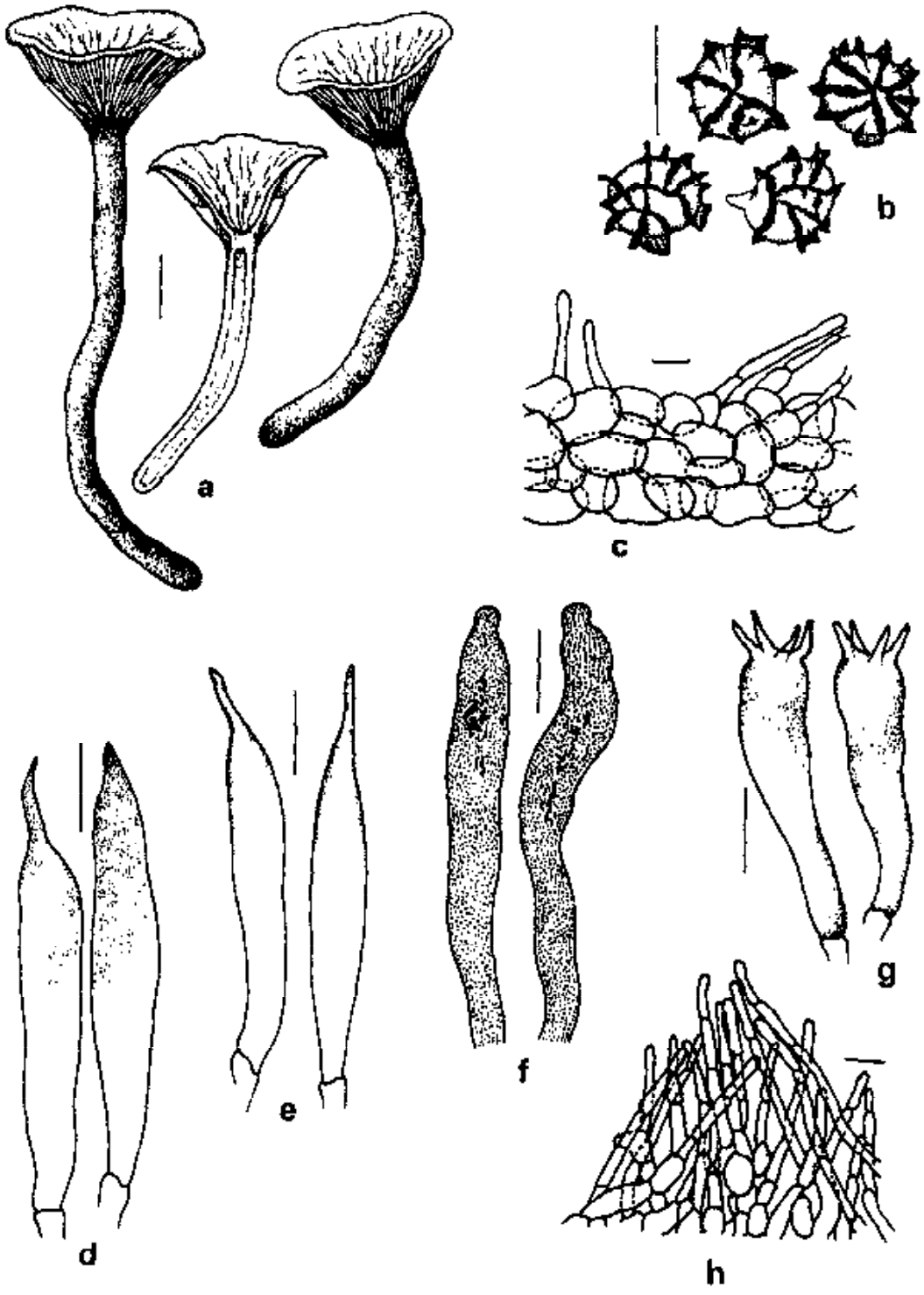


Fig. 37. *Lactarius sanjappae*: a. Basidiomes b. Basidiospores c & h. Cross section of pileipellis d. Pleuromacrocystidia e. Cheilomacrocystidia f. Pleuropseudocystidia g. Basidia. Bars: a = 10 mm; b-h = 10 µm.

is composed of continuous bands, with irregular margin, with some free extremes. Basidia 28-40 x 5-10 µm, subclavate to clavate, 4-spored; sterigma up to 6.5 µm long. Pleuromacrocystidia 48-74 x 7-10 µm, fusiform to oblanceolate, acute to rostrate, emerging 12-20 µm; contents refractive. Pleuropseudocystidia cylindric to subclavate, rounded at apex, up to 6 µm broad, numerous. Lamellar edges composed of basidia and cystidia. Cheilomacrocystidia 30-50 x 6-8 µm, lanceolate to narrowly fusiform. Hymenophoral trama cellular, with sphaerocytes and hyphae, laticifers up to 12 µm broad. Pileipellis a hyphoepithelium; subpellis a stratum up to 58 µm thick, composed of irregularly shaped, subisodiametric cells, frequently arranged in 3-6 layers, elements 15-35 x 10-20 µm; suprapellis of anticlinal, scattered, septate elements, frequently arranged in tufts (even in mature specimens), terminal cells 14-25 x 4-5 µm, thin walled.

Ecology : Common, grows in ectomycorrhizal association with *Quercus leucotrichophora* in temperate deciduous forests. It is interesting to record that *Lactarius verbekenae* (see below) was always found at the type locality of the present species.

Specimens examined : Uttaranchal, Nainital, Mukteswar, August 2002, col. K. Das, KD2129; *ibid.*, KD2172.

Notes : Morphologically, *Lactarius sanjappae* is characterized by the distinctly radially rugose-wrinkled pileus surface and the slender habit of its basidiomes. The pileipellis is composed of a hyphoepithelium and trichodermial tufts, which is a unique character of this taxon among the known species of the sections *Tabidi* (Heilmann-Claussen *et al.* 1998) and *Rhysocybella* Bon (Basso 1999).

Lactarius serifluus (DC.: Fr.) Fr.

Epicr. Syst. Mycol., 345, 1838. *Agaricus serifluus* DC: Fr. Syst. Mycol. 1: 75, 1821. *Agaricus serifluus* DC., Flore Francaise 6: 45, 1815; Atri *et al.*, Ind. Phytopath. 44(1991) 185; Das & Sharma, Phytotax. 4(2004)5. Fig. 38

Pileus 25-45 mm, convex to planoconvex with depressed center with an umbo or papilla; pileipellis dry, smooth to slightly wrinkled, medium to brownish orange or soft brown, darker towards center; margin incurved, regular to slightly wavy. Lamellae broadly adnate to decurrent, subdistant to close (5-6 per cm), yellowish pink to pale orange yellow; lamellulae in several rows. Stipe 45-90 x 5-6 mm, mostly cylindric, light yellowish brown to brownish orange. Context hollow. Latex watery white, unchanging. Taste mild. Odour aromatic. Spore print yellowish white to cream.

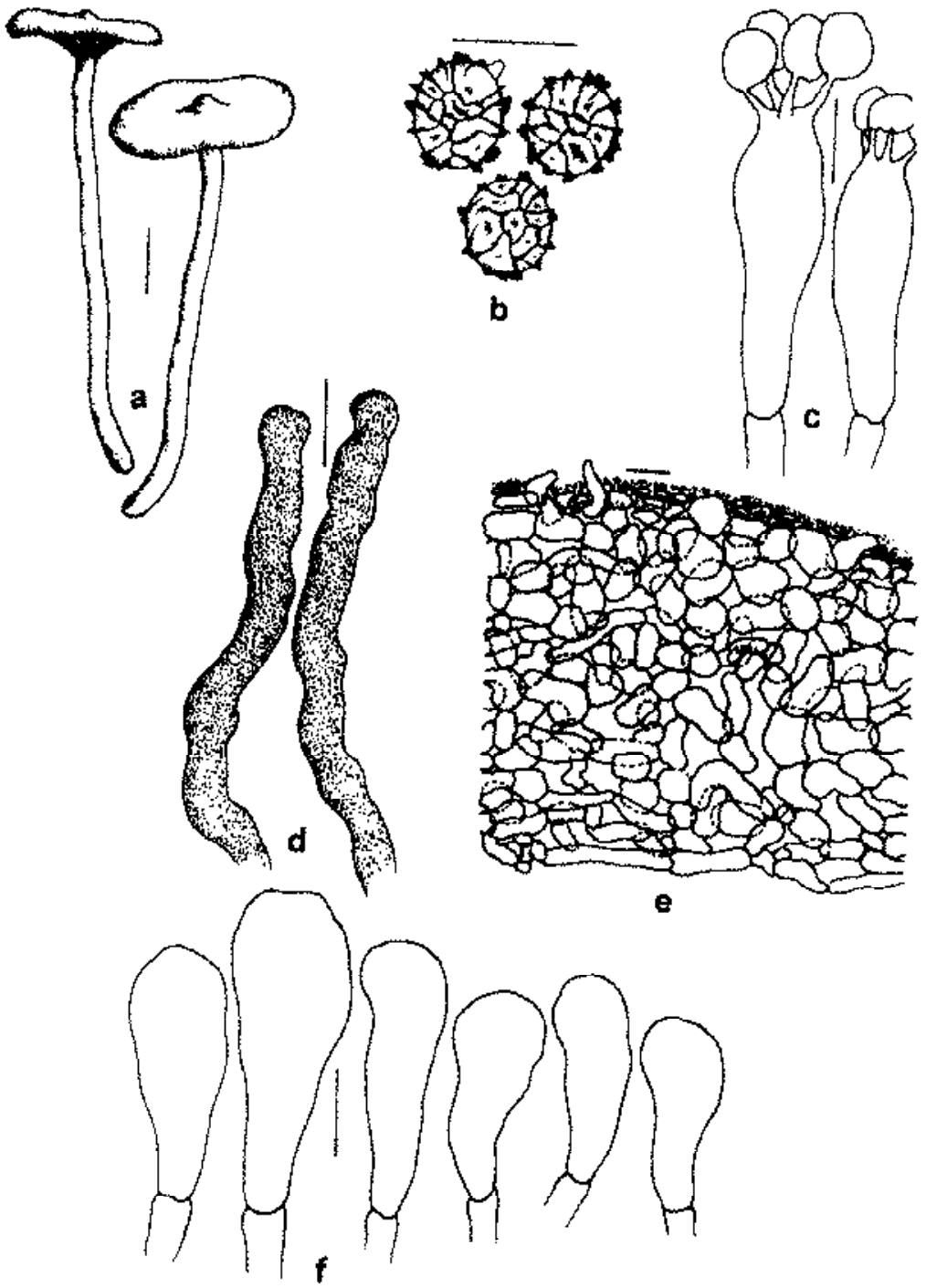


Fig. 38. *Lactarius serifluus*: a. Basidiomes b. Basidiospores c. Basidia d. Pleuropseudocystidia e. Cross section of pileipellis f. Paracystidia. Bars: a = 10 mm; b-f = 10 µm.

Basidiospores 7-8.5 x 6-7.6 µm, globose to broadly ellipsoid (Q = 1.04-1.23); ornamentation amyloid up to 1 µm high, composed of elongate warts and ridges forming almost complete reticulum. Basidia 34-54 x 8-11 µm, subclavate, 4-spored. True hymenial macrocystidia absent. Paracystidia 18-38 x 8-16 µm, clavate to pyriform. Pileipellis a hyphoepithelium, up to 110 µm thick; elements of subpellis are of cylindric, elliptic or rounded cells; suprapellis thiner, elements cylindric (up to 5 µm broad), forming an collapsed amorphous layer.

Ecology : Common, grows in ectomycorrhizal association with *Quercus leucotrichophora* in subtropical to temperate deciduous forests.

Specimens examined : Uttaranchal, Nainital, Mukteswar, August, 2002, **col.** K. Das, KD2170; Uttaranchal, Bageswar, Loharkhet top, October 1999, **col.** K. Das & J.R. Sharma, KD1086; Uttaranchal, Nainital, Nainapeak, September 1982, **col.** N.S. Atri, PUN 552.

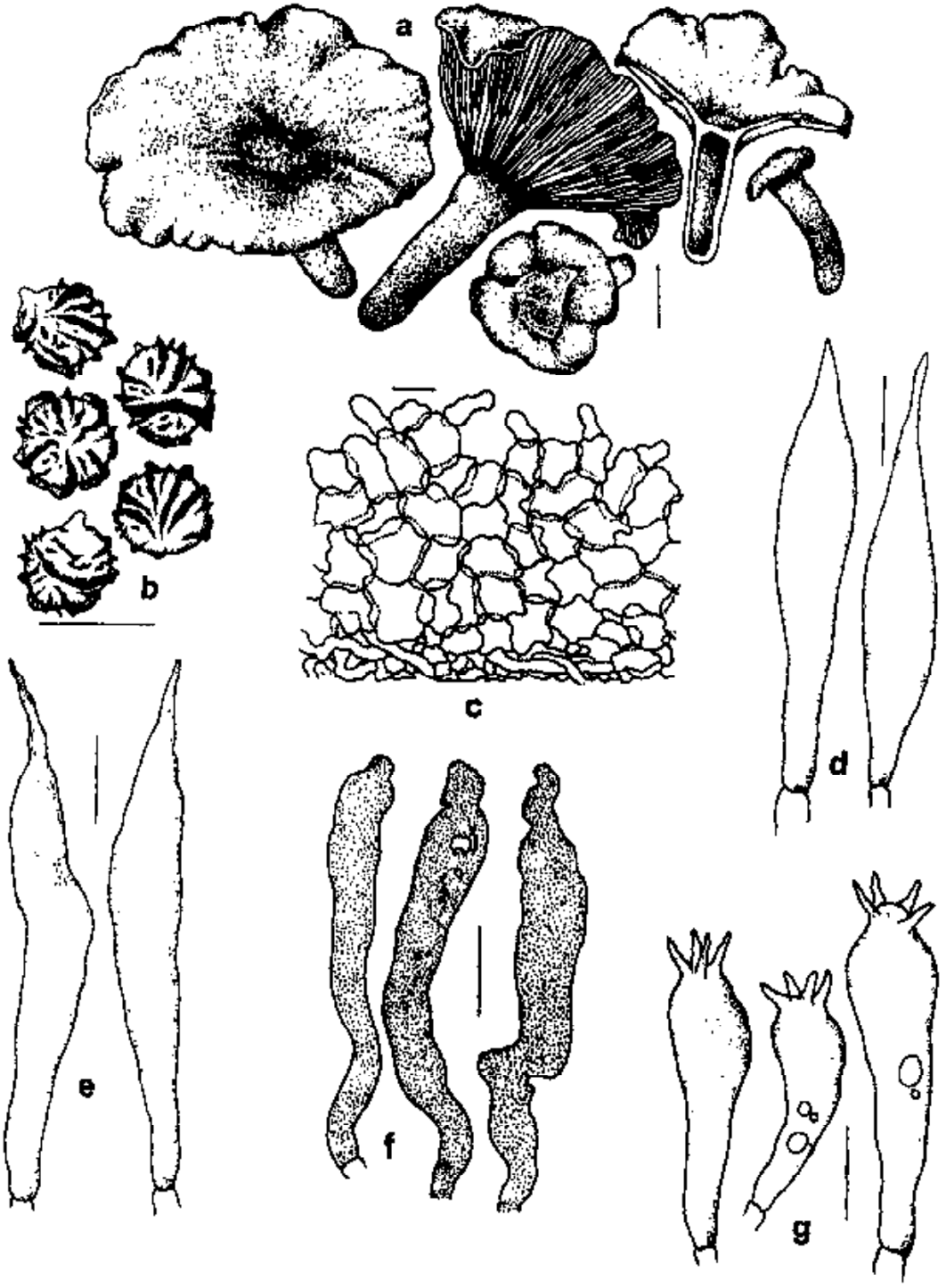
Notes : Lactarius serifluus is distinguished by its white unchanging latex, aromatic odour, basidiospores with reticulate ornamentation pattern and the absence of true hymenial cystidia. Macroscopically, it resembles *Lactarius subumbonatus* Lindgr. but the latter differs from the present species by having darker and more dull cap colours and more elongated paracystidia (Heilmann-Clausen *et al.* 1998).

Specimen no. PUN 552, collected from Naina peak by N.S. Atri and identified as *Lactarius subisabellinus* var. *murrillianus* (Hesler & A.H. Smith) Hesler & A.H. Smith, clearly belongs to *L. serifluus*.

Lactarius verbekenae K. Das, J.R. Sharma & Montoya

Fungal Diversity **16**: 29, 2004. Pl. 15, 16; fig. 39

Pileus 12-65 mm diam., convex, gradually plane with depressed center to funnel shaped, with or without an umbo, surface more or less smooth, azonate, grayish-reddish-orange, dark reddish-orange to pale reddish-brown, paler towards margin, darker towards center, often with grayish to dark grayish-purple tinge at center; margin incurved to inrolled when young, gradually expanding, irregularly wavy to folded when mature. Lamellae emarginate to decurrent, close to crowded (6-7 per cm at margin), lamellulae of different sizes, light to dark orange-yellow. Stipe 22-66 x 8-13 mm, cylindric to subcylindric, mostly concolorous to slightly darker towards base. Context hollow, pale orange-yellow. Latex yellowish-white, unchanging in colour, sticky after sometime. Odour strong, spicy, conserved when dried. Spore print yellowish white.



Flg. 39. *Lactarius verbekenae*: a. Basidiomes b. Basidiospores c. Cross section of pileipellis d. Cheilomacrocystidia e. Pleuromacrocystidia f. Pleuropseudocystidia g. Basidia. Bars: a = 10 mm; b-g = 10 µm.

Basidiospores 6-7.8 x 5.8-7 µm (Q = 1-1.1), broadly ellipsoid; ornamentation amyloid, up to 1.5 µm high, composed mostly of ridges and warts, which are arranged more or less parallel and in part giving the appearance of an spiral arrangement or in spiral coils (zebroid type), rarely branched, plage not distinct; under SEM ridges appearing with regular margin, oriented in bands, irregularly encircling basidiospore, interrupted warts also present. Basidia 27-38 x 7-10 µm, subclavate, mostly 4-spored; sterigma up to 6.4 µm long. Pleuromacrocystiia 50-70 x 8-12 µm, infrequent, lanceolate to narrowly fusiform, acuminate to rostrate at apex, emerging up to 25 µm, at times with refringent contents. Pleuropseudocystidia cylindric to subclavate with subacute, mucronate or rounded apex, up to 7 µm broad, common. Lamellar edges with basidia and few cystidia. Cheilomacrocystidia 28-54 x 5-8 µm, oblanceolate to fusiform. Subhymenial layer up to 20 µm, cellular. Hymenophoral trama cellular, composed of sphaerocytes and hyphae, laticifers scarce. Pileipellis almost a hyphoepithelium, up to 70 µm wide. subpellis composed of vesiculose to irregularly shaped cells, up to 6 layered; cells 10-28 x 8-18 µm; suprapellis elements 10-63 x 4-9 µm.

Ecology : Common, grows in ectomycorrhizal association with the species of *Quercus* and *Cedrus* in temperate deciduous and coniferous forests. *Lactarius sanjappae* described above was always observed in close association with the present species.

Specimens examined : Uttaranchal, Nainital, Mukteswar, August 2002, **col.** K. Das, KD2130; Uttaranchal, Champawat, Lohaghat, September 2002, **col.** K. Das & J.R. Sharma, KD4523.

Notes : Lactarius verbekenae is distinguished by white to yellowish latex which becomes typically sticky after exposure, its spicy odor, basidiospores with cristulate ornamentation pattern (of the so-called "zebroid type") and the presence of pleuromacrocystidia. Macroscopically, it resembles *Lactarius fragilis* (Burl.) Hesler & A.H. Sm. (var. *fragilis*), but the latter differs from the present Himalayan species by its smaller basidiomes, maize yellow lamellae, watery non-sticky latex and the reticulate ornamentation of the basidiospores.

Plate 15: a. *Lactarius sanjappae* b. *Lactarius verbekenae* c. *L. mukteswaricus.*

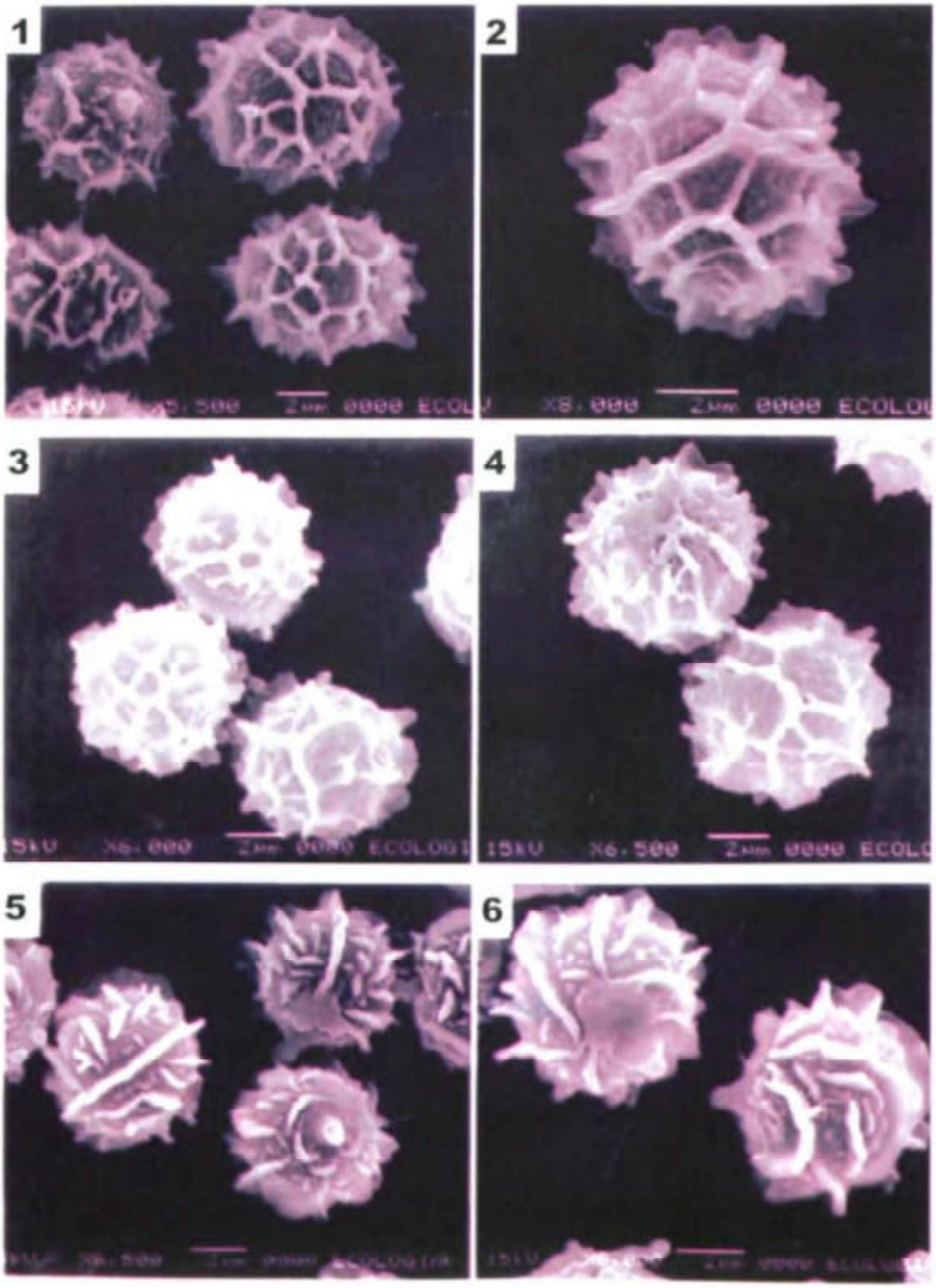


Plate16: Scanning Electron Micrographs of basidiospores: 1, 2. *Lactarius sanjappae* 3, 4. *Lactarius mukteswaricus* 5, 6. *Lactarius verbekenae* (*Fungal Diversity* **16:** 31).

Genus **Russula** Pers.: Fr.
Syst. Mycol. **I**: 54, 1821.

Basidiomes stipitate; pileus convex, planoconvex, sometimes infundibuliform at maturity, dry to viscid, smooth to velvety, white to vividly coloured; margin entire or forked, smooth, sulcate or striated; lamellae adnate to decurrent, crowded to distant, white to yellowish, unchanging or changing after bruising; lamellulae present or absent; stipe central, smooth to pruinose; taste mild or acrid; latex absent; spore print white to yellowish, basidiospores globose to ellipsoid, ornamentation amyloid with warts, lines or heavy ridges forming incomplete or complete reticulum to zebroid (parallel) or winged pattern; basidia 2-4 spored; pleurocystidia present or absent; cheilocystidia mostly present; pileipellis of varied pattern, often with suprapellis, subpellis and hypodermial layers; pileocystidia mostly present, hyphae sometimes incrusted; hymenophoral trama usually containing sphaerocytes. About 800 taxa in the world, about one hundred and eight taxa in India and forty three taxa from Kumaon Himalaya.

Type species : **Russula emetica** (Schaeff.: Fr.) Pers.

Literature : Maire 1910; Singer 1926; Singer 1932; Singer 1935; Schaeffer 1952; Rayner 1968-1970; Shaffer 1970; Singer 1986; Bon 1988; Kibby & Fatto 1990; Buyck 1993; Buyck 1994; Romagnesi 1996; Buyck 1997; Grgurinovic 1997; Sarnari 1998.

KEY TO THE SUBGENERA

1a. Context solid, initially whitish, unchanging or browning to blackening, sometimes preliminarily reddening; basidiomes initially whitish, unchanging or changing like the context; margin smooth; lamellae abundant; spore print white (Ia of Romagnesi) ..... subgenus **Compactae**

(P. 133)

b. Not with the above combination of characters 2

2a. Pileus gelatinous; margin tuberculately striate; stipe with large cavity; pileocystidia narrow (up to 6.5 µm broad) ..... subgenus **Ingratula**

(P. 176)

b. Not with the above combination of characters 3

3a. Dermatocystidia absent; hyphal ends of pileipellis typically subulate and up to 70 µm long ..... subgenus **Amoenula**

(P. 125)

b. Dermatocystidia present or absent; hyphal ends of pileipellis never subulate 4

4a. Pileus mostly greenish, sometimes brownish to violaceous; pileipellis with narrow pileocystidia; basidiospores usually small; taste mild ..... subgenus **Heterophyllidia**

(P. 151)

b. Not with the above combination of characters 5

5a. Pileocystidia absent ..... subgenus **Incrustatula**

(P. 166)

b. Pileocystidia present ..... subgenus **Russula**

(P. 193)

Subgenus **Amoenula** Sarnari
Monografia illustrata del Genere Russula in Europa 106, 1998

Pileus convex, planoconvex with depressed center or infundibuliform; lamellae adnexed to subdecurrent, close to subdistant, yellowish white to pale yellow, lamellulae abundant; stipe white with light reddish purple, grayish pink or red in part or yellowish at base; basidiospore ornamentations composed of warts and ridges forming incomplete reticulum; hymenial cystidia not graying or blackening with SBA; dermatocystidia absent; hyphal ends of pileipellis typically subulate and up to 70 µm long. Four taxa in India; three in Kumaon Himalaya.

KEY TO THE SPECIES

1a. Spore print pale yellow to light orange yellow (IIa - IIb of Romagnesi); stipe base red to purple 2

b. Spore print white (Ia of Romagnesi); stipe base distinctly greenish yellow ..... **Russula** sp. 1

2a. Pileus dark to deep red; basidiospores 7.5-9.2 x 6.7-7.8 µm .....
..... **R. amoenicolor**

b. Pileus gray to deep grayish purple; basidiospores 6.8-7.7 x 5.4-7.3 µm ..... **R. amoenicolor** var. **ramgarhensis**

Russula amoenicolor Romagnesi

Russules d'Europe et d' Afrique duNosd: 929, 1967; Rawla & Sarwal, Bib. Mycol. **91**(1983) 34; Atri, Curr. Res. Pl. Sci. (1994)82; Das & Sharma, Phytotax. **4**(2004)2. Pl. 17; fig. 40

Pileus 65-100 mm diam., convex, planoconvex with depressed center to infundibuliform; pileipellis slightly pruinose centrally, viscid, dark to deep red, medium red or paler towards the edge, often with soft orange yellow spots at the center; margin feebly striate, easily peeling. Lamellae broadly adnate to adnexed, subdistant (5-6 per cm), forked near the stipe, pale yellow, edge smooth, concolorous; lamellulae of unequal lengths. Stipe 50-88 x 13-24 mm, central, subclavate, yellowish white, flushed with soft red in part or entirely; context stuffed, yellowish white to pale yallow, $FeSO_4$ (+). Taste mild. Spore print pale yellow (IIa-IIb of Romagnesi).

Basidiospores 7.5-9.2 x 6.7-7.8 µm, subglobose to broadly ellipsoid [Q = (1.03) 1.06-1.22, av. 1.12-1.16]; ornamentation amyloid, up to 1 µm high, composed of warts and ridges arranged in incomplete reticulum. Basidia 40-50 x 9-12 µm, clavate, 4-spored. Pleurocystidia 80-108 x 13-17 µm, emergent

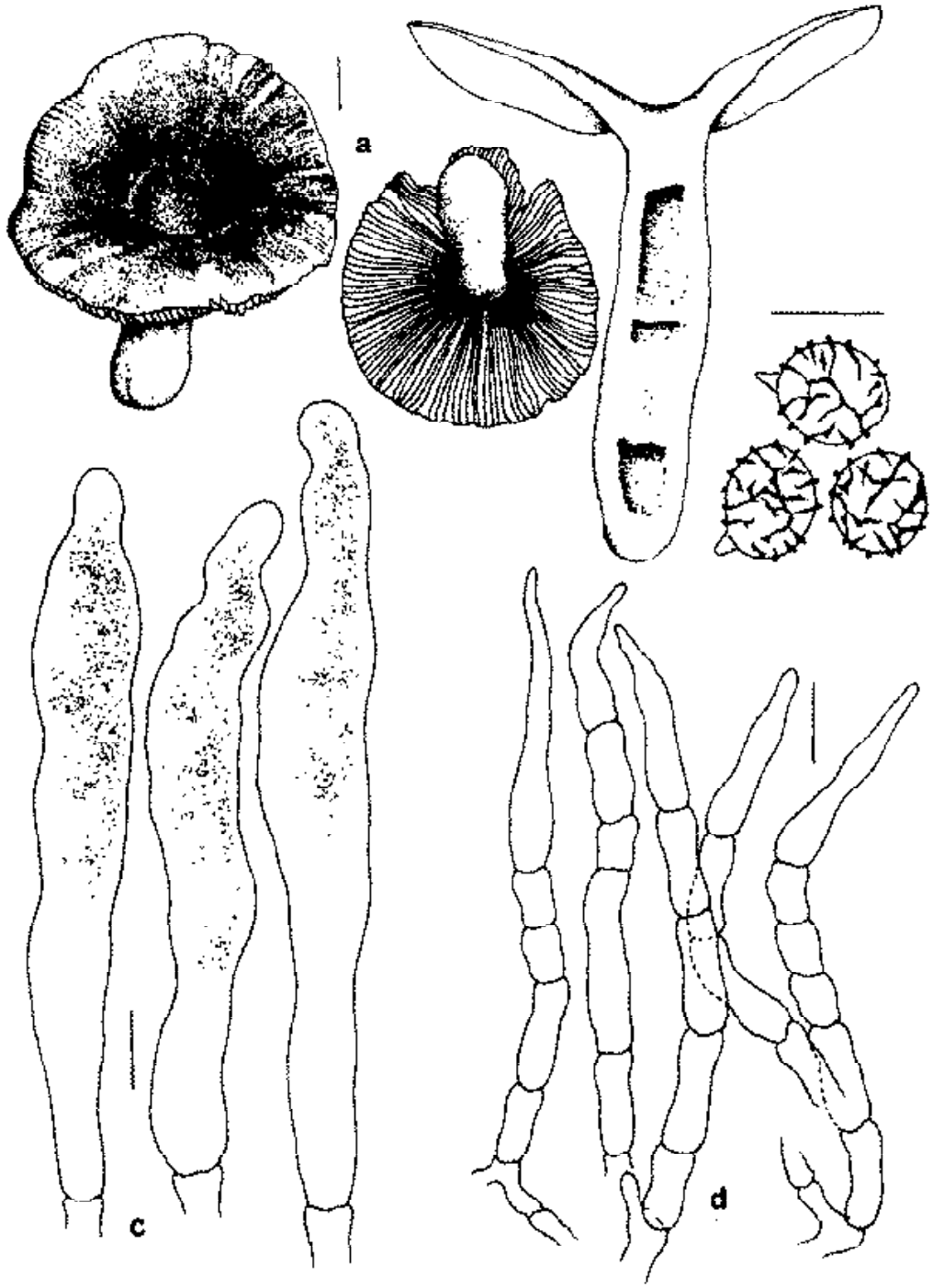


Fig. 40. *Russula amoenicolor* var. *amoenicolor*: a. Basidiomes b. Basidiospores c. Pleurocystidia d. Cross section of pileipellis. Bars: a = 10 mm; b-d = 10 µm.

up to 36 µm, abundant, subfusoid to ventricose, thick walled; wall up to 1.4 µm, mostly cylindrical with rounded apex. Cheilocystidia absent. Subhymenial layer up to 15 µm thick, cellular. Hymenophoral trama intermixed, composed of thick walled hyphae; hyphae up to 5 µm broad. Pileipellis two layered; suprapellis composed of suberect to repent subulate septate hyphae of 4-6 µm broad, pileocystidia absent; subpellis cellular.

Ecology : Common, grows in moist deciduous temperate forests, forming ectomycorrhizal association with species of *Rhododendron*.

Specimens examined : Uttaranchal, Pithoragarh, Dafia Dhura forest, September 2001, **col.** K. Das & J.R. Sharma, KD 4071; *ibid.*, KD4079.

Notes : The specimens from Kumaon Himalaya match closely with the *Russula amoenicolor* var. *amoenicolor* as described by Romagnesi (1996) and Sarnari (1998) except slightly larger spores for the Indian specimens.

Russula amoenicolor Romagnesi

Russules d'Europe et d'Afrique du Nord: 929, 1967. var. **ramgarhensis** K. Das, J.R. Sharma & R.P. Bhatt ***var. nov.***
Pl. 17; fig. 41

Etymology : Ramgarh, referring to the type locality.

*Pileus 70 82 mm diam., planoconvexus ad depressus in centro, purpureus. Lamellae late adnatae ad annexae luteae. Stipes 45 50 x 18 23 mm, cylindricus, purpureus. Sporae in cululo luteae, 6.8 7.7 x 5.9 7.3 µm, subglobosae vel late ellipsoidae. Pleurocystidia 100-160 x 11-16 µm, subfusoidae ad ventricosae. Pileocystidia nulla. India. Uttaranchal: Nainital, Ramgarh, August 2002, leg. K. Das, KD3220 (**Holotypus**, BSD).*

Pileus 70-82 mm diam., planoconvex to applanate with depressed center; pileipellis slightly pruinose, viscid, grayish to deep grayish purple with black purple center, sometimes with medium yellow patches; margin feebly striate; easily peeling. Lamellae broadly adnate to adnexed, subdistant (5-8 per cm), forked near the stipe, pale yellow, edge smooth, concolorous; lamellulae of unequal lengths. Stipe 45-50 x 18-23 mm, central, cylindric or gradually narrower towards base, pinkish purple, paler upwards; context stuffed, light brown in Phenol. Spore print pale yellow (IIa of Romagnesi). Taste not known.

Basidiospores 6.8-7.7 x 5.4-7.3 µm, subglobose to broadly ellipsoid [Q = 1.06-1.13, av. 1.08-1.1]; ornamentation amyloid, up to 1.2 µm high, composed of warts and ridges arranged in incomplete reticulum. Basidia 35-45 x 7-11 µm, subclavate to clavate, 4-spored. Pleurocystidia 100-160

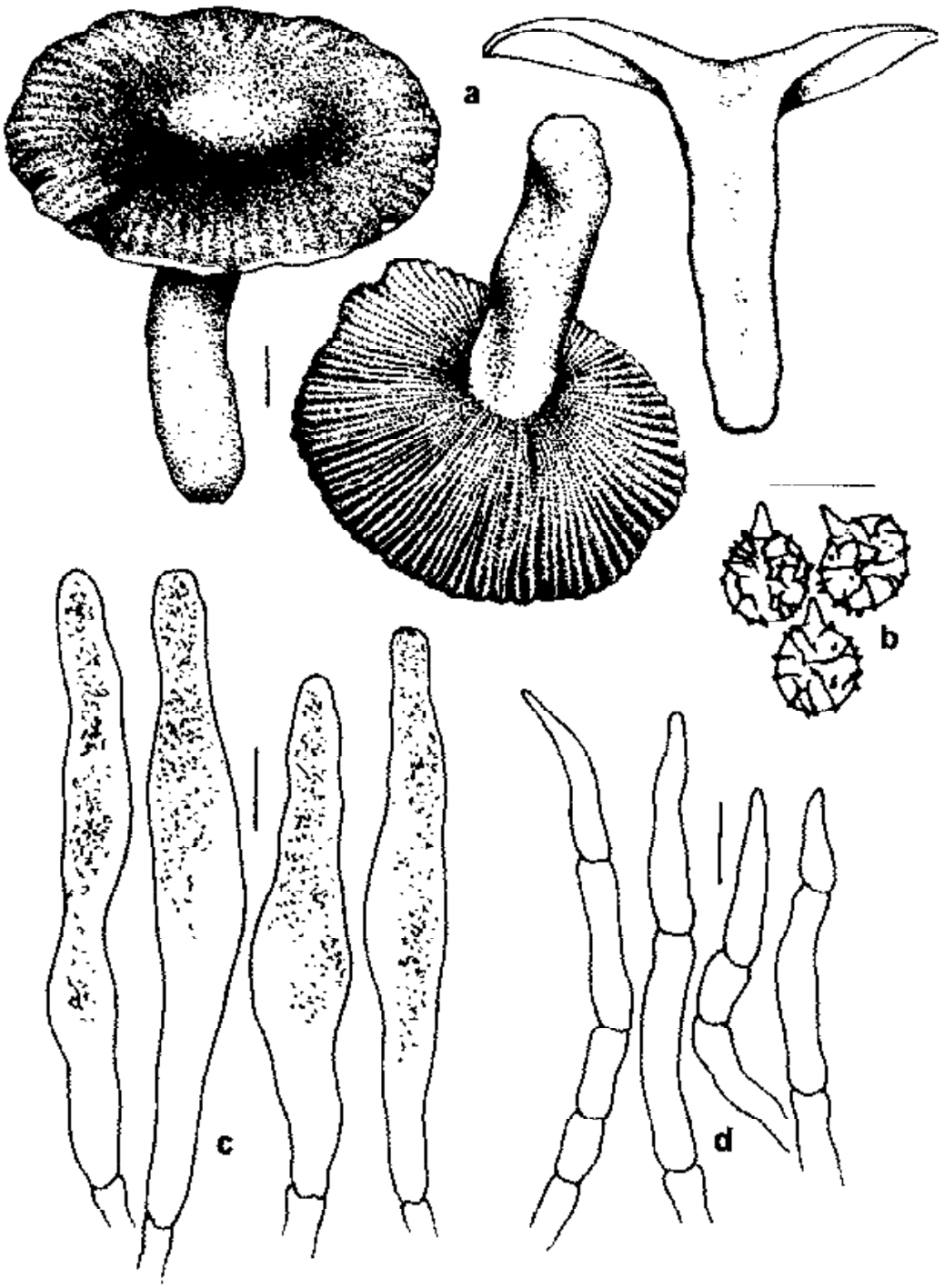


Fig. 41. *Russula amoenicolor* var. *ramgarhensis*: a. Basidiomes b. Basidiospores c. Pleurocystidia d. Cross section of pileipellis. Bars: a = 10 mm; b-d = 10 µm.

x 11-16 µm, emergent up to 50 µm, abundant, subfusoid to ventricose, thick walled; content dense. Cheilocystidia same as pleurocystidia. Subhymenial layer up to 15 µm thick, cellular. Hymenophoral trama intermixed, composed of thick walled hyphae; hyphae up to 3-5 µm broad. Pileipellis two layered; suprapellis composed of suberect to repent subulate septate hyphae, 4-5 µm wide, pileocystidia absent; subpellis cellular.

Ecology : Russula amoenicolor var. *ramgarhensis* is rare and grows ectomycorrhizally with species of *Quercus* in temperate mixed forests.

Specimens examined : India. Uttaranchal: Nainital, Ramgarh, August, 2002, leg. K. Das, KD3020 (**Holotype**, BSD); *ibid.*, KD2185.

Notes : Russula amoenicolor var. *ramgarhensis* is close to *R. amoena* Quélet. However, the context of *R. amoena* turns violet with Phenol. Moreover, the presence of narrower pleurocystidia (not wider than 10 µm) make *R. amoena* distinct from the present variety. Furthermore, the variety in discussion is close to the typical variety (Sarnari 1998), but differs in the colour of pileipellis and smaller size of spores. Besides, two varieties also differ in their association with forest trees.

Russula sp. 1

Pl. 17; fig. 42

Pileus 65-130 mm diam., planoconvex, becoming umbilicate with depressed center at maturity; pileipellis dry, viscid when moist, pruinose to subvelvety, dark purple, deep to very deep purple or deep to dark violet, light to brilliant or very greenish yellow at the center; margin slightly decurved, almost plain at maturity, irregularly lobed, splitted, peeling up to 1/4th of the radius. Lamellae broadly adnate to adnexed, close (7-9 per cm), forked from the base, brittle, cream to pale yellow or light greenish yellow; lamellulae present; edges even. Stipe 45-87 x 14-27 mm, cylindric to subclavate, dry, pruinose, light reddish purple at the top, gradually with white areas downwards but always with a white rim between the juncture of lamellae and stipe, pale greenish yellow (lemon yellow) at the base. Context stuffed, cream, changing light brown with phenol. Taste mild. Spore print white (Ia).

Basidiospores 7.6-9.3 x 7.3 8.2 µm, globose to subglobose (Q = 1 1.15, av. 1.05 1.10); ornamentation amyloid, composed of warts (up to 0.75 µm long) and ridges forming incomplete reticulum. Basidia 30 45 x 7 9 µm, subclavate to clavate, 4-spored; sterigmata up to 6.5 7 µm. Pleurocystidia 80 110 x 11 17 µm, abundant, emergent up to 40 µm, ventricose, subfusiform to fusiform, thick walled, content dense; wall up to 1.3 µm thick. Lamellae edge fertile, composed of basidia and cystidia.

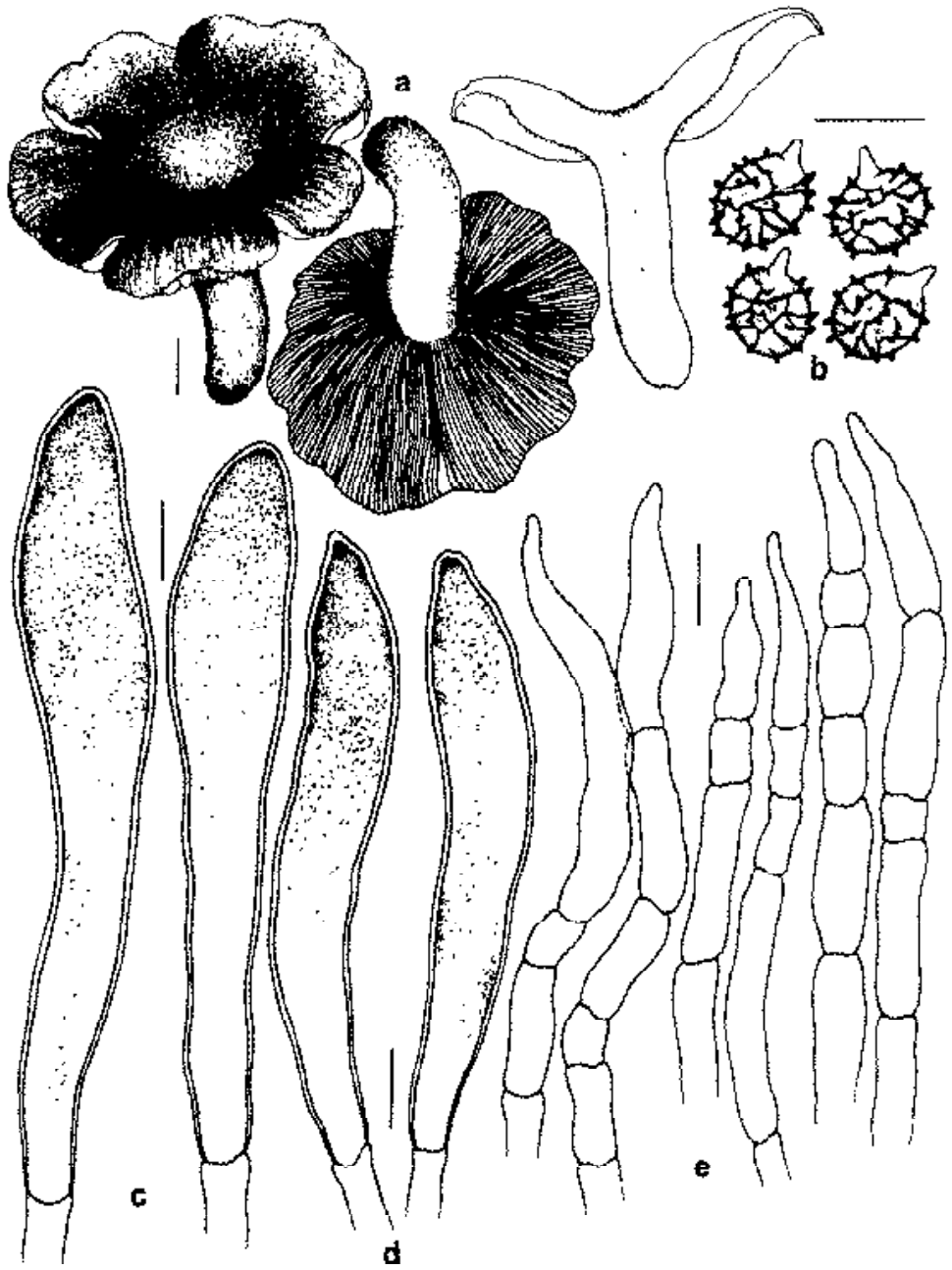


Fig. 42. *Russula* sp. 1: a. Basidiomes b. Basidiospores c. Pleurocystidia d. Cheilocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

Cheilocystidia 70 100 x 11 16 µm, thick walled, same as pleurocystidia. Subhymenium layer narrow, up to 12 µm thick, cellular. Pileipellis two layered; upper layer composed of suberect to erect subulate, septate hyphae, 5 11 µm broad, pileocystidia absent; subpellis cellular.

Ecology : This species grows in close association with species of *Quercus* in moist deciduous to mixed subtropical to temperate forests.

Specimens examined : India, Uttaranchal : Nainital, Mukteshwar, August 2003, **col.** K. Das, KD2120 (**Holotype,** BSD; isotype, TUR-A); *ibid.*, KD2127 (BSD, GUH); *ibid.*, Pithoragarh, Dafia Dhura, September 2001, **col.** K. Das & J.R. Sharma, KD4082 (BSD, GUH).

Notes : Typically subulate, up to 70 µm long hyphal ends of pileipellis and absence of dermatocystidia undoubtedly place the taxon in the subgenus *Amoenula* Sarnari. Present species resembles with *Russula amoenicolor* Romagnesi, *R. violeipes* Quélet and *R. amoena* Quélet. However, all these three species have a different colour of the spore print which vary from IIa-IIc (Romagnesi 1996). Moreover, red to purple colour of stipe base in *R. amoenicolor*, presence of distinctly globose lower cells of pilear hyphae in *R. violeipes* and comparatively narrower pleurocystidia and reddish stipe base in *R. amoena* further separate these species from the present taxon. Molecular analysis gathered from the rDNA sequencing has also confirmed that the present taxon belongs to the subgenus *Amoenula* and is the closest to *R. violeipes* on the parsimonious phylogenetic tree (Fig. 79).

Plate 17: a. *Russula amoenicolor* var. *amoenicolor* b. *R. amoenicolor* var. *ramgarhensis* c & d. *Russula* sp. 1.

Subgenus **Compactae** (Fr.) Bon
Doc. Myc., **65**: 53, 1986; Epicr. 349, 1838.

Pileus convex, planoconvex to infundibuliform; pileipellis dry to viscid, margin smooth; lamellae adnate to subdecurrent, lamellulae abundant; context hard chalky, changing or unchanging after bruising; basidiospore ornamentations composed of mostly warts and ridges forming very much incomplete to almost complete reticulum; cystidia narrow; pileipellis with or without cystidia. Thirteen taxa in India; eight in Kumaon Himalaya.

KEY TO THE SPECIES

1a. Context browning or blackening, on exposure 2

b. Context unchanging on exposure 6

2a. Context changing brownish orange to soft brown but never blackening ..... **R. compacta**

b. Context always changing to black finally 3

3a. Context quickly changing to black without showing intermediate reddening ..... **R. albonigra**

b. Context showing intermediate reddening before turning to black 4

4a. Pileus mostly areolate at maturity; lamellae distinctly thick ..... **R. nigricans**

b. Pileus never areolate, lamellae thin 5

5a. Lamellae distant; basidiospores apparently smooth, ornamentation not higher than 0.2 µm ..... **R. adusta**

b. Lamellae rather crowded; basidiospores ornamentation up to 0.7 µm high ..... **R. densifolia**

6a. Lamellae distant; basidiospores ornamentation up to 1 µm high ..... **R. delica**

b. Lamellae close to crowded; basidiospores ornamentation up to 1.8 µm high 7

7a. Taste mild; lamellae margin and stipe apex not bluish green ..... **R. brevipes**

b. Taste acrid; lamellae margin and stipe apex both bluish green ..... **R. brevipes** var. **acrior**

Russula adusta (Pers.: Fr.) Fr.

Stirpium Agri. Femsionensis Index: 57, 1825. *Agaricus adustus* Pers., Synopsis: 459, 1801; Rawla, Pl. Div. Him. (2001) 4; Atri & Saini, J. Ind. Bot. Soc. **69**(1990) 344; Das & Sharma, Phytotax. **4**(2004)2.
Pl. 18; fig. 43

Pileus 80-115 mm diam., convex to planoconvex with depressed center, slightly infundibuliform at maturity; pileipellis viscid brownish pink to light grayish brown to somewhat gray; margin irregular, often splitting, nonstriate. Lamellae subdecurrent, rather distant (3-4 per cm) at maturity, thin, edges smooth, white to cream, reddish brown after bruising; lamellulae present. Stipe 54-80 x 27-37 mm, central, cylindric to subclavate, whitish, reddish brown to gray at maturity, $FeSO_4$ (+); context solid, white, pinkish red, slowly reddish brown to black after bruising. Taste mild. Odor of sour wine. Spore print white.

Basidiospores 7-9.5 x 6-7 µm, subglobose to broadly ellipsoid, ornamentation amyloid, composed of minute warts (less than 0.3 µm high) and ridges forming incomplete reticulum. Basidia 40-60 x 6-9 µm, clavate, 4-spored; sterigmata up to 7.5 µm high. Pleurocystidia 65-100 x 6-8 µm, mostly fusiform to clavate, abundant; content dense. Cheilocystidia 35-50 x 4-8 µm, same as pleurocystidia. Pileipellis composed of repent to suberect septate, branched hyphae (up to 6 µm broad), pileocystidia narrow, up to 5 µm.

Ecology : Common, grows in ectomycorrhizal association with species of *Cedrus* in coniferous temperate forests.

Specimens examined : Uttaranchal, Champawat, Lohaghat, July 2002, **col.** K. Das, KD2119; Uttaranchal, Champawat, Mayawati, October 2002, **col.** K. Das & J.R. Sharma, KD4593; Uttaranchal, Almora, Jageshwar, August 2001, **col.** K. Das, KD909.

Notes : Russula nigricans differs from the present species in having characteristic thick lamellae and typically areolate pileipellis at maturity.

Russula albonigra (Krombh.) Fr.

Monogr. Hymen. Suec. **2**: 324, 1863. *Agaricus alboniger* Krombh., Naturg. Abbitd. Schw. IX: 27, 1845; Rawla, Pl. Div. Him. (2001) 5; Atri & Saini, J. Ind. Bot. Soc. **69**(1990) 345; Roy & Samaj. Ind. J. Mycol. Res. **18**(1980); Das & Sharma, Phytotax. **4**(2004)2. Fig. 44

Pileus 40-85 mm diam., convex to planoconvex with depressed center, infundibuliform at maturity; pileipellis viscid when wet, white with gray yellowish brown, gradually dark gray to black after bruising or maturity;

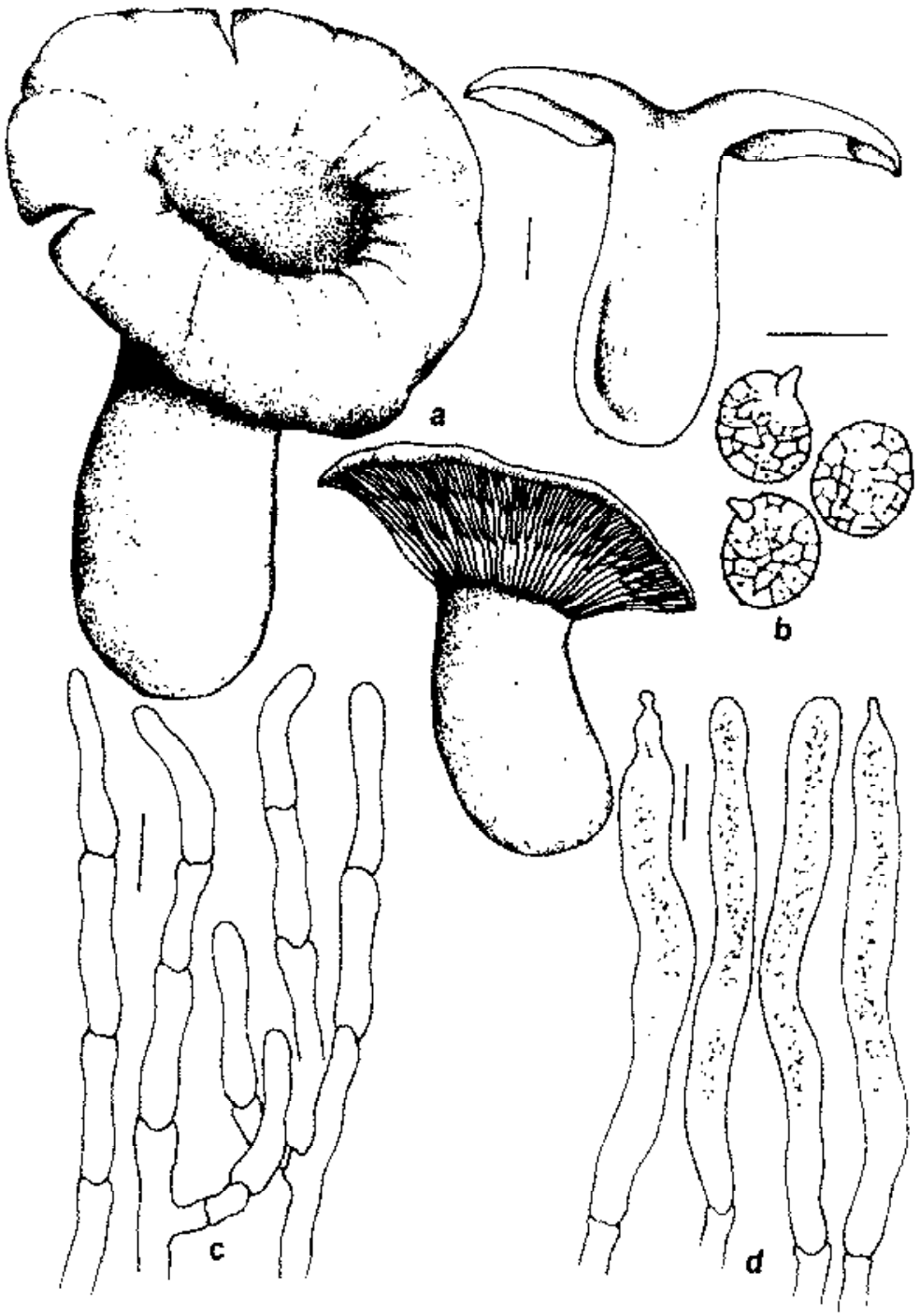


Fig. 43. *Russula adusta*: a. Basidiomes b. Basidiospores c. Cross section of pileipellis d. Pleurocystidia. Bars: a = 10 mm; b-d = 10 µm.

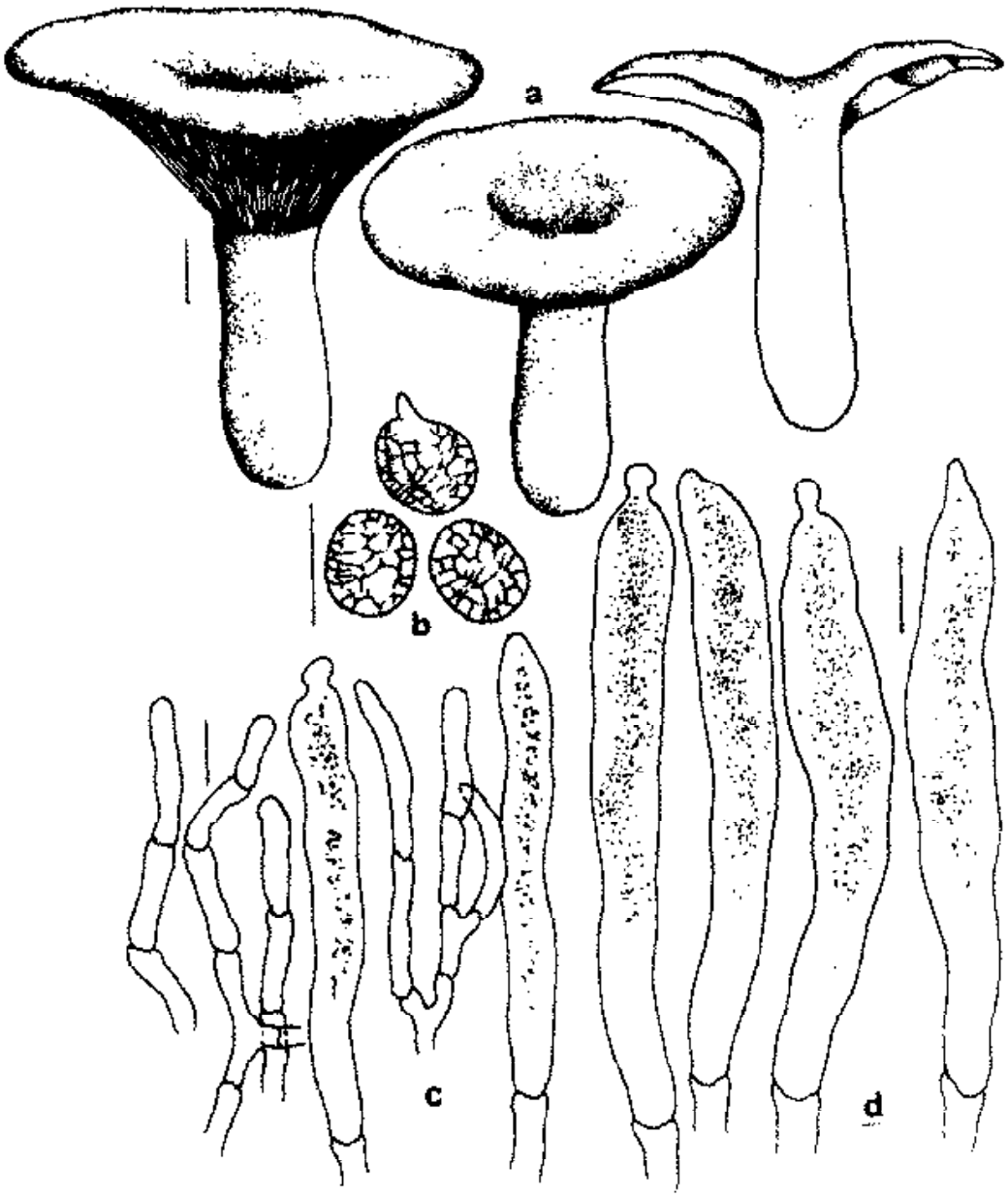


Fig. 44. *Russula albonigra*: a. Basidiomes b. Basidiospores c. Cross section of pileipellis d. Pleurocystidia. Bars: a = 10 mm; b-d = 10 µm.

margin inrolled to incurved, nonstriate. Lamellae broadly adnate to subdecurrent, crowded, forked near the stipe, thin, white, blackening directly after bruising; lamellulae numerous. Stipe 30-53 x 18-25 mm, central, cylindric to subclavate, white, quickly blackening after bruising, $FeSO_4$ (+); context white, quickly changing directly to black without any intermittent reddening. Spore print white. Taste slowly mild.

Basidiospores 7.2-9.4 x 5.8-7.4 µm, subglobose to broadly ellipsoid or rarely ellipsoid [Q = 1.09-1.30 (1.36)]; ornamentation amyloid, up to 0.3 µm high, composed of warts and ridges forming almost broken reticulum. Basidia 30-60 x 7-10 µm, clavate, 2 to 4-spored. Pleurocystidia 45-80 x 7-10 µm, ventricose to clavate with capitate, mucronate, appendiculate or moniliform apex; wall up to 1.4 µm, mostly cylindrical with rounded apex. Cheilocystidia 35-55 x 5-7 µm, ventricose to clavate with tapered apex. Subhymenium thick, up to 40 µm, cellular. Hymenophoral trama composed of sphaerocytes and hyphae. Pileipellis an ixocutis, up to 100 µm thick, composed of parallel hyphae (3-4.5 µm broad); pileocystidia up to 8 µm broad, subfusoid to capitate.

Ecology : Common, grows in ectomycorrhizal association with species of *Rhododendron*, *Quercus*, *Pinus* in moist coniferous to mixed subtropical to temperate forests.

Specimens examined : Uttaranchal, Pithoragarh, Maitly, September 2001, **col.** K. Das & J.R. Sharma, KD4039; Uttaranchal, Bageshwar, Dhakuri, September 2003, **col.** K. Das & J.R. Sharma, KD7010; ibid., September 1999, **col.** K. Das & J. R. Sharma, KD1073.

Notes : Russula albonigra can be confused with *R. densifolia* in the field but direct blackening of basidiomes make the present species distinct from *R. densifolia*.

Russula brevipes Peck

Rep. N.Y. St. Mus. **43**: 20, 1890; Atri *et al.*, Bot. Res. Ind. (1991); Watling & Gregory, N. Hedwigia **32**(1980) 538; Das & Sharma, Phytotax. **4**(2004)2. Pl. 19; fig. 45

Pileus 50-150 mm diam., planoconvex, with shallow central depression, becoming umbilicate; pileipellis dry, mat to rugulose; white, yellow white to buff, brownish somewhat at maturity towards center; margin incurved, nonstriate. Lamellae decurrent, crowded, forked from the base, intervenose, yellowish white to cream; lamellulae abundant of varying lengths. Stipe 25-55 x 18-30 mm, central, cylindric, white, sometimes brownish at maturity, $FeSO_4$ (+); context solid, white. Taste mild. Spore print white.

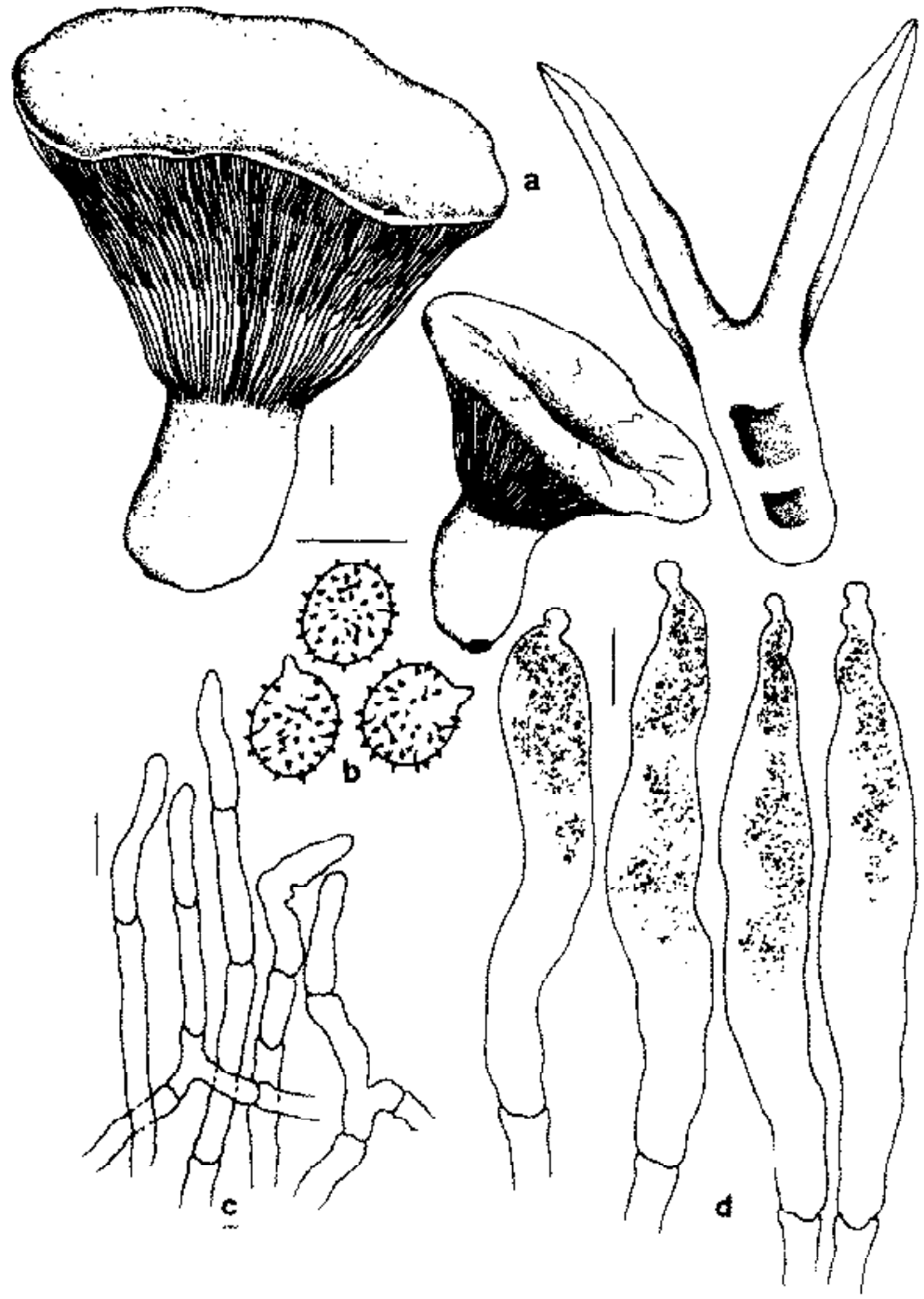


Fig. 45. *Russula brevipes* var. *brevipes*: a. Basidiomes b. Basidiospores c. Cross section of pileipellis d. Pleurocystidia. Bars: a = 10 mm; b-d = 10 µm.

Basidiospores 7.8-10.5 x 7-8.5 µm, subglobose to broadly ellipsoid [Q = 1.11-1.31], ornamentation partially amyloid, composed of conic to acute tipped warts (up to 1.8 µm high) and ridges forming incomplete reticulum. Basidia 50-65 x 8-13 µm, clavate, 4-spored. Pleurocystidia 50-90 x 7-12.5 µm, emergent up to 20 µm, clavate to fusiform with capitate to submoniliform apex. Cheilocystidia 30-65 x 6-11 µm, same as pleuropseudocystidia. Subhymenium layer up to 35 µm thick, cellular. Pileipellis composed of repent septate branched hyphae (up to 6 µm broad), pileocystidia absent.

Ecology : Common, grows in ectomycorrhizal association with species of *Cedrus* in coniferous to mixed temperate forests.

Specimens examined : Uttaranchal, Almora, Jageshwar, Aug. 2001, **col.** K. Das, KD903; Uttaranchal, Champawat, Mayawati, September 2002, **col.** K. Das & J.R. Sharma, KD4592; KD4596.

Notes : Earlier, Manjula (1983) excluded *Russula brevipes* from the valid list of Indian species of *Russula* during her studies on the revision of Indian *Russula* at Kew. However, the morphological and microscopic characters of the above specimens, repeatedly collected from the Kumaon Himalaya during our extensive and intensive surveys have confirmed that the specimens under study are *R. brevipes*. Our view was further strengthened by the study on our material by some foreign workers. The mild taste and absence of characteristic bluish tinge in lamellae margin and in the stipe apex separates var. *brevipes* from var. *acrior*.

Russula brevipes Peck

Rep. N.Y. St. Mus. **43**: 20, 1890. var. **acrior** Shaffer, Mycologia **56**: 223, 1964. Pl. 19; fig. 46

Pileus 65-190 mm diam., convex to planoconvex with depressed center, typically infundibuliform at maturity; pileipellis dry sometimes minutely felted, yellow white to buff, pale yellow pink to brownish at maturity; margin nonstriate. Lamellae broadly adnate to decurrent, close to crowded, forked at the stipe, yellowish white to pale yellow, edge smooth, bluish green; lamellulae abundant. Stipe 25-60 x 20-40 mm, central, cylindric or slightly broder at base, white to yellow white, bluish green rim at the apex, $FeSO_4$ (+); context solid. Taste acrid. Odor not distinctive. Spore print white.

Basidiospores 8.0-11.2 x 7.5-8.4 µm, subglobose to broadly ellipsoid, rarely globose [Q = (1.01) 1.06-1.3]; ornamentation amyloid, up to 1.7 µm high, composed of conic, cylindric or acute tipped warts and ridges arranged in incomplete reticulum. Basidia 48-64 x 10-13 µm, subclavate to clavate, 4-spored; sterigmata up to 7 µm. Pleurocystidia 60-90 x 7-10 µm, fusiform

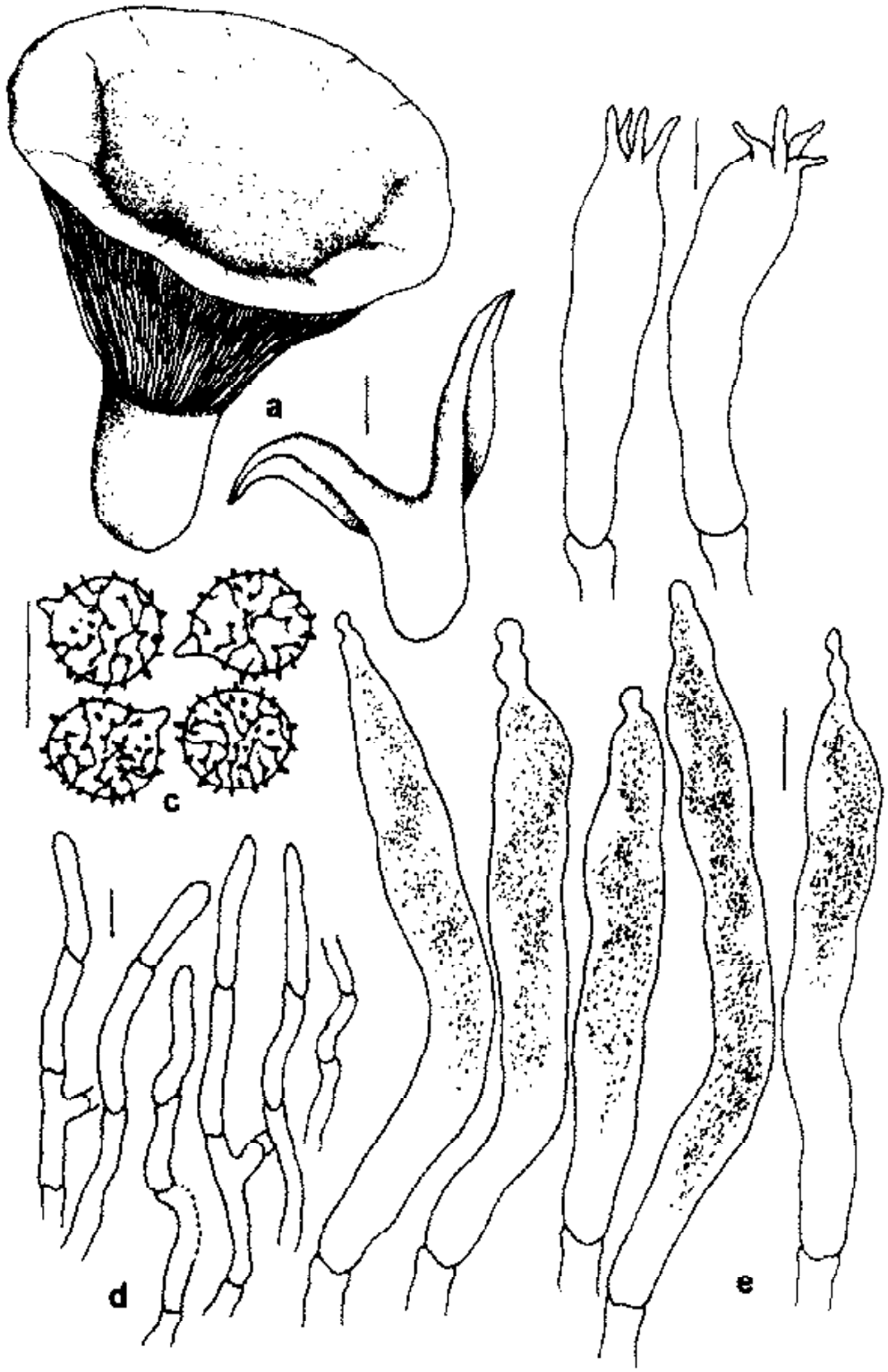


Fig. 46. *Russula brevipes* var. *acrior*: a. Basidiomes b. Basidia c. Basidiospores d. Cross section of pileipellis e. Pleurocystidia. Bars: a=10 mm; b-e=10 µm.

to subfusiform with capitate, mucronate to moniliform apex; content dense. Cheilocystidia same as pleurocystidia. Subhymenial layer thick up to 45 µm thick, cellular. Pileipellis composed of repent septate branched interwoven hyphae (up to 5.5 µm broad), pileocystidia absent.

Ecology : Common, grows in ectomycorrhizal association with species of *Cedrus* in coniferous to mixed temperate forests.

Specimens examined : Uttaranchal, Pithoragarh, Sandev, September 2001, **col.** K. Das & J. R. Sharma, KD4011; Uttaranchal, Champawat, Lohaghat, September 2002, **col.** K. Das & J.R. Sharma, KD4504, KD4506, KD4516; Uttaranchal, Champawat, Mayawati, September 2002, **col.** K. Das & J.R. Sharma, KD4548, KD4553.

Notes : For difference between *Russula brevipes* var. *acrior* and *R. brevipes* var. *brevipes* see notes under the latter.

Russula compacta Frost & Peck

Ann. Report N. Y. State Mus. **32**: 32. 1880; Das & Sharma, J. Mycol. Pl. Pathol. **34**(2004) 149; Das & Sharma, Phytotax. **4**(2004)2.

Pl. 18; fig. 47

Basidiocarps scattered to gregarious. Pileus 50-140 mm diam., convex, applanate to vase-shaped at maturity; cuticle dry, viscid when wet, smooth to somewhat cracked, deep brownish orange to soft reddish brown; margin decurved at first, plane gradually; context brittle, white. Lamellae close (9-12 per cm), forked, white, quickly brownish orange to soft brown on bruising. Stipe 30-80 x 13-23 mm, white, bruising soft brown (being concolorous with pileus), grayish olive green with $FeSO_4$. Taste indistinct. Odour strong, unpleasant. Spore print white.

Basidiospores subglobose to broadly ellipsoid, 7.2-9.8 x 6-8.3 µm, amyloid, ornamentation of warts (up to 0.5 µm) forming partial to complete reticulation; suprahilar spot absent. Basidia 31-40 x 5-7 µm, subclavate to clavate, 4-spored. Pleurocystidia 49-72 x 5.4-8 µm, abundant, deeply embedded, projecting up to 7 µm above hymenial layer, narrowly clavate to cylindrical with mucronate to moniliform or acute apices, sometimes with dense cytoplasmic contents. Cheilocystidia 46-60 x 5-7 µm, same as pleurocystidia. Subhymenium layer up to 14 µm broad, cellular. Hymenial trama convergent. Pileipellis an ixotrichoderm to ixocutis; pilear hyphae 4-6 µm broad, thick-walled; wall 1-1.16 µm thick. Sphaerocysts frequently present in the pilear trama.

Ecology : Common, grows in ectomycorrhizic associations with *Quercus leucotrichophora* A. Camus in the temperate deciduous forests.

Specimens examined : Uttaranchal, Pithoragarh, Sandev, September 2001, **col.** K. Das & J.R. Sharma, KD4003; Pithrogarh, Dafia Dhura, September 2001, **col.** K. Das & J.R. Sharma, KD4083; Champawat, Abbot Mount, September

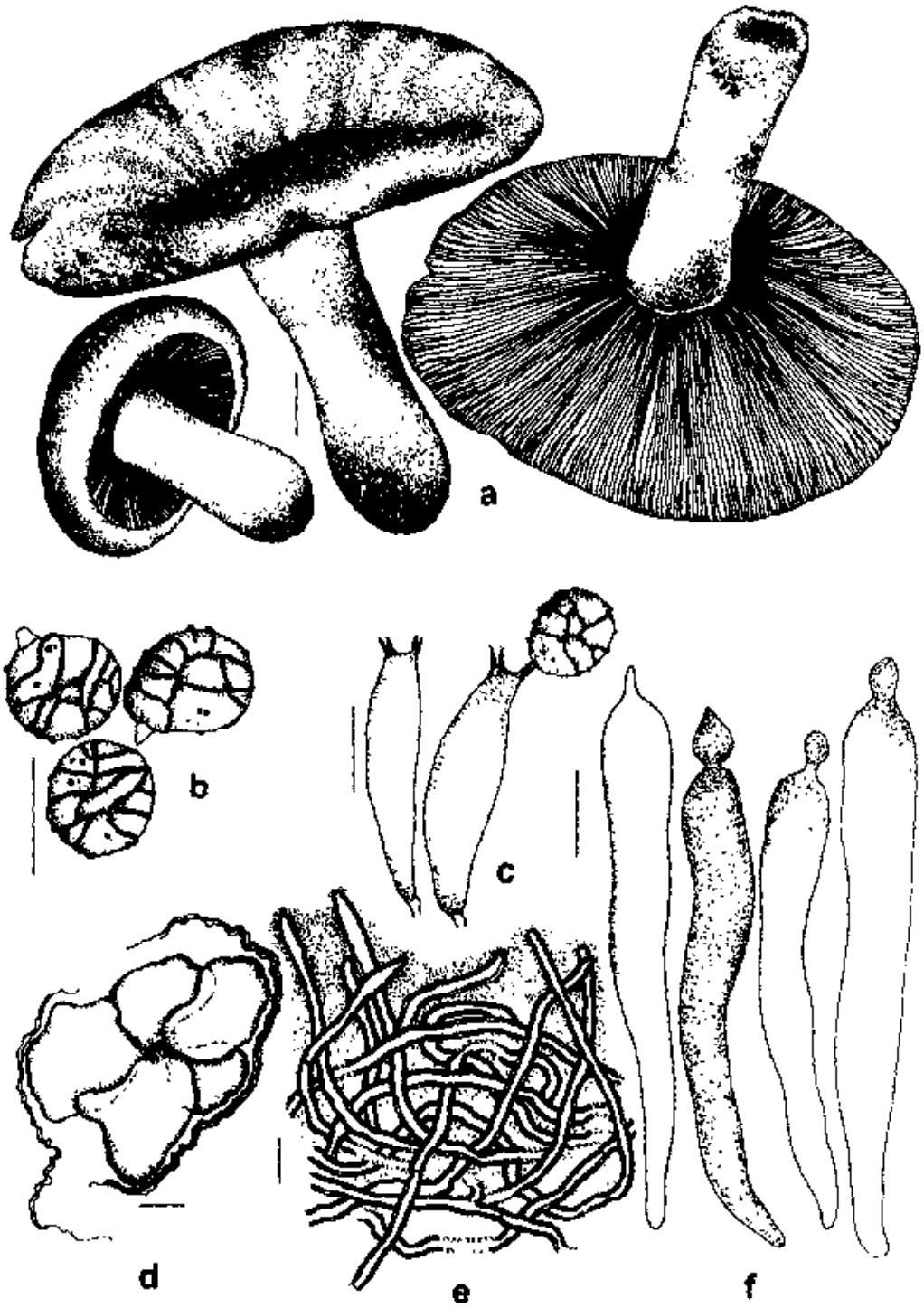


Fig. 47. *Russula compacta*: a. Basidiomes b. Basidiospores c. Basidia d. Sphaerocytes e. Cross section of pileipellis f. Pleurocystidia. Bars: a = 10 mm; b-f = 10 µm.

2002, **col.** K. Das & J.R. Sharma, KD4538.

Notes : Russula compacta is easily distinguished in the field by brownish orange pileus, white lamellae and stipe which turns brownish orange to brown after bruising. Microscopically, thick-walled hyphae in pileipellis and deeply embedded pleurocystidia are characteristic. Moreover, reticulated spores with no suprahilar spot (Singer, 1986) is also a distinguishing character. Morphologically, *R. compacta* appears closely related to *Russula nigricans*, but the characteristic blackening of the basidiomes after bruising, distant lamellae and absence of thick-walled pilear hyphae in the latter separate it from the former.

Russula delica Fr.

Epcr. Syst. Mycol. 350, 1838; Atri & Saini, Geob. N. Rep. **5**(1986) 103; Saini & Atri, Geob. N. Rep. **3**(1984) 5; Kumar *et al.*, Ind. J. Mush. **5**(1979) 22; Atri *et al.*, Bot. Res. Ind. (1991) 94; Abraham *et al.*, Kavaka **8**(1980); Bakshi, FRI **78** (1974); Das & Sharma, Phytotax. **4**(2004)2. Pl. 23; fig. 48

Pileus 60-120 mm diam., convex to planoconvex with depressed center; pileipellis dry, cracked to areolate at maturity, yellowish white, yellowish pink to brownish at maturity; margin inrolled to incurved. Lamellae adnate, distant (*ca* 3 per cm), thick, yellowish white, brownish at maturity, forked, intervenose; lamellulae present. Stipe 20-45 x 15-2.4 mm, central, cylindrical, white to yellowish white, $FeSO_4$ (+); context solid, unchanging. Taste slightly acrid. Spore print white.

Spores 8.0-10.5 x 7.0-8.0 µm (Q = 1.11-1.34), subglobose to ellipsoid, ornamentation partially inamyloid, up to 1 µm high, composed of conic or cylindric warts and ridges forming partially complete reticulation. Basidia 50-60 x 9-11 µm, clavate, 4-spored. Pleurocystidia 60-110 x 7.5-12 µm, fusiform with capitate to somewhat moniliform apex; contents dense. Cheilocystidia 55-75 x 7.5-8.5 µm, same as pleurocystidia. Subhymenium up to 30 µm thick, cellular. Pileipellis composed of septate, branched hyphae, hyphae (up to 6 µm broad); pileocystidia narrow up to 4.5 µm, cylindric with rounded to capitate apices.

Ecology : Common, grows in ectomycorrhizal association with species of *Pinus* and *Shorea* in moist coniferous to deciduous subtropical to temperate forests.

Specimens examined : Uttaranchal, Almora, on the way to Binsar, August 2001, **col.** K. Das, KD928; Uttaranchal, Pithoragarh, near Askot, September 2001, **col.** K. Das & J.R. Sharma, KD4029; Uttaranchal, Champawat, near Tanakpur, August 2002, **col.** K. Das, KD2101; Uttaranchal, Nainital, Nainipeak, September 1982, **col.** Atri & Saini, PUN585.

Notes : The comperatively closer lamellae and higher spore ornamentations separate *Russula delica* from the closely related *R. brevipes*.

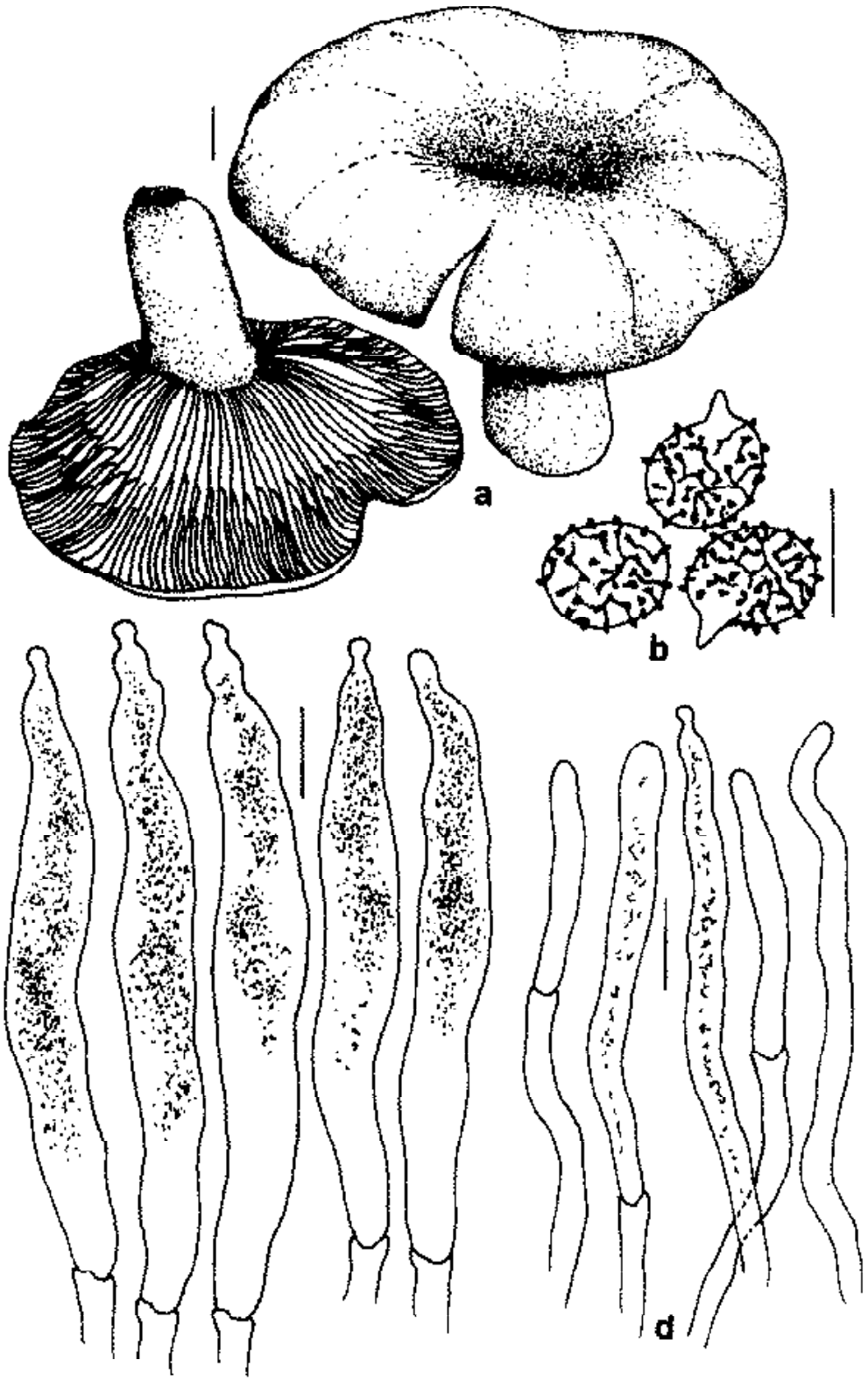


Fig. 48. *Russula delica*: a. Basidiomes b. Basidiospores c. Pleurocystidia d. Cross section of pileipellis. Bars: a = 10 mm; b-d = 10 µm.

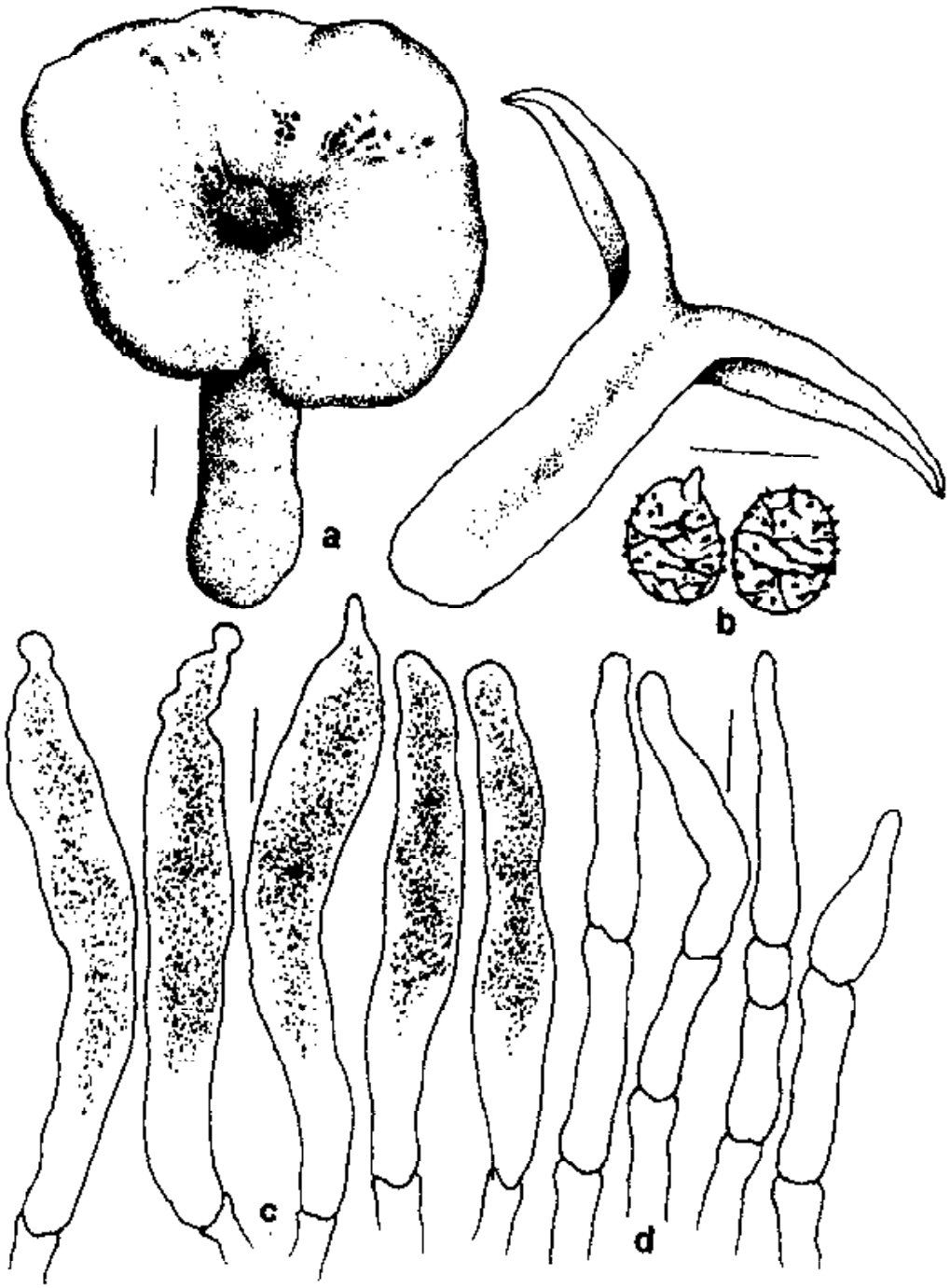


Fig. 49. *Russula densifolia*: a. Basidiomes b. Basidiospores c. Pleurocystidia d. Cross section of pileipellis. Bars: a = 10 mm; b-d = 10 µm.

Russula densifolia Secr.: Gill.

Hymen. Eur. **1**: 231, 1874. Champignons de France : 231, tav. : 173, 1874. *Agaricus adustus densifolius* Secr., Micogr. Suisse **1**: 476, nom inval., 1833; Rawla, Pl. Div. Him. (2001) 11; Watling & Gregory, N. Hedwigia **32** (1980) 540; Abraham, Kavaka **9**(1981); Atri & Saini, J. Ind. Bot. Soc. **69**(1990) 343; Geob. N. Rep. **5**(1986) 102; Kaul & Kachroo, J. Bomb. Nat. Hist. **68**(1971) 498. Pl. 18; fig. 49

Pileus 55-80 mm diam., convex to planoconvex with depressed center, infundibuliform at maturity; pileipellis viscid when moist, cream, incurved nonstriate. brownish pink, medium yellowish brown or light gray yellowish brown,; margin incurved nonstriate. Lamellae adnate, rather crowded (up to 10 per cm), forked, yellowish white, pinkish, then black at maturity; lamellulae abundant. Stipe 35-65 x 16-21 mm, central, cylindric, white, soft reddish orange to reddish black at maturity, $FeSO_4$ (+); context solid, white, yellowish pink to finally black on bruising. Taste hot. Odor not distinctive. Spore print white.

Basidiospores 7-9 x 6.4-7.5 µm, subglobose to broadly ellipsoid.; ornamentation amyloid, up to 0.7 µm high, composed of conic warts and ridges arranged in incomplete reticulum. Basidia 30-44 x 7.5-10 µm, clavate, 4-spored; sterigmata up to 5 µm high. Pleurocystidia 45-65 x 5-6.5 µm, clavate to cylindric with capitate, mucronate to acute apices. Cheilocystidia 40-50 x 3.5-6 µm, same as pleurocystidia. Subhymenial layer thick up to 30 µm thick, cellular. Pileipellis an ixocutis, composed of repent septate hyphae (up to 9 µm broad), pileocystidia not found. Stipitipellis composed of multiseptate hyphae (up to 5.5 µm broad).

Ecology : Common, grows in ectomycorrhizal association with species of *Cedrus* and *Quercus* in deciduous to mixed temperate forests.

Specimens examined : Uttaranchal, Almora, Mornoula, October 2002, **col.** K. Das & J.R. Sharma, KD4569; Uttaranchal, Champawat, Mayawati, September 2002, **col.** K. Das & J.R. Sharma, KD4560; Uttaranchal, Nainital, Nainipeak, September 1982, **col.** Atri & Saini, PUN588.

Notes : Present species resembles *Russula albonigra* and *R. adusta* in the field. However, *R. albonigra* does not show intermediate pinkish coloration before turning to black atlast, while *R. adusta* has very minute spore ornamentation (less than 0.3 µm).

Russula nigricans Fr.

Epicr. Syst. Myc.: 350, 1838; Rawla, Pl. Div. Him. (2001)19; Saini & Atri, Geob. N. Rep. **3**(1984) 5; Saini *et al*, Ind. Phytopath. **41**(1988) 622; Das & Sharma, Phytotax. **4**(2004)3. Pl. 18; fig. 50

Pileus 40-110 mm diam., convex to planoconvex with broadly depressed center; pileipellis dry, often cracked and gradually areolate at maturity,

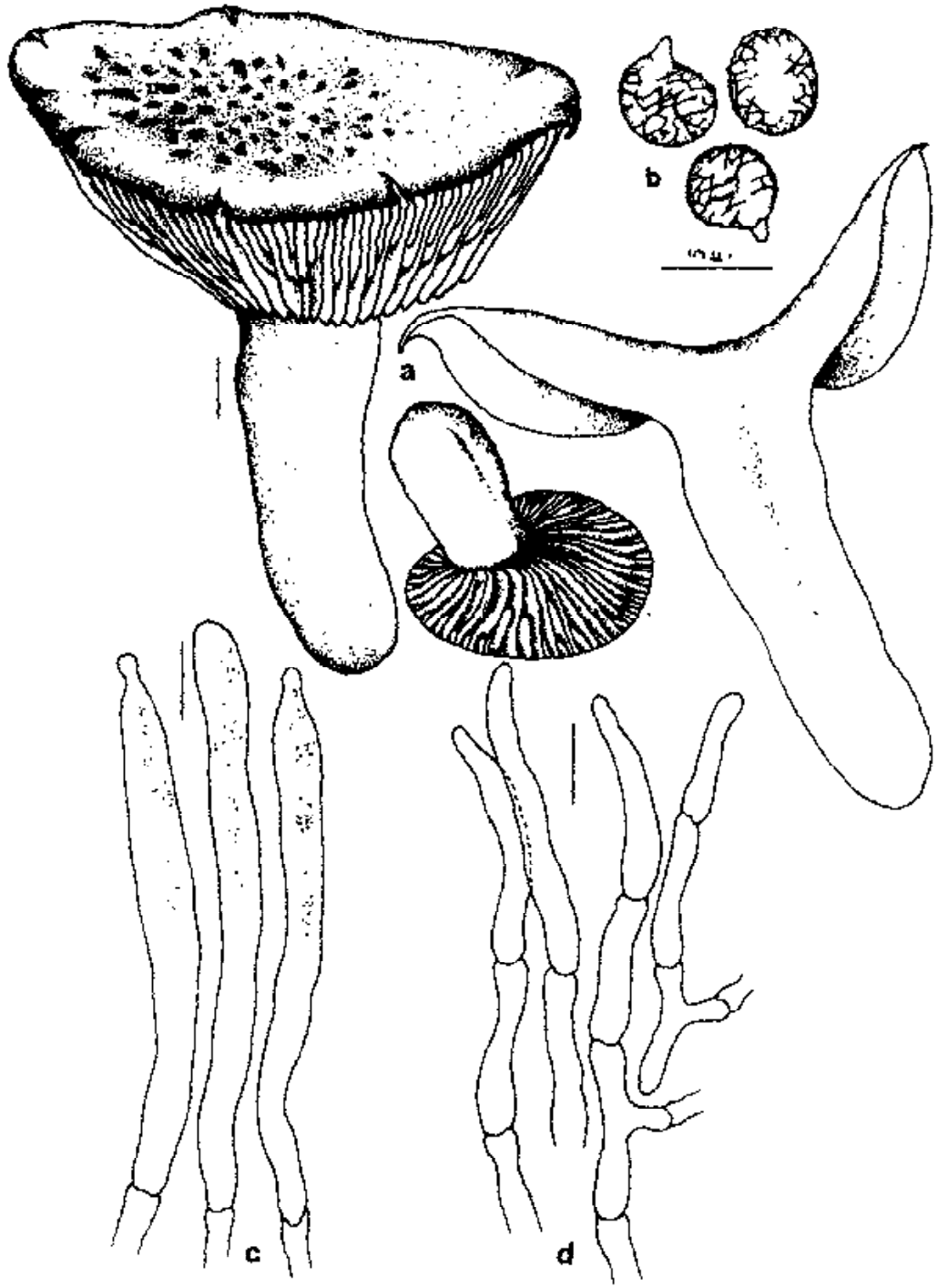


Fig. 50. *Russula nigricans*: a. Basidiomes b. Basidiospores c. Pleurocystidia d. Cross section of pileipellis. Bars: a = 10 mm; b-d = 10 µm.

pale brown, brownish black to black at maturity; margin incurved, nonstriate. Lamellae broadly adnate, distant (*ca* 2-3 per cm), very thick, yellowish white, reddish brown to black after bruising, lamellulae present. Stipe 40-65 x 18-33 mm, central, cylindric to clavate, white, very dark red, brownish black to black after bruising, $FeSO_4$ (+); context white, quickly dark red to finally black after bruising. Taste mild. Odor fruity. Spore print white.

Basidiospores 6.4-8.5 x 5.5-7.3 µm, subglobose to broadly ellipsoid [Q = 1.1-1.30]; ornamentation amyloid, less than 0.5 µm high, composed of warts and fine lines forming incomplete reticulum. Basidia 40-61 x 6.8-9 µm, subclavate to clavate, 4-spored. Pleurocystidia 50-110 x 5-7 µm, cylindric, fusoid or subclavate with capitate, mucronate or rounded apices. Cheilocystidia 37-55 x 5-9 µm, same as pleurocystidia. Pileipellis an ixocutis, up to 200 µm thick, composed of parallel branched septate hyphae (3-5 µm broad); pileocystidia absent.

Ecology : Abundant, grows in ectomycorrhizal association with species of *Quercus* and *Cedrus* in coniferous, deciduous, mixed or coniferous temperate forests.

Specimens examined : Uttaranchal, Champawat, Hingla Devi forest, August 2002, **col.** K. Das, KD2103; Uttaranchal, Almora, Dandeshwar, August 2001, **col.** K. Das, KD904; Uttaranchal, Nainital, Mukteshwar, August 2002, **col.** K. Das, KD2138.

Notes : Russula nigricans is a common species in Kumaon Himalaya. The cracked to areolate pileus surface and unusual thickness of lamellae separate *R. nigricans* from *R. adusta* in the field. It is very interesting to record the frequent parasitic association of *Asterophora parasitica* on the old fruiting bodies of the present taxon in the field.

Plate 18: a. *Asterophora parasitica* growing on basidiomes of *Russula nigricans* b. *R. densifolia* c. *R. compacta* d. *R. adusta* e. *R. nigricans*.

Plate 19: a. *Russula brevipes* var. *brevipes* b. *R. delica* c. *R. brevipes* var. *acrior*.

Subgenus **Heterophyllidia** Romagnesi
Doc., Myc., 69: 39, 1987. emend. Sarnari, Monografia illustrata del Genere *Russula* in Europa; 103, 1998.

Pileus convex to planoconvex often with depressed center; pileipellis mostly dry sometimes viscid, margin smooth to striate; lamellae broadly adnate to subdecurrent, lamellulae present; context hard chalky, unchanging after bruising; basidiospore ornamentations composed mostly of isolated warts, sometimes connected to form complete reticulum; pileipellis composed of cylindric to inflated cells; pileocystidia often present. Twenty taxa in India; six in Kumaon Himalaya.

KEY TO THE SPECIES

1a. Subterminal cells consisting of sphaerocytes ..... **R. virescens**

b. Subterminal cells not consisting of sphaerocytes 2

2a. Pileocystidia not distinctly characterized 3

b. Pileocystidia distinctly characterised 4

3a. Pileipellis cracked to areolate near the margin ..... **Russula** sp. 2

b. Pileipellis never cracked or areolate ..... **R. heterophylla**

4a. Pileipellis veined, spore print white, $FeSO_4$ (-) .....
..... **R. cyanoxantha**

b. Pileipellis not veined, spore print cream, $FeSO_4$ (+) 5

5a. Pileipellis cracked to areolate towards margin ..... **R. anatina**

b. Pileipellis never cracked ..... **R. grisea**

Russula anatina Romagnesi

Russules d'Europe et d'Afrique du Nord; 306. 1967; Das & Sharma, Ind. J. For. **26**(2003) 323. Pl. 21; fig. 51

Pileus 40-75 mm diam., convex with slightly depressed center, planoconvex to slightly infundibuliform at maturity; pileipellis viscid when moist, velvety, grayish yellow green to olive green or grayish green with dark grayish olive green center; margin plane at maturity, slightly sulcate, broken into crustose patches, peeling up to 1/4th of the radius. Lamellae adnexed, close (8-10 per cm), forked near the stipe, lamellulae absent, yellowish white. Stipe 50-60 x 14-19 mm, cylindric to subclavate, yellowish white, $FeSO_4$ (+). Context yellowish white, stuffed. Taste mild. Spore print cream.

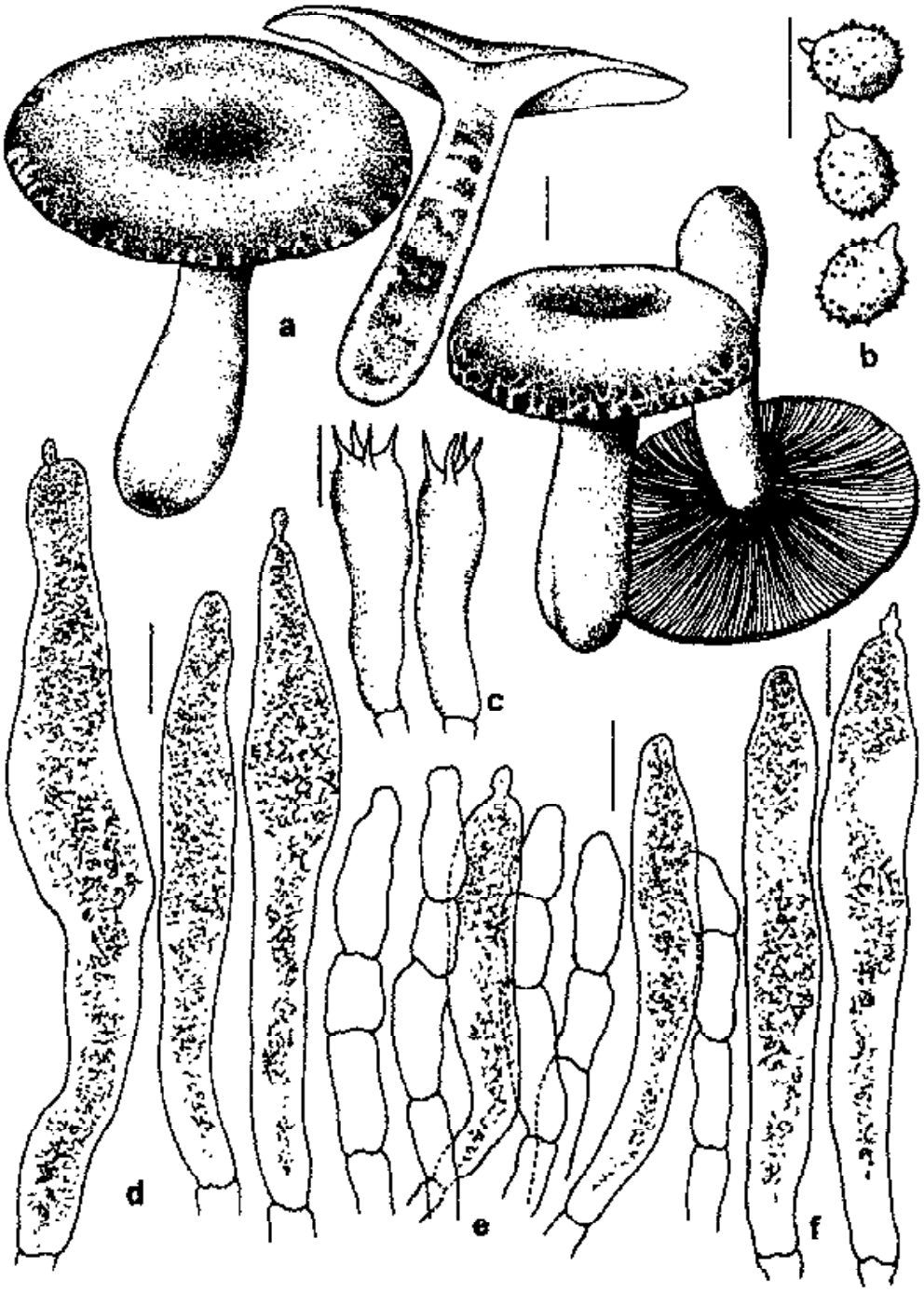


Fig. 51. *Russula anatina*: a. Basidiomes b. Basidiospores c. Basidia d. Pleurocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

Spores 6-7.5 x 5.5-6.5 µm (Q = 1.05-1.2, av. 1.13-1.16), subglobose to broadly ellipsoid; ornamentation amyloid, up to 0.7 µm high of conic isolated warts. Basidia 35-46 x 7-9 µm, clavate to subclavate, 4-spored; sterigmata up to 6 µm long. Pleurocystidia 65-100 x 8-15 µm, abundant, subclavate, broadly fusiform to fusiform with rounded to mucronate apex, emergent up to 34 µm; contents refractive. Lamellae edge fertile with basidia, cystidia and sterile cells. Cheilocystidia 55-70 x 8-10 µm, subfusiform to fusiform with rounded to mucronate apices; contents refractive. Subhymenium layer up to 15 µm thick, cellular. Pileipellis composed of ascending to erect hyphae and dermatocystidia; hyphae made up of 3-5 rows of mostly cylindric cells (up to 7.5 µm broad), apical cells subcylindric to inflated; Pileocystidia clavate to fusiform, up to 9 µm broad, contents refractive. Stipipellis made up of connective hyphae, up to 4.5 µm broad and mostly fusiform caulocystidia with dense contents.

Ecology : Common, grows in ectomycorrhizal association with species of *Quercus* in temperate deciduous to mixed forests.

Specimens examined : Uttaranchal, Pithoragarh, Dafia Dhura forest, October 4, 2001, **col.** K. Das & J.R. Sharma, KD4082, KD4087, KD4099; Uttaranchal, Bageshwar, Dhakuri, October 5, 1999, **col.** K. Das & J.R. Sharma, KD1071.

Notes : Russula anatina is close to *R. aeruginea* Lindbl. : Fr. but the latter has distinctly larger spores (6-10 x 5-7 µm) and characteristic narrow cuticular hairs in pileipellis (Kibby & Fatto 1990, Romagnesi 1996). *Russula anatina* is also similar to *R. monspeliensis* var. *monspeliensis* Sarnari but differs in having scurfy and distinctly cracked pileus surface. *R. monspeliensis* var. *sejuncta* (Sarnari) Sarnari also resembles the present species in having scurfy and cracked pileus surface but the larger spores (7.2-10 x 5.8-7 µm) in the former separates them (Sarnari 1998).

Russula cyanoxantha (Schaeff.) Fr.

Monographia Hymenomycetum Sueciae II: 194, 1863. *Agaricus cyanoxantha* Schaeff., Fung. Bavaria Icones, IV: 40, 1774. ; Rawla, Pl. Div. Him. (2001) 10; Atri *et al.*, Bot. Res. Ind. (1991) 95; Saini *et al.*, J. Ind. Bot. Soc. (1993) 36; Saini & Atri, Geob. N. Rep. **3**(1984) 5; Atri & Saini, J. Ind. Bot. Soc. **69**(1990) 428; Atri & Saini, Geob. N. Rep. **5**(1980) 102; Das & Sharma, Phytotax. **4**(2004)2. Pl. 20; fig. 52

Pileus 65-150 mm diam., convex to planoconvex with depressed center; pileipellis viscid to slimy when moist, feebly veined, sometimes areolate, gray purple to dark gray purple, deep purple, gray violet, dark grayish green or greenish purple; margin often splitted at maturity. Lamellae subdecurrent or sometimes decurrent, close (6 per cm), entire, forked near the base, white;

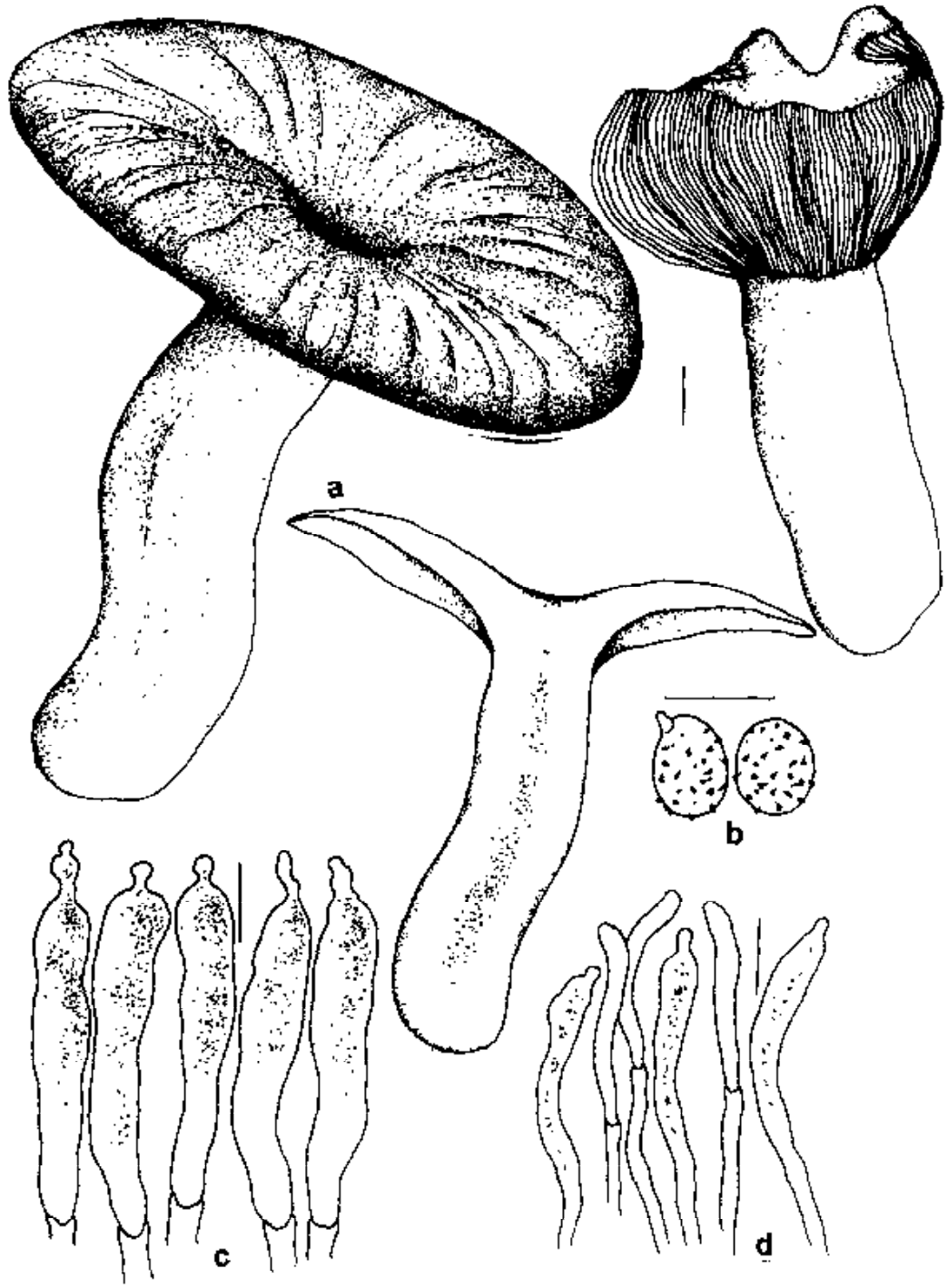


Fig. 52. *Russula cyanoxantha*: a. Basidiomes b. Basidiospores c. Pleurocystidia d. Cross section of pileipellis. Bars: a = 10 mm; b-d = 10 µm.

lamellulae present. Stipe 40-90 x 18-30 mm, central, cylindrical, white, veined, yellowish brown after bruising, $FeSO_4$ (-); context solid. Taste mild. Spore print white.

Basidiospores 7.0-9 x 6-7 µm (Q = 1.12-1.30), subglobose to ellipsoid, ornamentation amyloid, up to 0.5 µm high, composed of conic to blunt warts, sometimes joined by lines, never forming reticulum. Basidia 40-55 x 7-11 µm, clavate, 4-spored. Pleurocystidia 30-55 x 5-7.5 µm, fusiform to clavate with mucronate, capitate to somewhat moniliform apices; content dense. Cheilocystidia 30-45 x 4.5-7 µm, fusoid to ventricose with acute, appendiculate apices. Subhymenial layer up to 30 µm thick, cellular. Hymenophoral trama mostly composed of sphaerocytes. Pileipellis an ixocutis composed of narrow hyphae, up to 3 µm broad and subclavate pileocystidia (up to 4 µm broad) with mucronate apex.

Ecology : Abundant, grows ectomycorrhizally with species of *Cedrus* and *Quercus* in coniferous deciduous or mixed subtropical to temperate forests.

Specimens examined : Uttaranchal, Champawat, Lohaghat, Sept. 2002, **col.** K. Das & J.R. Sharma, KD4502, KD4504, KD4522; Uttaranchal, Champawat, Mayawati, Oct. 2002, **col.** K. Das & J.R. Sharma, KD4552, KD4554; Uttaranchal, Pithoragarh, Dafia Dhura forest, Sept. 2001, **col.** K. Das & J.R. Sharma, KD4063; Uttaranchal, Bageshwar, Maitly, **col.** K. Das & J.R. Sharma, KD4034; Uttaranchal, Nainital, Ramgarh, August 2002, **col.** K. Das, KD2140.

Notes : Typically large and veined pileus, white spore print and very thin terminal hyphae of suprapellis make the present taxon distinct from all other species of this subgenus.

Russula grisea Pers.: Fr.

Epi. Syst. Mycol. 361, 1838; Rawla, Pl. Div. Him. (2001) 15 (= *ionochlola*); Atri *et al.*, Geob. N. Rep. **12**(1993) 138. Pl. 20; fig. 53

Pileus 40-65 mm diam., convex to planoconvex, sometimes depressed centrally at maturity; pileipellis dry, never cracked or areolate, light brilliant to medium green, often with medium to light greenish blue towards center; margin decurved to plane, nonstriate. Lamellae adnexed to subdecurrent, close (8-10 per cm), forked from the base, cream; lamellulae abundant. Stipe 45-60 x 10-15 mm, central, cylindric, yellowish white to cream. $FeSO_4$ (+); context solid, white, yellowish brown after bruising. Taste mild. Spore print cream.

Basidiospores 6-7.5 x 5.2-6 µm, subglobose to broadly ellipsoid [Q = 1.09-1.3], ornamentation up to 0.6 µm, amyloid, composed of conic to blunt

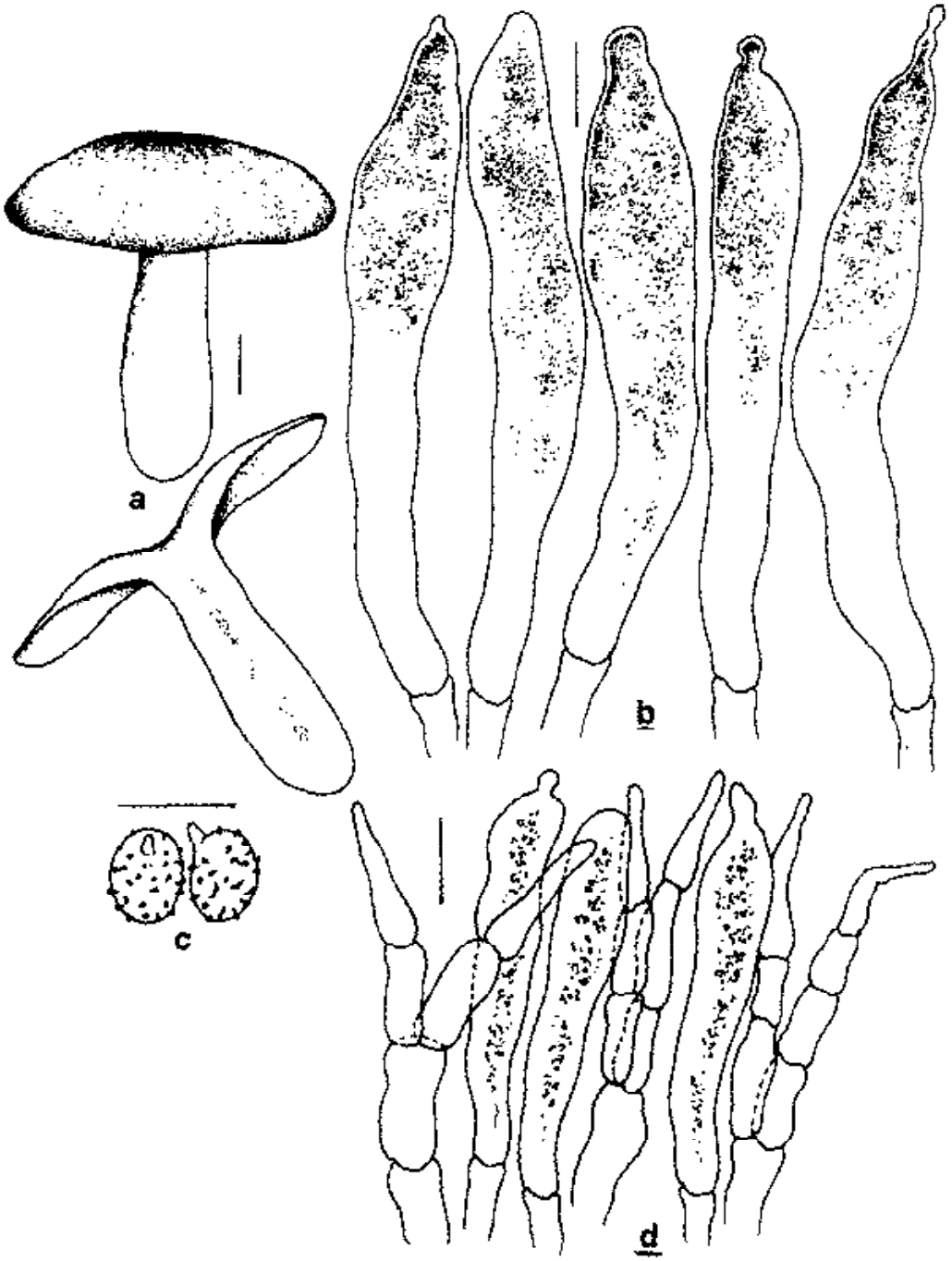


Fig. 53. *Russula grisea*: a. Basidiomes b. Pleurocystidia c. Basidiospores d. Cross section of pileipellis. Bars: a = 10 mm; b-d = 10 µm.

tipped isolated warts a few are connected, never forming reticulum. Basidia 36-45 x 6-9 µm, subclavate, 4-spored. Pleurocystidia 60-80 x 7.9-11.5 µm, emergent up to 38 µm, ventricose to fusoid with mucronate to capitate, thick walled, dense. Cheilocystidia 35-50 x 8-10 µm, subclavate to clavate. Subhymenium layer up to 17 µm thick, cellular. Pileipellis composed of erect repeatedly branched septate hyphae and cystidia; terminal cells of hyphae subulate with obtuse tips; pileocystidia 7-11 µm broad, clavate to subclavate with mucronate apex.

Ecology : Common, grows ectomycorrhizally with species of *Quercus* in deciduous temperate forests.

Specimens examined : Uttaranchal, Pithoragarh, Dafia Dhura forest, October 2001, **col.** K. Das & J.R. Sharma, KD4055; *ibid.*, KD4056, KD4044.

Notes : Russula grisea resembles *R. anatina* but the latter however, has the pileipellis which is areolate towards margin. Moreover the pileius of *R. grisea* have a blue-green tinge all over while in *R. heterophylla* sometimes the greenish colour is only towards the periphery of the pileus. This feature assists in their easy separation in the field.

Russula heterophylla (Fr.: Fr.) Fr.

Epi. Syst. Mycol. 352, 1838; *Agaricus furcatus* var. *heterophyllus* Fr., Syst. Mycol. 1: 59, 1821; Berk., Hook. J. Bot. 3(1851) 42 (=*R. furcata*); Roy & Samaj., Ind. J. Mycol. Res. 18 (1980); Rawla, Pl. Div. Him. (2001) 14; Saini & Atri, Geob. N. Rep. **3**(1984) 5; Atri & Saini, Geob. N. Rep. **5**(1986) 101; J. Ind. Bot. Soc. **69** (1990) 427; Das & Sharma, Phytotax. **4**(2004)3. Fig. 54

Pileus 40-63 mm diam., convex, then planoconvex with broadly depressed center at maturity; pileipellis viscid, smooth, medium to reddish brown at the center, medium yellow, golden yellow to light reddish brown towards periphery or dark yellowish green to dark green; margin irregularly splitted. Lamellae adnexed, crowded (8-10 per cm), forked, white to cream; lamellulae present. Stipe 45-60 x 12-15 mm, central, cylindric, white, with a reddish tinge in some areas, $FeSO_4$ (+); context solid, white, unchanging. Spore print white (Ia). Taste mild.

Basidiospores 6.5-8.5 x 5.6-7 µm, globose to broadly ellipsoid or rarely ellipsoid [Q = 1.03-1.33, av. 1.18-1.23]; ornamentation amyloid, up to 0.3 µm high, composed of warts, few jointed by connectives. Basidia 30-45 x 7-9 µm, clavate to subclavate, 4-spored; sterigmata up to 6 µm long. Pleurocystidia 46-70 x 6-9 µm, abundant, fusiform with acuminate, mucronate to moniliform apices; content dense. Lamellae edge fertile with numerous basidia and

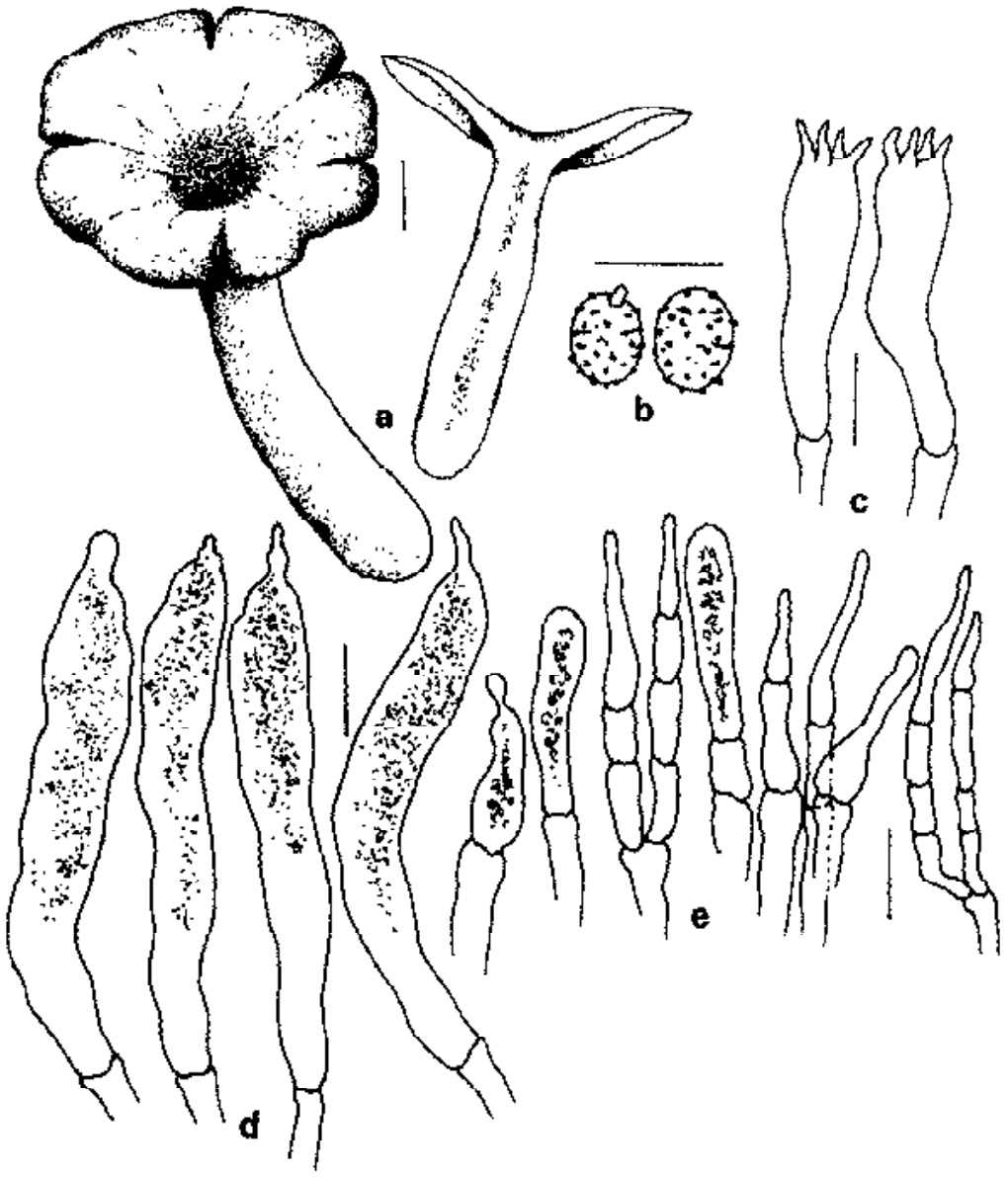


Fig. 54. *Russula heterophylla*: a. Basidiomes b. Basidiospores c. Basidia d. Pleuro- cystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

few cystidia. Cheilocystidia same as pleurocystidia. Subhymenial layer narrow, up to 16 µm, cellular. Pileipellis composed of erect hyphae with cylindrical to clavate structures having mucronate to capitate or rounded apices which cannot be distinctly characterized as pileocystidia. Terminal cells of the hyphae of suprapellis 5-8 µm broad.

Ecology : Common, grows in ectomycorrhizal association with species of *Quercus, Rhododendron* and *Cedrus* in coniferous to mixed temperate forests.

Specimens examined : Uttaranchal, Champawat, Lohaghat, September 2002, **col.** K. Das & J.R. Sharma, KD4507; Uttaranchal, Bageshwar, Kausani, August 2001, **col.** K. Das, KD961; Uttaranchal, Champawat, Mayawati, August 2002, **col.** K. Das, KD2115; Uttaranchal, Nainital, Nainipeak, September 1983, **col.** Atri & Saini, PUN 611.

Notes : Russula heterophylla is separated from the closely resembling *R. grisea* by features discussed under the latter.

Russula virescens (Schaeff.) Fr.

Epi. Syst. Mycol. 355, 1838; *Agaricus virescens* Schaeff., Fungor. Bavar. Icones, IV: 40, 1774; Rawla, Pl. Div. Him. (2001) 26; Atri *et al.*, Bot. Res. Ind. (1991) 96; Saini & Atri, Geob. N. Rep. **3**(1984) 5; Saini *et al.*, J. Ind. Bot. Soc. (1993) 36; Atri & Saini, Geob. N. Rep. **5**(1986) 103; Das & Sharma, Phytotax. **4**(2004)4. Pl. 20; fig. 55

Pileus 60-150 mm diam., convex to planoconvex with depressed center, typically infundibuliform at maturity; pileipellis viscid when moist, smooth at first, areolate forming crustose patches (up to 5 mm in diam), medium yellowish green or medium to dark grayish olive green with brilliant to soft yellow or light olive brown patches; margin tuberculately striate. Lamellae broadly adnate to adnexed, close, equal, entire, forked at the stipe, cream to pale yellow; lamellulae abundant. Stipe 50-95 x 18-28 mm, central, cylindric, yellowish white, $FeSO_4$ (+); context stuffed, unchanging. Taste mild. Spore print cream or pale yellow.

Basidiospores 6.5-8.5 x 5.7-7 µm, subglobose to broadly ellipsoid, rarely globose [Q = 1.14-1.24]; ornamentation amyloid, up to 0.7 µm high, composed of conic or convex warts and ridges arranged in incomplete to almost complete reticulum. Basidia 38-50 x 6.9-11 µm, clavate, 4-spored. Pleurocystidia 43-76 x 6-12 µm, emergent up to 30 µm, subcylindric, fusiform to clavate with appendiculate, capitate or moniliform apices; contents dense. Cheilocystidia same as pleurocystidia. Subhymenial layer thick, up to 40 µm, cellular. Pileipellis composed of erect hyphae; hyphae composed of a chain of 3-8 cells; terminal

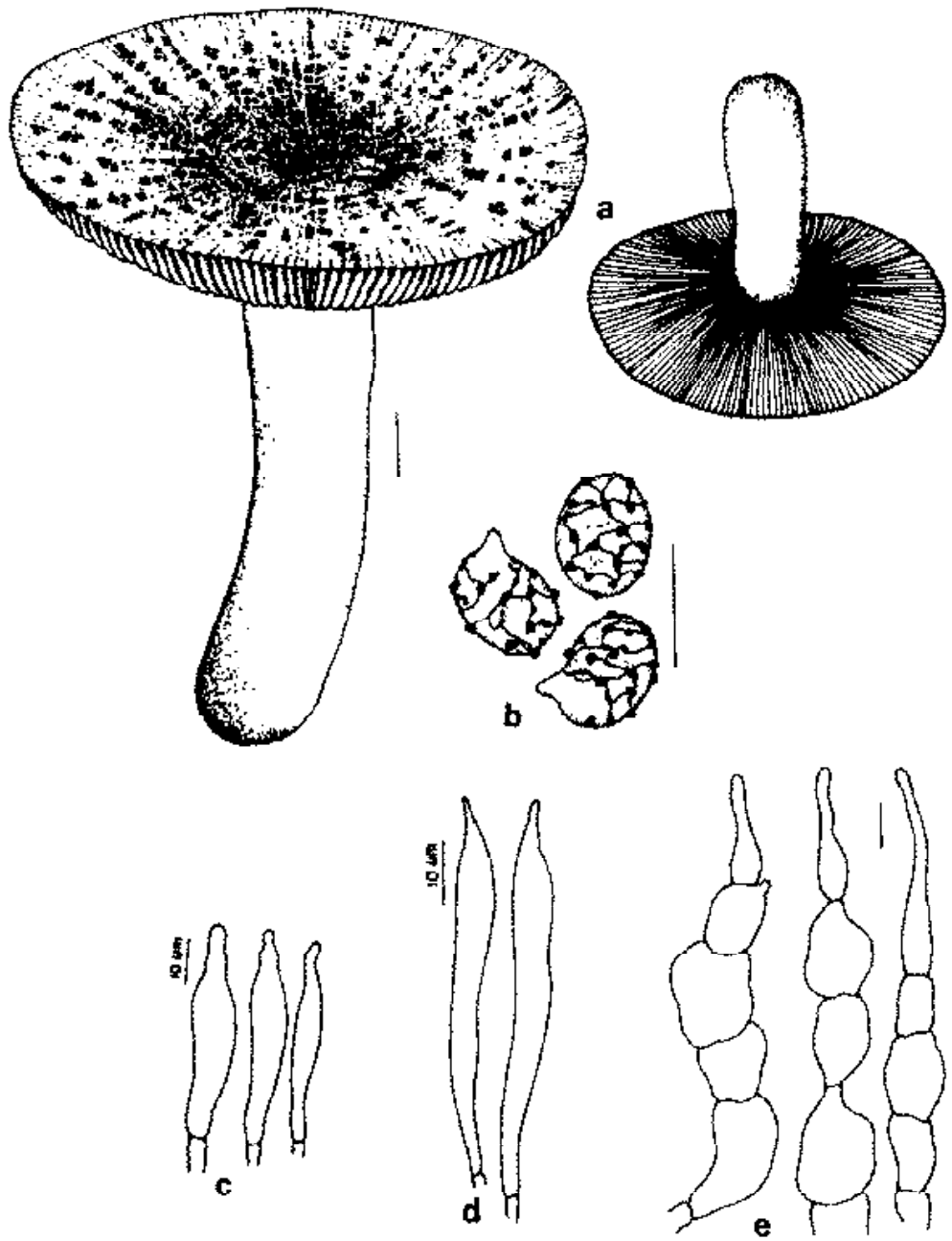


Fig. 55. *Russula virescens*: a. Basidiomes b. Basidiospores c. Cheilocystidia d. Pleurocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

cell subcylindric, tapered from base to apex, subterminal cells rounded (inflated), sphaerocytes forming pseudoparenchymatous layer.

Ecology : Common, grows ectomycorrhizally with species of *Pinus* in coniferous to mixed subtropical to temperate forests.

Specimens examined : Uttaranchal, Almora, on the way to Binsar, August 2001, **col.** K. Das, KD911; Uttaranchal, Pithoragarh, Maitly, September 2001, **col.** K. Das & J.R. Sharma, KD4029.

Notes : Russula virescens is easily distinguished by areolate to crustose patches on pileipellis, tuberculately striate margin and presence of sphaerocytes as subterminal cells of the pileipellis.

Russula sp. 2 Pl. 21; fig. 56

Pileus 60-90 mm diam., convex, planoconvex to umbelliform with depressed center; pileipellis dry, cracked to areolate towards margin,

brownish pink, light gray brown or gray yellowish brown with cream to pale yellow at the center, gray yellow, medium yellow, dark yellow or dark grayish yellow at maturity; margin plane, nonstriate. Lamellae broadly adnexed, close (7-8 per cm), forked near the stipe or from the middle, pale yellow; lamellulae in two rows. Stipe 37-70 x 13-18 mm, central, cylindric to subclavate, yellowish wihite, $FeSO_4$ (+); context stuffed, white unchanging. Taste mild. Spore print not found.

Basidiospores (6) 7-8.8 x 5.4-7.8 µm, globose to broadly ellipsoid [Q = 0.95-1.2 (1.30)]; ornamentation amyloid, 0.2-0.4 µm high, composed of irregular isolated warts, few connected by isolated lines, never forming reticulum. Basidia 38-50 x 8-12 µm, clavate, 4-spored. Pleurocystidia 80-100 x 9.5-12 µm, cylindric, fusoid or ventricose with rounded, mucronate, appendiculate or narrowly lageniform (tailed) apices, emergent up to 40 µm. Cheilocystidia 50-70 x 8-11 µm, cylindrical to clavate. Pileipellis composed of suberect septate branched hyphae and cylindrical to clavate, indistinctly characterised pileocystidia with rounded to mucronate apices.

Ecology : Rare, grows in ectomycorrhizal association with species of *Pinus* in mixed temperate forests.

Specimens examined : India, Uttaranchal : Champawat, Mayawati, September 2002, **col.** K. Das & J.R. Sharma, KD4541 (**Holotype**, BSD; isotype, TUR-A, GUH), KD4579; *ibid.*, Nainital, Gagar, August 2002, **col.** K. Das, KD2176.

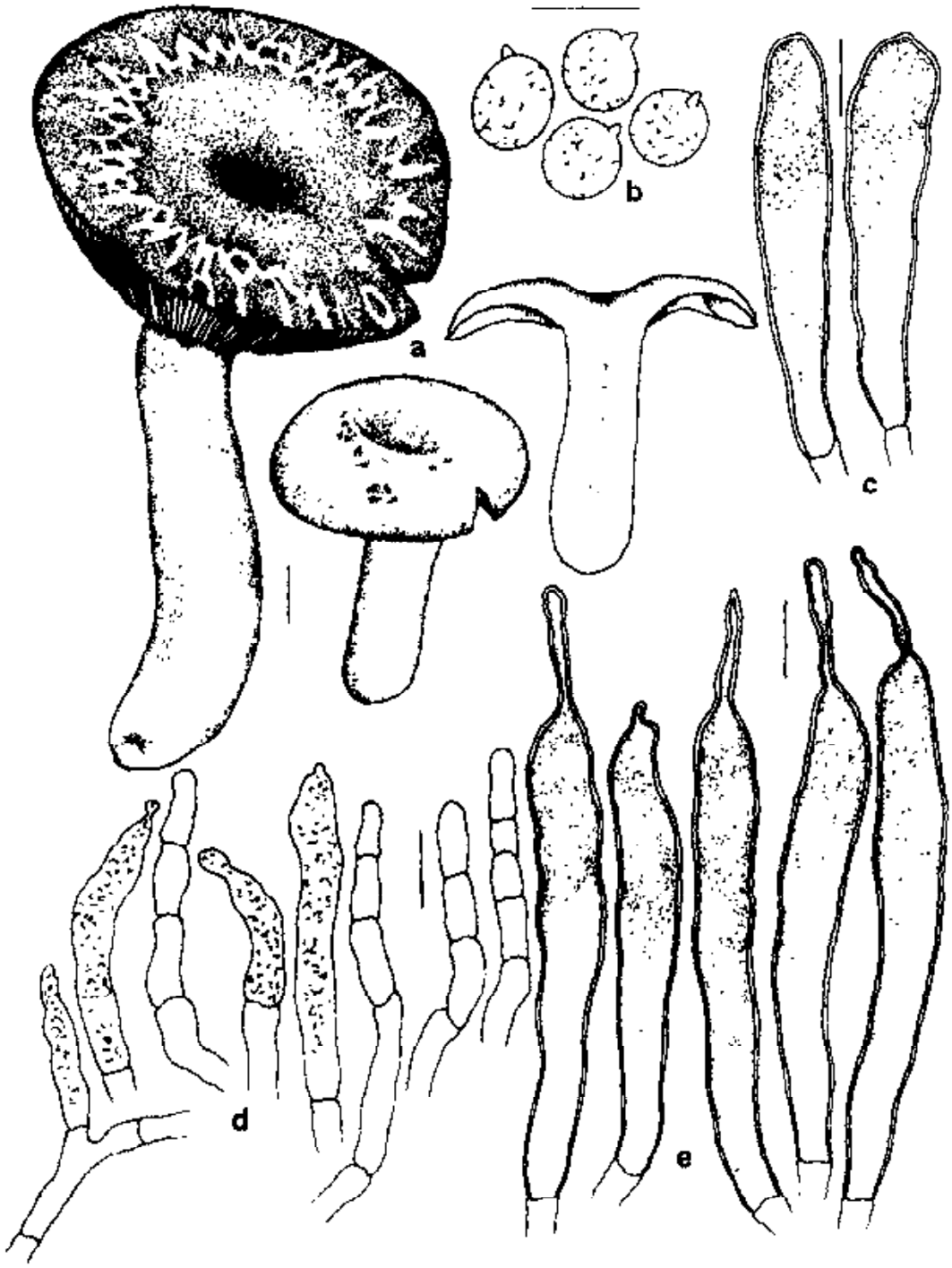


Fig. 56. *Russula* sp. 2: a. Basidiomes b. Basidiospores c. Cheilocystidia d. Cross section of pileipellis e. Pleurocystidia. Bars: a = 10 mm; b-e = 10 µm.

Plate 20: a. *Russula virescens* b. *R. grisea* c. *R. cyanoxantha*.

Plate 21: a. *Russula* sp. 2 b. *R. anatina*.

Notes : Based on the coloration of pileus and nature of the pileipellis, the present taxon is placed in the subgenus *Heterophyllidia* Romagnesi. It matches morphologically with *R. virescens* (Schaeff.) Fr. but the distinct pseudoparenchymatous subpellis, absence of appendiculate (tailed) pleurocystidia and spore reticulation in the latter separate the two taxa. The unusual combination of characters like the distinctly areolate pileipellis, lageniform to tailed, thick-walled pleurocystidia and spores with low irregular isolated warts justify a new specific status to these specimens. Moreover, molecular analysis (Fig. 79) place the present taxon (clade 2) quite distantly from *R. virescens* (clade 5).

Subgenus **Incrustatula** Romagnesi
Doc. Myc., 69: 39, 1987. emend. Sarnari, Monografia illustrata del Genere Russula in Europa, 125, 1998.

Pileus convex to planoconvex with often depressed center; pileipellis smooth to pruinose or subvelvety or rimose, orange red to purplish; lamellae adnate to adnexed; basidiospores composed of isolated warts or with connectives; hymenial cystidia present; pileipellis with incrusted hyphae; pileocystidia absent; subpellis composed of inflated cells or hyphae; taste mild. Eleven taxa in India; five in Kumaon Himalaya.

KEY TO THE SPECIES

1a. Pileipellis and stipitipellis rimose to scurfy (scaly) ..... **R. nothofaginea**

b. Pileipellis and stipitipellis not rimose or scurfy 2

2a. Dried specimens never turn red with SV; subpellis hyphal ..... **Russula** sp. 3

b. Dried specimens turn bright red with SV; subpellis pseudoparenchymatous 3

3a. Pileus up to 120 mm diam.; pileipellis never velvety 4

b. Pileus 35-45 mm diam.; pileipellis velvety ..... **R. dafianus**

4a. Lamellae edge concolorous with the face of lamellae ..... **R. rosea**

b. Lamellae edge not concolorous (red) ..... **R. minutula** var. **robusta**

Russula dafianus K. Das & J.R. Sharma *sp. nov.*
Pl. 22; fig. 57

Etymology: Dafia Dhura, referring to the type locality.

*Pileus 35-45 mm diam., applanatus to planoconvexus, purpureus. Lamellae annexae, densae, luteae. Stipes 20-25 x 8-12 mm, cylindricus, purpureus. Sporae 7.8-90 x 61-73 µm, late ellipsoidae. Pleurocystidia 56-80 x 8.0-10 µm, fusiformia. Pileocystidia absentia. India, Uttaranchal, Dafia Dhura, September 2001, leg. K. Das & J.R. Sharma, KD4004 (**Holotypus, BSD**).*

Pileus 35-45 mm diam., applanate to planoconcave with slightly depressed center; pileipellis moist, downy-wooly to tomentose (velvety), dark purplish pink, medium or soft to deep purplish red with light yellowish center; margin regular, incurved. Lamellae adnexed crowded (*ca* 13-14 per cm), yellowish

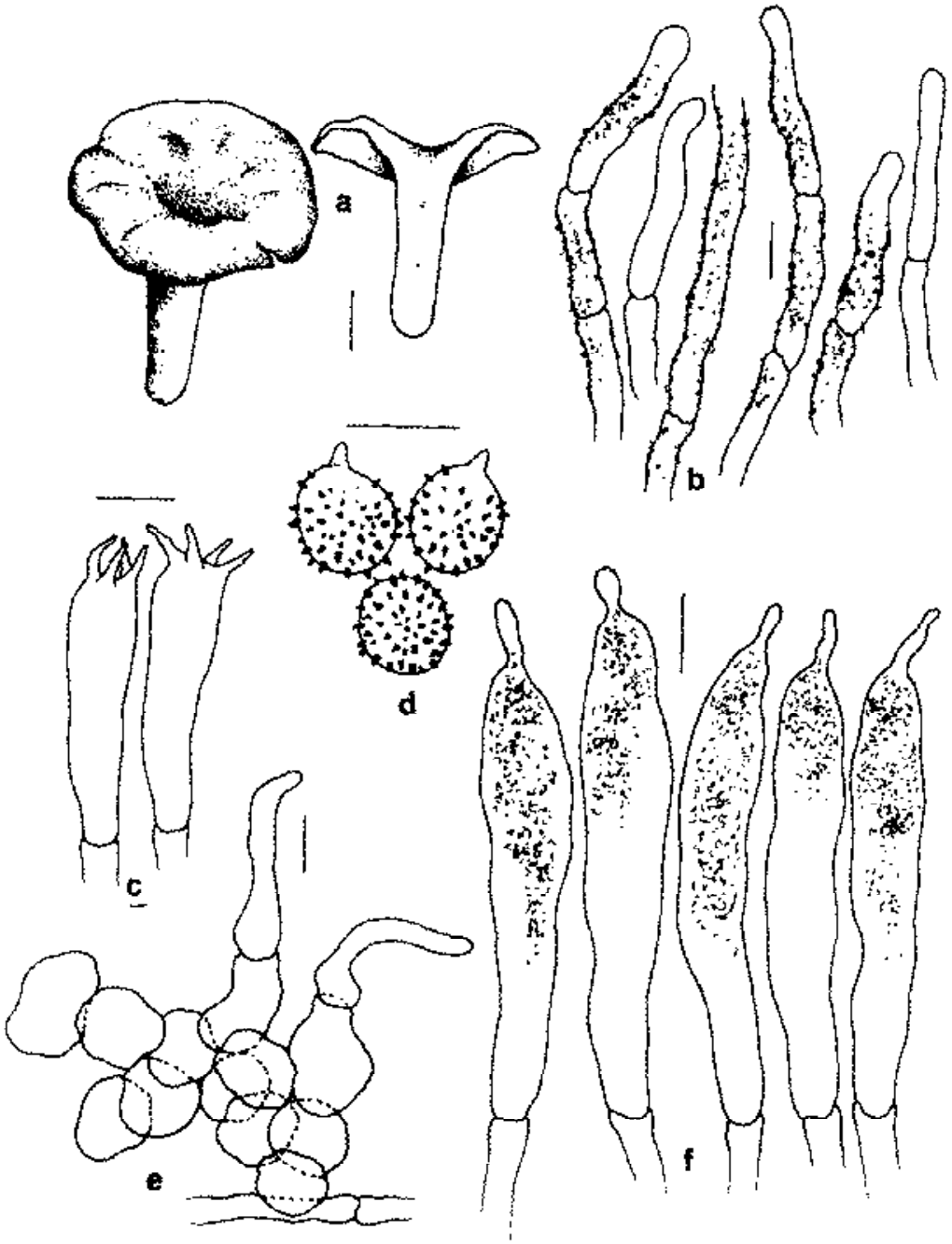


Fig. 57. *Russula dafianus*: a. Basidiomes b & e. Cross section of pileipellis c. Basidia d. Basidiospores f. Pleurocystidia. Bars: a = 10 mm; b-f = 10 µm.

white to pale yellow; sometimes forked near the stipe. Stipe 20-25 x 8-12 mm, central, cylindrical, medium to grayish purplish red at the base, gradually paler towards apex, $FeSO_4$ (+); context yellowish white to pale yellow, dried samples dark red with SV. Taste mild. Spore print not found.

Basidiospores 7.8-9 x 6.1-7.3 µm, broadly ellipsoid (Q = 1.17-1.27); ornamentation amyloid, up to 1.1 µm high, composed of spinoid to conical or cylindrical warts. Basidia 24-35 x 6-8 µm, subclavate, 4-spored. Pleurocystidia 56-80 x 8-10 µm, emergent up to 24 µm, abundant, fusoid to ventricose with appendiculate or narrowly lageniform (tailed) apices; contents dense towards apices. Lamellae edge fertile with basidia and cystidia. Cheilocystidia same as pleurocystidia. Pileipellis composed of erect to suberect, septate, hyphae (up to 7 µm broad); terminal element cylindrical with rounded apices, often with incrustations; pileocystidia absent. Subpellis pseudoparenchymatous, 3-5 cells deep.

Ecology : Rare, grows in ectomycorrhizal association with species of *Quercus* in temperate mixed forests.

Specimens examined : Uttaranchal, Pithoragarh, Dafia Dhura forest, Sept. 2001, **col.** K. Das & J.R. Sharma, KD4004; Uttaranchal, Bageshwar, Dhakuri, Sept. 1999, **col.** K. Das & J.R. Sharma, KD1082.

Notes : The presence of hyphal incrustations and cellular subpellis with the absence of pileocystidia in pileipellis, justify the placement of these specimens under subgenus *Incrustatula*. Present species is quite distinct by velvety appearance of pileipellis, presence of basidiospores with isolated spinoid warts and pseudoparenchymatous nature of the subpellis. The characters are quite distinct and do not match presently with any known taxon of the subgenus.

Russula minutula var. **robusta** Saini, Atri & Singer

Sydowia, Ann. Mycol. Ser. II. **35**: 239, 1982; Rawla, Pl. Div. Him (2001) 17; Atri *et al.*, Bot. Res. Ind. (1991) 97; Saini, *et al.*, J. Ind. Bot. Soc. (1993) 36; Atri & Saini, Geob. N. Rep. 5(1986) 101; Das & Sharma, Phytotax. 4(2004)3.

Pileus up to 70 mm diam., convex to applanate, depressed to infundibuliform at maturity; pileipellis dry, deep red; margin irregular, slightly splitted at maturity. Lamellae adnexed crowded, forked, white, unchanging after bruising; lamellulae absent; margin red. Stipe 80 x 17 mm cylindrical to subclavate, veined, white, pinkish after bruising. Sulfovanilline on stipe distinctly red, brown after sometime. Context white, unchanging. Taste mild. Odour undistinguished. Spore print white.

Basidiospores 6.5-7.5 (7.8) x 5.5-6.5 (6.8) µm; ornamentation amyloid, up to 0.3 µm high, composed of isolated to jointed warts, forming partial reticulum. Basidia 20-41 x 6-9.5 µm, clavate, 4-spored; sterigmata up to 3 µm long. Hymenial cystidia 40-62 x 5-11.5 µm, subfusiform, to fusiform, obtuse, cylindrical to clavate, often with incrustations. Pileipellis composed of erect to suberect hyphae; hyphae often with incrustations.

Ecology : Rare, grows in ectomycorrhizal association with species of *Rhododendron* in mixed temperate forest.

Specimens examined : Uttaranchal, Nainital, Naini Peak, September 1982, **col.** N.S. Atri, PUN 603.

Notes : The present taxon appears to be close to its typical variety *Russula minutula* Velen. (Saini *et al* 1989), but the basidiomes of the latter are only up to 20 mm in diam. in Indian specimens (Saini *et al* 1989) and up to 30 mm in diam in European specimens (Romagnesi 1996).

Russula nothofaginea Singer

Rev. Mycol. (Paris) **15**: 127, 1950. Pl. 22; fig. 58

Pileus 40-65 mm diam., convex, planoconcave with slightly depressed center; pileipellis dry, rimose or scurfy (scaly), grayish or dark to very deep red with pale yellowish areas; margin regular, plane to slightly incurved. Lamellae broadly adnate close (6-7 per cm), yellowish white to pale yellow; lamellulae present. Stipe 23-37 x 5-10 mm, central, subclavate, scurfy to scaly, concolorous with the pileus, $FeSO_4$ (+); context white, slowly blackish after bruising. Taste not known. Spore print yellowish white.

Basidiospores 7.4-9.6 x 6-8.5 µm, broadly ellipsoid to ellipsoid (Q = 1.2-1.33); ornamentation amyloid, composed of irregular warts (up to 0.8 µm) and fine lines forming incomplete reticulum. Basidia 28-44 x 7-9.5 µm, clavate, 4-spored; sterigmata up to 7.5 µm long. Pleurocystidia 34-50 x 10-13.5 µm, emergent up to 20 µm, abundant, clavate; contents dense. Lamellae edge fertile. Cheilocystidia 30-38 x 8-10 µm, subclavate. Subhymenial layer up to 15 µm thick. Pileipellis a trichoderm composed of erect to suberect branched, septate, hyphae up to 6 µm broad; terminal elements fusoid to obtanceolate or clavate, often with incrustations; pileocystidia absent. Subpellis pseudoparenchymatous.

Ecology : Rare, grows in ectomycorrhizal association with species of *Rhododendron* and *Quercus* in temperate deciduous forests.

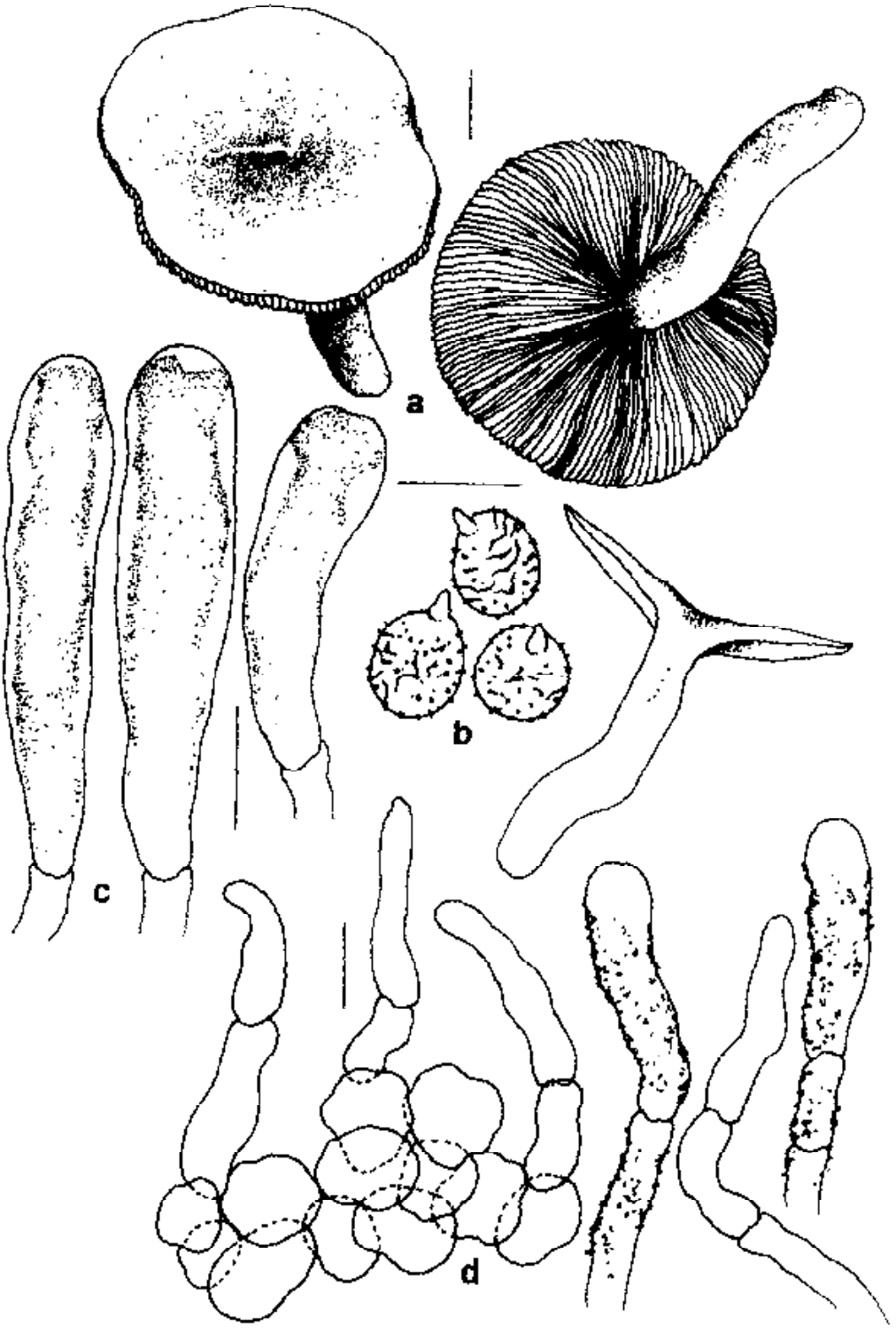


Fig. 58. *Russula nothofaginea*: a. Basidiomes b. Basidiospores c. Pleurocystidia d. Cross section of pileipellis. Bars: a = 10 mm; b-d = 10 µm.

Specimens examined : Uttaranchal, Pithoragarh, Dafia Dhura forest, Oct. 4, 2001, **col.** K. Das & J.R. Sharma, KD4047.

Notes : The present species is characterized by scurfy to scaly appearance of its basidiomes in the field. Microscopically, the clavate pleurocystidia, incrusted hyphae in pileipellis and cellular subpellis help in the characterization of this taxon. The characters recorded for the Indian specimens are in close agreement with the characters of the holotype described by Singer (1950) except the size of spores and cystidia is smaller for Indian specimens.

Russula rosea Quel.

Ench. Fung. 184, 1886; Rawla, Pl. Div. Him. (2001) 23; Atri & Saini, Geob. N. Rep. **5**(1986) 102; Saini *et al.*, J. Ind. Bot. Soc. **68**(1989) 207; Saini & Atri, Geob. New Rep. **3**(1984) 5; Das & Sharma, Phytotax. **4**(2004)3.

Pl. 22; fig. 59

Pileus 75-120 mm diam., convex, planoconvex with depressed center at maturity; pileipellis dry, viscid when moist very red, never velvety or scurfy, deep red or reddish orange, paler towards margin, peeling up to 1/3rd of radius; margin slightly decurved to plane, tuberculately sulcate, often splitted. Lamellae adnexed, close to rather crowded (9-10 per cm), forked, light yellow to pale orange yellow, spotted at maturity. Stipe 60-80 x 15-24 mm, central, cylindrical, white with tinge of deep pink, $FeSO_4$ (+); context pale yellow. Dried specimen immediately turns bright red after treating with SV. Odour indistinct. Taste mild. Spore print pale yellow.

Basidiospores 6.75-8.5 x 5.9-7.2 µm, subglobose to broadly ellipsoid (Q = 1.08-1.30); ornamentation amyloid, composed of irregular warts (up to 0.5 µm) and fine lines forming incomplete reticulation. Basidia 34-45 x 6-9 µm, clavate, 4-spored; sterigmata up to 7 µm long. Pleuromacrocystidia abundant 55-90 x 7-11.3 µm, emergent up to 30 µm fusiform to subfusiform; contents dense. Lamellae edge fertile with basidia and cystidia. Cheilocystidia 35-60 x 6.75-8 µm. Subhymenium layer up to 20 µm thick, cellular. Pileipellis composed of erect to suberect hyphae. Hyphae up to 4 µm broad, often with incrustations. Subpellis pseudoparenchymatous.

Ecology : Common, grows in ectomycorrhizal association with species of *Quercus* in temperate deciduous to mixed forests.

Specimens examined : Uttaranchal, Nainital, Mukteshwar, August 2002, **col.** K. Das, KD2126, KD 2128; Uttaranchal, Almora, Mornoula, September 2002, **col.** K. Das & J.R. Sharma, KD4590.

Notes : Russula rosea is easily characterized by deep to orange red pileus, concolorous lamellae and stipe with a tinge of pink colour. Further,

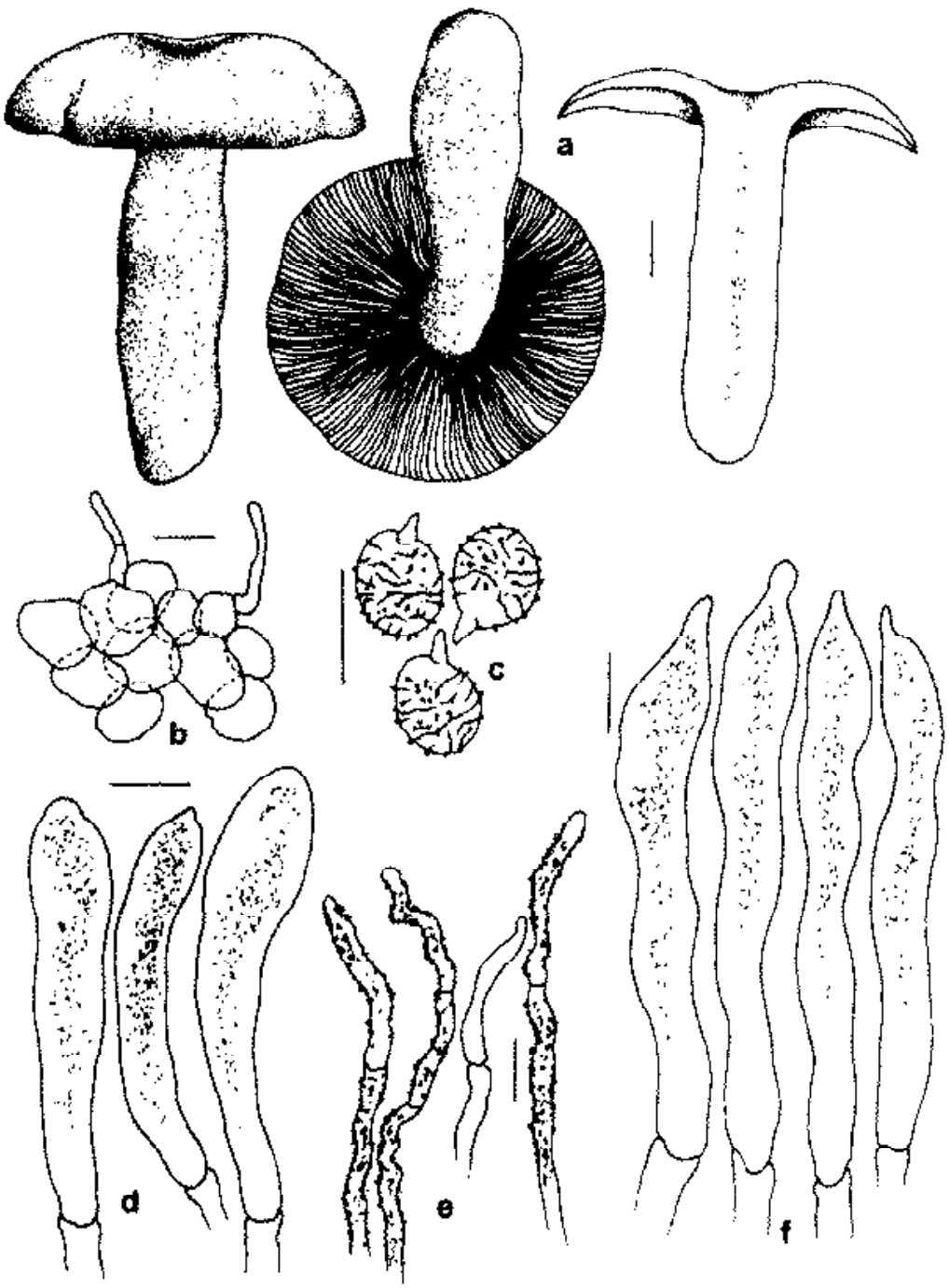


Fig. 59. *Russula rosea*: a. Basidiomes b & e. Pileipellis c. Basidiospores d. Cheilocystidia f. Pleurocystidia. Bars: a = 10 mm; b-f = 10 µm.

the turning of the dried specimens to bright red with sulphovanillin is also very characteristic. It resembles morphologically with *Russula* sp. 3 but, microscopically, the latter differs from the present species by having hyphal nature of subpellis and larger spores. Moreover, *Russula* sp. 3 is always found associated with the species of *Rhododendron*.

Russula sp. 3 Pl. 22; fig. 60

Pileus 80-120 mm diam., convex, planoconvex with depressed center to uplifted at maturity; pileipellis dry, somewhat pruinose but never velvety or scurfy, soft to medium to deep red, often with brilliant orange yellow areas; margin often tuberculately sulcate, splitted. Lamellae adnexed to subdecurrent close to rather crowded (8 per cm), often forked from the stipe, brilliant to light orange yellow; lamellulae absent. Stipe 50-125 x 20-28 mm, central, subclavate to clavate, yellowish with deep pink to medium red areas, white with tinge of deep pink, $FeSO_4$ (+); context pale yellow. Odour indistinct. Taste mild. Spore print not obtained.

Basidiospores 6.5-10.2 x 6-7.7 µm, globose to broadly ellipsoid (Q = 1.03-1.26); ornamentation amyloid, composed of isolated conic to spiny warts (up to 1.75 µm). Basidia 40-60 x 9-14 µm, subclavate, 4-spored; sterigmata up to 7.5 µm long. Pleurocystidia 72-115 x 8-12 µm, emergent up to 45 µm, abundant, cylindrical to subfusoid, thick walled; wall up to 1.5 µm thick; contents dense. Lamellae edge fertile with basidia and cystidia. Cheilocystidia 60-75 x 9-13 µm, clavate to fusoid, thick walled; wall up to 1.75 µm thick. Pileipellis composed of erect to suberect hyphae; hyphae up to 5 µm broad, often with incrustations. Pileocystidia absent. Pilear trama with abundant sphaerocytes. Stipitipellis composed of suberect to repent hyphae and cystidia.

Ecology : This species grows in close association with species of *Rhododendron* in moist mixed temperate forests.

Specimens examined : India, Uttaranchal : Bageshwar, Dhakuri, September 2003, **col.** K. Das & J.R. Sharma, KD7029 (**Holotype**, BSD; isotype, GUH); *ibid.*, KD7092, KD7093.

Notes : Morphologically, bright coloulration of pileipellis and microscopically, the presence of incrusted hyphae and absence of pileocystidia in pileipellis, undoubtedly place these specimens under the subgenus *Incrustatula*. The characters recorded for these specimens are quite close to *Russula rosea* Qúelet, as also confirmed by molecular analysis (Fig. 79) but, the latter differs by having cellular nature of subpellis and smaller basidiospores.

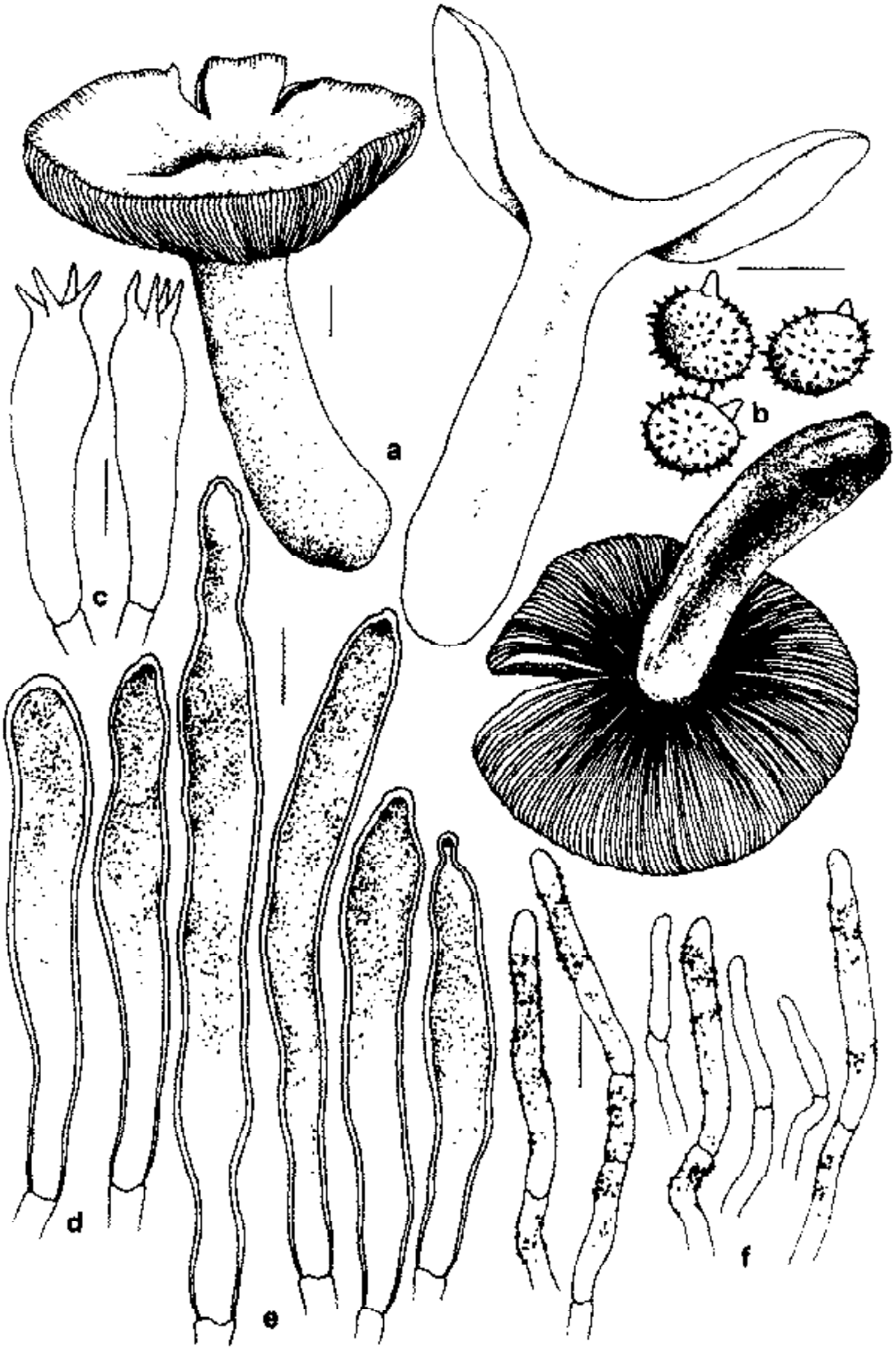


Fig. 60. *Russula* sp. 3: a. Basidiomes b. Basidiospores c. Basidia d. Cheilocystidia e. Pleurocystidia f. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

Plate 22: a. *Russula nothofaginea* b & c. *R. dafianus* d. *R. rosea* e. *Russula* sp. 3.

Subgenus **Ingratula** Romagnesi
Doc. Myc. 69: 39, 1987

Pileus convex, planoconvex with broadly depressed center at maturity; pileipellis viscid, sticky or gelatinous, margin tuberculately striate to sulcate; lamellae adnexed to subdecurrent; context stuffed to hollow; basidiospore ornamentations composed of isolated warts or warts with connectives forming a broken reticulum, rarely winged in a zebroid fashion; hymenial cystidia present; pileocystidia present. Twelve taxa in India; seven in Kumaon Himalaya.

KEY TO THE SPECIES

1a. Pileipellis areolate, atleast at maturity ..... **R. abbotensis**

b. Pileipellis never areolate 2

2a. Stipe base purplish red ..... **R. praetervisa**

b. Stipe base not purplish red 3

3a. Pileus white to yellowish white ..... **Russula** sp. 4

b. Pileus yellowish, yellowish orange, brown grayish yellow or grayish brown 4

4a. Basidiospores ornamentation typically winged to zebroid .....
..... **R. laurocerasi**

b. Basidiospores ornamentation never winged or zebroid 5

5a. Basidiospores ornamentation with isolated warts ..... **R. foetens**

b. Basidiospores ornamentation forming incomplete reticulum 6

6a. Context distinctly lemon yellow after bruising or with KOH .....
..... **R. subfoetans**

b. Context not changing as above ..... **R. pectinata**

Russula abbotensis K. Das & J.R. Sharma *sp. nov.*
Pl. 24; fig. 61

Etymology: Abbot Mount, referring to the type locality.

Pileus 80-120 mm diam., convexus, planoconvexus ad leviter depressus in centro. Lamellae annexae ad subdecurrentes, densae, luteoalbae. Stipes 30-70 x 14-21 mm, brunneolus ad rufulus. Sporae in cumulo luteoalbae,

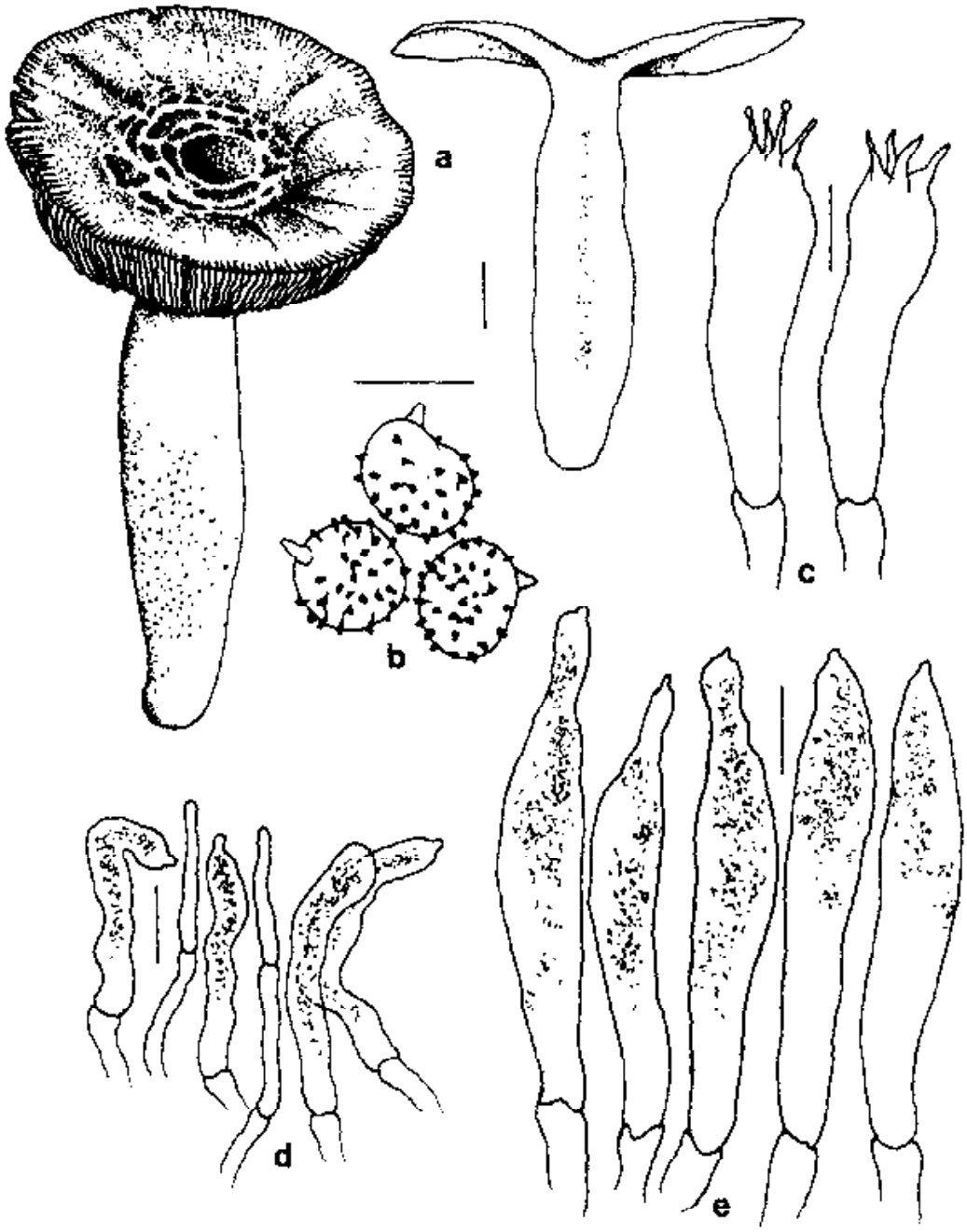


Fig. 61. *Russula abbotensis*: a. Basidiomes b. Basidiospores c. Basidia d. Cross section of pileipellis e. Pleurocystidia. Bars: a = 10 mm; b-d = 10 µm.

*8.0-10 x 7.3-8.5 µm, subglobosae ad late ellipsoidae. Pleurocystidia 50-75 x 8.0-10 µm, fusiformia ad subfusiformia. Cheilocystidia 38-60 x 7.0-10 µm, fusiformia. Pileocystidia cylindricus. INDIA, Uttaranchal, Champawat, Abbot Mount, September 2002, K. Das & J.R. Sharma, KD4531 (**Holotypus**, BSD).*

Pileus 50-80 mm diam., convex when young, gradually planoconvex to slightly umbelicate with broadly depressed center; pileipellis viscid to glutinous, towards center breaking into crustose patches to become areolate at maturity, grayish yellow, light gray purplish red to light reddish brown, deep to dark reddish brown or dark purplish red at center; margin decurved when young, plane at maturity, tuberculately striate. Lamellae adnexed to subdecurrent, rather crowded (8-10 per cm), thick, yellowish white; lamellulae in a single row. Stipe 30-70 x 14-21 mm, central, tapered towards both the end, pruinose to scurfy towards base, white, very light brown to light gray purplish red towards base after bruising or maturity, $FeSO_4$ (+). Taste mild. Spore print yellowish white.

Basidiospores 8.0-10 x 7.3-8.5 µm, subglobose to broadly ellipsoid [Q = 1.07-1.20]; ornamentation amyloid, less than 1 µm high, composed of conic to spiny warts sometimes jointed by fine lines. Basidia 30-51 x 10-13 µm, subclavate, 4-spored. Pleurocystidia 50-75 x 8-10 µm, emergent up to 18 µm, abundant, fusiform to subfusiform often tapering to mucronate apices. Cheilocystidia 38-60 x 7-10 µm, mostly fusoid, some tapering to mucronate apices. Subhymenial layer narrow, up to 14 µm, cellular. Pileipellis purely ixotrichoderm, composed of hyphae and pileocystidia; hyphae up to 5 µm broad, pileocystidia up to 5 µm broad, cylindric with mucronate apices.

Ecology : Common, grows in ectomycorrhizal association with species of *Quercus* in mixed temperate forests.

Specimens examined : Uttaranchal, Champawat, Abbot Mt., September 2002, **col.** K. Das & J.R. Sharma, KD4531; *Ibid.*, KD4534.

Notes : The areolate nature and colour of the pileipellis are so distinct that the taxon is readily identifiable in the field itself. These characters do not match with characters of any of the recorded species under this subgenus.

Russula foetens Pers.: Fr.

Observationes mycologicae **1**: 102, 1796. Pl. 23; fig. 62

Pileus 55-110 mm diam., convex, applanate to broadly depressed at maturity; pileipellis viscid to sticky when moist, brilliant to dark or deep orange yellow, soft yellowish brown; margin tuberculately sulcate to striate. Lamellae adnexed

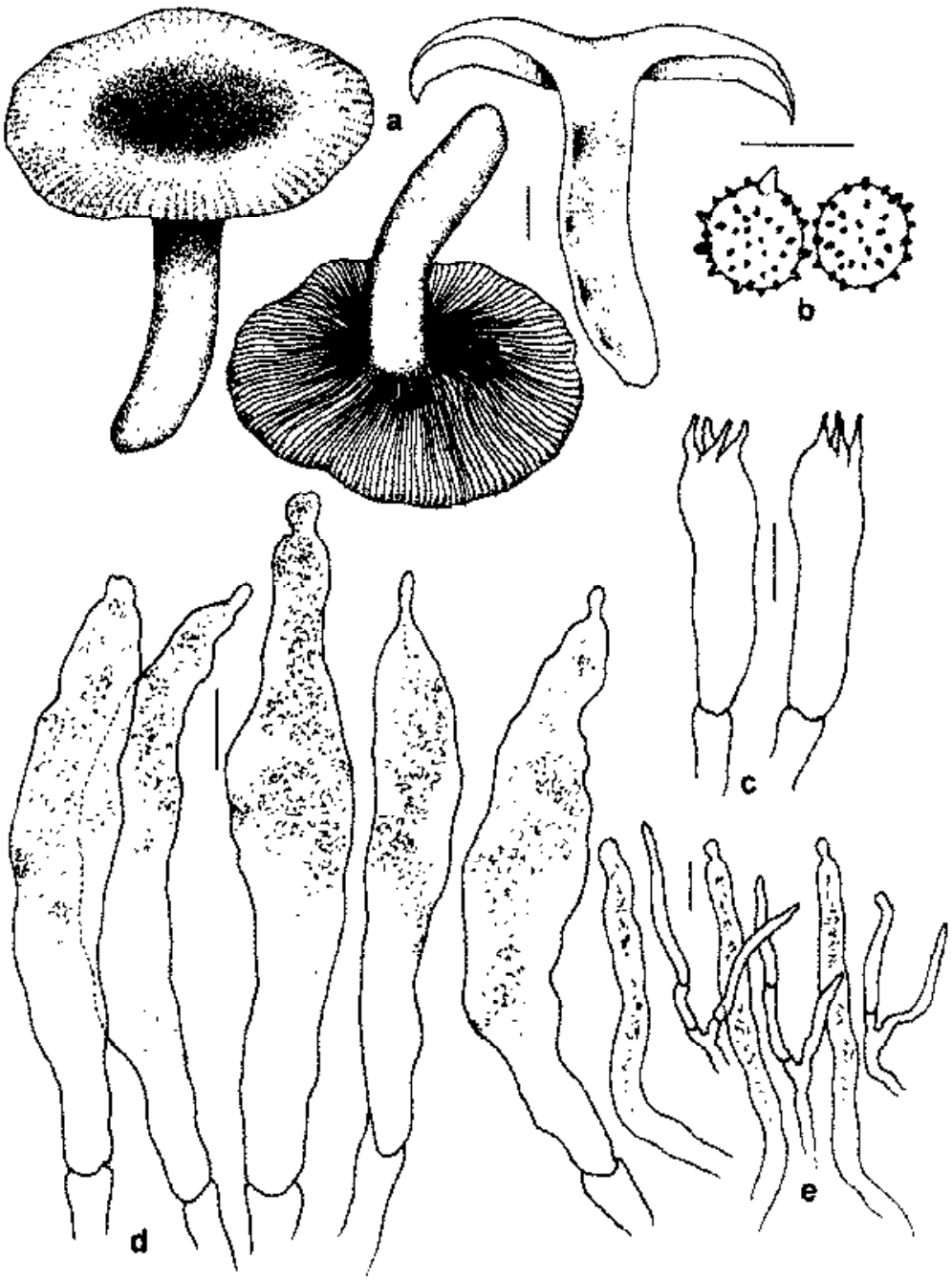


Fig. 62. *Russula foetens*: a. Basidiomes b. Basidiospores c. Basidia d. Pleurocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

to subdecurrent, crowded, (9-11 per cm), sometimes forked near stipe, yellowish white; lamellulae few in two rows. Stipe 95-110 x 24-27 mm, central, mostly cylindric, veined; context gradually hollow at maturity, yellowish white, unchanging on bruising, but slightly brownish at maturity, $FeSO_4$ (+). Context never turning yellow to golden yellow in KOH or after bruising. Taste acrid. Spore print pale yellow.

Basidiospores 7.5-9 x 6.8-8.1 µm, subglobose [Q = 1.07-1.13]; ornamentation up to 1.5 µm, partially amyloid, composed mostly of conic to acute tipped isolated warts, usually without any connectives. Basidia 32-45 x 7-10 µm, clavate, 4-spored; sterigmata up to 6 µm long. Pleurocystidia 50-117 x 8-12 µm, emergent up to 60 µm, fusoid with mucronate, capitate, appendiculate apices; contents dense towards apex. Cheilocystidia absent. Subhymenium layer up to 24 µm thick, cellular. Pileipellis composed of parallel hyphae and pileocystidia; hyphae 2-4 µm broad; pileocystidia fusoid with mucronate apices.

Ecology : Abundant, grows ectomycorrhizally with species of *Cedrus* or rarely with *Quercus* in coniferous to mixed temperate forests.

Specimens examined : Uttaranchal, Champawat, Lohaghat, September 2002, **col.** K. Das & J.R. Sharma, KD4501, KD4505, KD4513; Uttaranchal, Champawat, Mayawati, September 2002, **col.** K. Das & J.R. Sharma, KD4544, KD4553; Uttaranchal, Nainital, Tiffin top, September 1982, **col.** Atri & Saini, PUN 596.

Notes : Russula foetens sometimes forms typical fairy rings in the forest and is easily characterized by the crowded arrangement of lamellae and lamellulae, acrid taste and basidiospores with isolated warts. It is also close to *R. laurocerasi* and R. *subfoetens* but unlike the present species *R. laurocerasi* has distinctly winged spores, while in *R. subfoetens* (Sarnari 1998), the context changes lemon to golden yellow after bruising.

Russula laurocerasi Melzer

Casop. Cesk. Houb. **2**: 243, 1921; Rawla, Pl. Div. Him. (2001) 13; Saini & Atri, Geob. N. Rep. **3**(1984) 5; Current Science **50**(1981) 460; Das & Sharma, Phytotax. **4**(2004)3. Pl. 23; fig. 63

Pileus 65-120 mm diam., convex, planoconvex to applanate with slightly depressed center at maturity; pileipellis viscid to sticky, light yellow to brilliant yellow or orange yellow; margin tuberculately sulcate, brownish. Lamellae broadly adnate to adnexed, close (7-8 per cm), some forked, yellowish white; lamellulae present. Stipe 50-90 x 15-20 mm, central, cylindrical or tapered below, dirty yellowish white, $FeSO_4$ (+); context stuffed, unchanging, gradually hollow at maturity. Taste hot. Odor fruity. Spore print pale yellow.

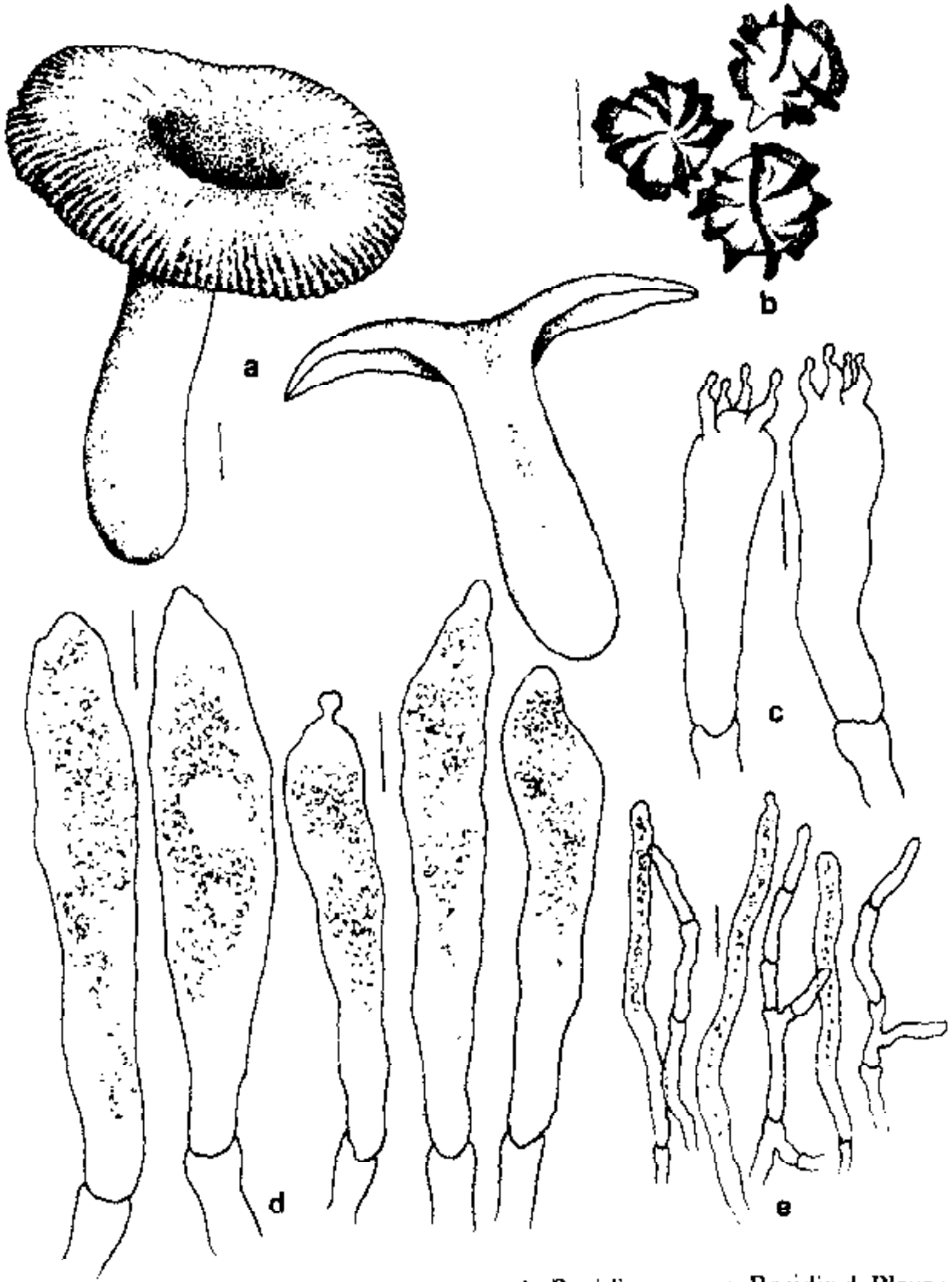


Fig. 63. *Russula laurocerasi*: a. Basidiomes b. Basidiospores c. Basidia d. Pleurocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

Basidiospores 8-10 x 7.8-9.4 µm, globose to subglobose [Q = 1.02-1.1], ornamentation amyloid, up to 2.3 µm high, composed of mostly parallel ridges forming somewhat zebroid pattern of wings, sometimes connected. Basidia 35-55 x 9-12 µm, clavate, 2 to 4-spored; sterigmata long, up to 8 µm. Hymenial cystidia 45-90 x 6-12 µm, fusiform to ventricose with capitate to blunt or mucronate apices; content dense. Subhymenium thick, up to 40 µm, cellular. Pileipellis an ixotrichoderm, composed of septate, branched hyphae, hyphae and pileocystidia; hyphae up to 5 µm broad; pileocystidia mostly cylindrical also up to 5 µm broad.

Ecology : Common, grows ectomycorrhizally with species of *Quercus* in deciduous to mixed temperate forests.

Specimens examined : Uttaranchal, Nainital, Mukteshwar, Aug. 17, 2002, **col.** K. Das, KD2125; *ibid.* KD2131; Uttaranchal, Nainital, Ramgarh, Aug. 2002, **col.** K. Das, KD2142; Uttaranchal, Champawat, Champawat, Aug. 2002, KD2107.

Notes : The basidiospore ornamentation consisting of mostly parallel ridges in a zebroid pattern, separates this taxon from all other taxa in the subgenus.

Russula pectinata Fr.

Epicr. Syst. Mycol. 358, 1838; ; Rawla, Pl. Div. Him. (2001) 21; Atri *et al.*, Bot. Sci. Res. Ind. (1991) 96; Rawla & Sarwal, Bib. Mycol. **91**(1983) 37; Atri & Saini, Geob. N. Rep. **5**(1986) 101; Saini & Atri, Kavaka **17**(1989) 26; Das & Sharma, Phytotax. 4(2004)3. Pl. 24; fig. 64

Pileus 40-55 mm diam., applanate to uplifted with depressed center; pileipellis viscid when moist, grayish brown at center, paler towards margin; margin regular, plane, tuberculately sulcate. Lamellae adnexed, close (7-8 per cm), forked near stipe, yellowish white to pale yellow. Stipe 43-50 x 13-16 mm, central, white, gray yellowish brown after bruising or maturity, $FeSO_4$ (+); context solid, unchanging after bruising and with KOH. Taste acrid. Spore print white.

Basidiospores 7.4-10.3 x 6-7 µm, broadly ellipsoid, to ellipsoid; ornamentation amyloid, up to 1.3 µm high, composed of conic warts and ridges arranged in incomplete reticulum. Basidia 30-44 x 7.5-10 µm, clavate, 4-spored. Pleurocystidia 66-80 x 5-8.5 µm, cylindric with fusoid to narrowly acute apices. Cheilocystidia 33-42 x 4.9-6.8 µm, cylindrical with fusoid to acute apices. Pileipellis an ixotrichoderm, terminal elements cylindric to subclavate, thick walled. Pileocystidia present. Stipitipellis composed of mostly vesiculose cells, caulocystidia absent.

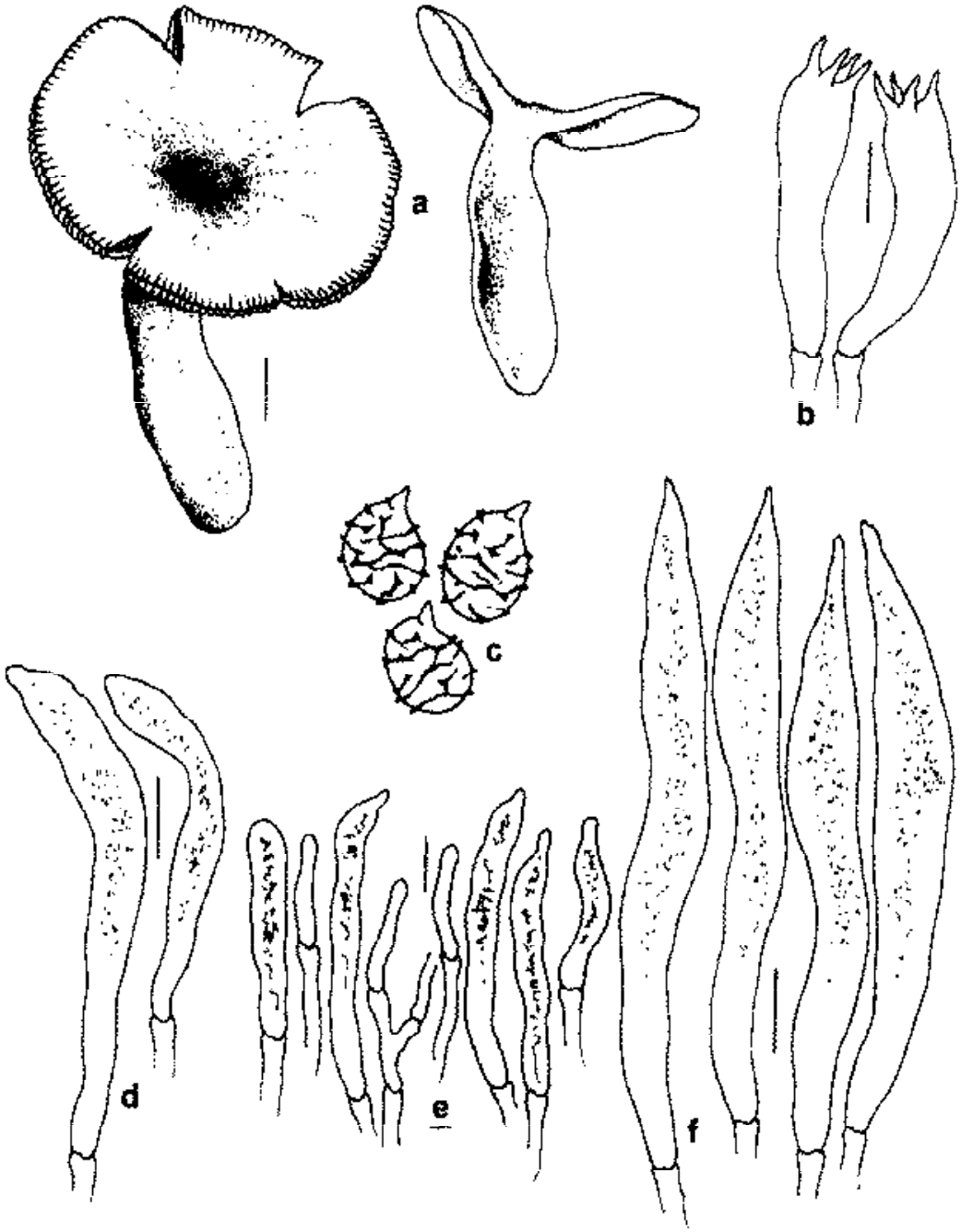


Fig. 64. *Russula pectinata*: a. Basidiomes b. Basidia c. Basidiospores d. Cheilocystidia e. Cross section of pileipellis f. Pleurocystidia. Bars: a = 10 mm; b-f = 10 µm.

Ecology : Abundant, grows ectomycorrhizally with species of *Quercus* in deciduous to mixed temperate forests.

Specimens examined : Uttaranchal, Nainital, Gagar, August 2002, **col.** K. Das, KD3070; Uttaranchal, Pithoragarh, Dafia Dhura, September 2001, **col.** K. Das & J.R. Sharma, KD4079.

Notes : The present species is close to *R. praetervisa* and it is difficult to separate them morphologically in the field. However, a distinct purplish to brownish red colour at the stipe base and the mild taste separate *R. praetervisa* from the present taxon.

Russula praetervisa Sarnari

Monografia Illustrata del Genere Russula in Europa 463; 1998; Sharma *et al.*, Ind. J. For. **27**(2005) 78. Pl. 24; fig. 65

Pileus 36-80 mm diam., planoconvex, gradually infundibuliform at maturity, center mostly depressed; pileipellis viscid, light grayish brown to grayish brown or brownish gray when young, light grayish yellowish brown at maturity, paler towards margin, center darker, peeling up to ½ of the radius; margin tuberculately sulcate, regular, incurved, gradually plane. Lamellae broadly adnate to subdecurrent, close (*ca* 6-8 per cm), edge smooth, chalky white, brown orange, light brown or light to medium reddish brown spots and patches at maturity. Stipe 35-70 x 13-18 mm, central, cylindric to subclavate or slightly tapering downwards, yellowish white, often purplish to brown red at the base with brownish spots on the other areas, $FeSO_4$ (+). Context stuffed, gradually hollow at maturity. Taste mild. Spore print white to yellowish white.

Basidiospores 6.9-8.3 x (5) 5.5-6.3 µm, broadly ellipsoid to ellipsoid [Q = 1.19-1.38 (1.5), av. 1.23-1.30]; ornamentation amyloid, up to 1 µm high, composed of conic warts and ridges, forming somewhat broken reticulation. Basidia 35-54 x 6-10 µm, subclavate to clavate, 4-spored; sterigma up to 8.5 µm high. Pleurocystidia 65-95 x 8-11 µm, abundant, ventricose with acute to obtuse tips; contents refractive. Lamellae edge fertile with basidia and scattered cystidia. Cheilocystidia 40-70 x 7-9 µm, same as pleurocystidia. Subhymenium layer up to 30 µm thick, cellular. Hymenophoral trama composed of hyphae and sphaerocytes. Pileipellis composed of repent to suberect hyphae (up to 4.5 µm broad) and pileocystidia. Pileocystidia 4.5-6.5 µm broad, fusiform to ventricose, content refractive. Stipitipellis composed of connective hyphae, up to 5.5 µm broad. Caulocystidia absent.

Ecology : Common, grows etomycorrhizally under the species of *Quercus*, *Rhododendron* and *Cedrus* in deciduous to mixed temperate forests.

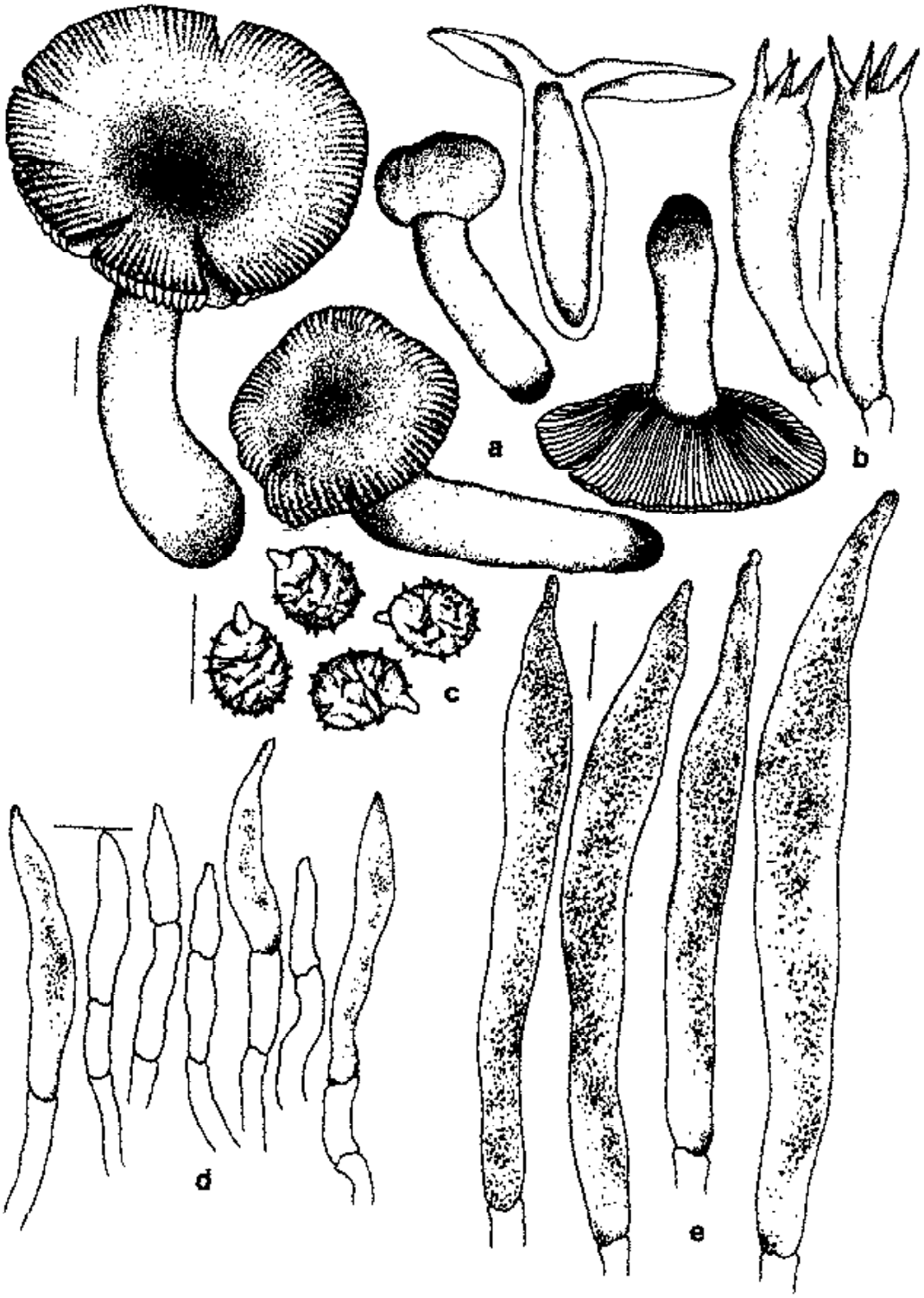


Fig. 65. *Russula praetervisa*: a. Basidiomes b. Basidia c. Basidiospores d. Cross section of pileipellis e. Pleurocystidia. Bars: a = 10 mm; b-e = 10 µm.

Specimens examined : Uttaranchal, Bageshwar, Dhakuri, September, 2003, **col.** K. Das, KD7009; *ibid.* September 1999, **col.** K. Das & J.R. Sharma, KD1018; *ibid.*, KD1038; Uttaranchal, Champawat, Mayawati, September 2002, **col.** K. Das, KD4569; Uttaranchal, Almora, Mornoula, October 2002, **col.** K. Das, KD 4578.

Notes : Russula praetervisa appears to be one of the most common species in different parts of Kumaon Himalaya. It shares many characters with *Russula pectinata* Fr. But unlike the present species, the latter has a distinct acrid taste (Sarnari 1998) without purplish red stains at stipe base. *R. hortensis* Sarnari also resembles but *R. praetervisa* differs in having darker basidiomes, no purplish red stains at the stipe base and more complete reticulation in basidiospores.

Russula subfoetens W.G. Smith

Journ. Bot. London **11**: 337, 1873; Rawla, Pl. Div. Him. (2001) 25; Saini & Atri, Kavaka **17**(1989) 25. Fig. 66

Pileus 67-105 mm diam., convex to applanate with slightly depressed center; pileipellis viscid brilliant to very yellow or medium to deep orange yellow; margin tuberculately striale, sulcate. Lamellae adnexed, rather distant, few forked, yellow white; lamellulae present. Stipe 80-130 x 25-35 mm, central, cylindric, slightly narrow towards apex and base, yellowish white, slightly brownish after maturity, $FeSO_4$ (+); context hollow at maturity, yellowish white, lemon yellow after bruising, distinctly golden yellow in KOH. Taste slightly acrid. Spore print yellowish white.

Basidiospores 7.5-9.5 x 6.8-8.8 µm, subglobose to broadly ellipsoid; ornamentation partially amyloid, up to 1 µm high, composed mostly of conic warts and few connectives, forming atmost broken reticulum. Basidia 38-50 x 9-13 µm, clavate, 4-spored; sterigmata long, up to 9 µm. Pleurocystidia 50-120 x 7-14 µm, ventricose with acute, mucronate or appendiculate apices. Cheilocystidia 32-50 x 5-9 µm, cylindric to clavate or ventricose. Pileipellis composed of interwoven hyphaeand pileocystidia; Pileocystidia up to 6 µm broad, fusoid to cylindric with mucronate, capitate to appendiculate apices.

Ecology : Rare, grows ectomycorrhizally with species of *Quercus* in moist mixed temperate forests.

Specimens examined : Uttaranchal, Bageshwar, Dhakuri, September 2003, **col.** K. Das & J.R. Sharma, KD7020.

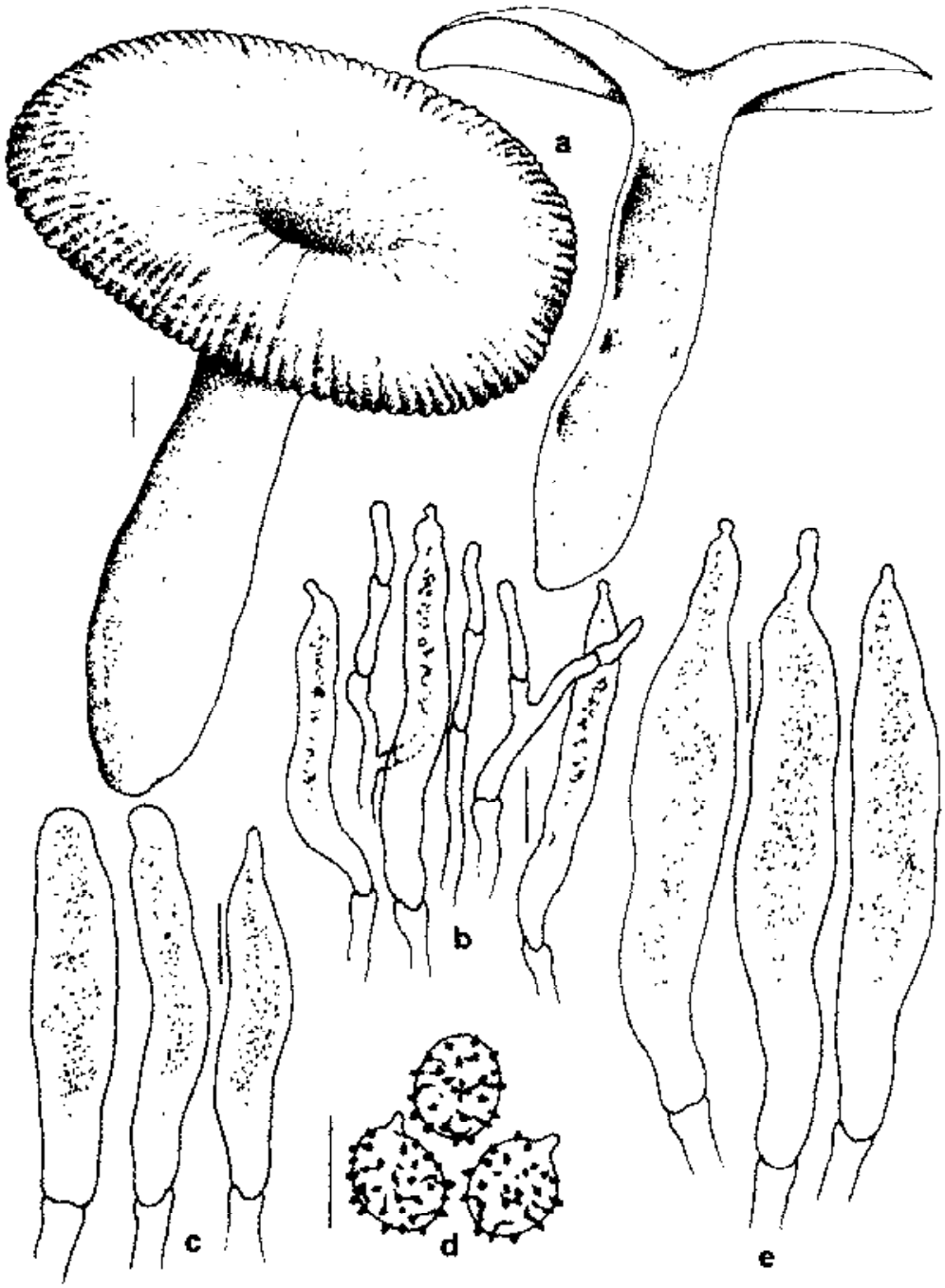


Fig. 66. *Russula subfoetens*: a. Basidiomes b. Cross section of pileipellis c. Cheilocystidia d. Basidiospores e. Pleurocystidia. Bars: a = 10 mm; b-e = 10 µm.

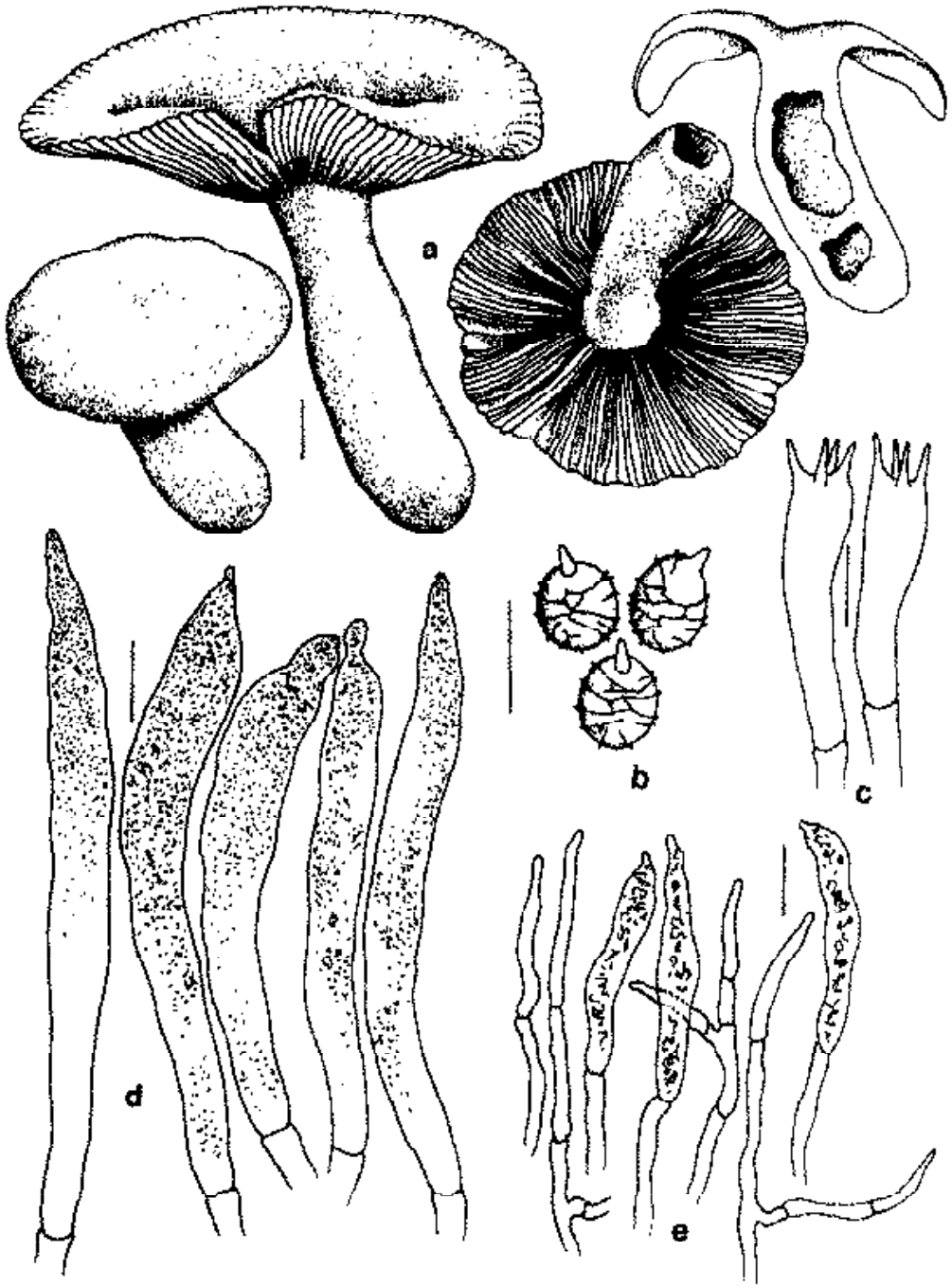


Fig. 67. *Russula* sp. 4: a. Basidiomes b. Basidiospores c. Basidia d. Pleurocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

Notes : Russula subfoetens and *R. foetens* resemble closely in macro- and microscopic characters but both can be separated by characters discussed under *R. foetens*.

Russula sp. 4 Pl. 23; fig. 67

Pileus 60-105 mm diam., convex, planoconvex, planoconcave to umbelicate at maturity; pileipellis dry, viscid when moist, slight glutinous, tuberculately sulcate, white, yellowish white with yellowish gray in the center, sometimes light to medium brown spots at the periphery, unchanging; margin decurved, gradually plane at maturity. Lamellae adnexed, subdistant to close (6-7 per cm), forked near stipe, brittle, yellowish white to cream; lamellulae absent; edges even. Stipe 40-70 x 16-22 mm, dry, central, cylindric to subclavate, concolorous with pileus; context solid to stuffed, white to yellowish white, unchanging $FeSO_4$(+). Taste mild. Odor insignificant. Spore print yellowish white.

Basidiospores 6.5-8.8 x 5.8 7.1 µm, subglobose to broadly ellipsoid, Q = 1.08-1.25 (1.34); ornamentation amyloid, up to 0.4 µm high, composed mostly of minute warts and ridges forming incomplete reticulum. Basidia 28-35 x 7.5-9 µm, subclavate to clavate, 4-spored; sterigmata up to 6 µm long. Pleurocystidia 60-90 x 6-10.5 µm, emergent up to 30 µm, fusiform with mucronate to capitate apices, content dense. Lamellae edge fertile. Cheilocystidia not found. Subhymenium layer up to 27 µm thick, cellular. Pileipellis composed of suberect hyphae and pileocystidia; pileocystidia up to 5 µm broad. Stipitipellis composed of parallel hyphae (up to 3 µm broad). Stipe trama composed of numerous sphaerocytes.

Ecology : This species grows in close association with species of *Quercus* in moist temperate (2300-2700 m) deciduous to mixed forests in Kumaon Himalaya.

Specmens examined : India, Uttaranchal : Pithoragarh, Dafia Dhura, October 2001, **col.** K. Das & J.R. Sharma, KD4097 (**Holotype**, BSD); *ibid.*, Bageshwar, Dhakuri, September 2003, **col.** K. Das & J.R. Sharma, KD7008 (GUH); *ibid.*, KD7070 (BSD).

Notes : This species is distinguished in the field by having the unique combination of characters like whitish coloration of pileipellis which is unchanging on bruishing or with age, tuberculate margin of the pileus and basidiospores with minute warts and ridges. Based on the viscid pileipellis, sulcate pilear margin, adnexed lamellae, low ornamented basidiospores and presence of pileocystidia, the present taxon is placed in the subgenus *Ingratula* Romagnesi emend. Sarnari.

Plate 23: a. *Russula foetens* b. *R. laurocerasi* c. *Russula* sp. 4.

Plate 24: a & c. *Russula praetervisa* b. *R. pectinata* d. *R. abbotensis*.

In the field, this species appears quite close to *R. brevipes* Peck var. *brevipes* and *R. delica* Fr. However, typically shorter stipe, presence of numerous lamellulae, absence of tuberculately sulcate margin of pileus (Shaffer 1964, Sarnari 1998), acrid taste of basidiomes and higher spore ornamentation differentiate both *R. brevipes* var. *brevipes* and *R. delica* from the present species. Moreover, presence of typically decurrent lamellar attachment also help in the separation of *R. brevipes* var. *brevipes* from the present taxon.

Subgenus **Russula** emend. Sarnari
Monografia Illustrata del Genera Russula in Europa : 110, 1998.

Pileus convex to umbelicate, pileipellis dry or viscid, always bright coloured, red, purple or yellowish, smooth, pruinose or rarely areolate; margin smooth sulcate or tuberculately striate; lamellae adnexed to subdecurrent; stipe white to reddish purple; basidiospore ornamentations with isolated warts and connectives; hymenial cystidia present; pileocystidia septate or aseptate. Forty eight taxa in India; fourteen in Kumaon Himalaya.

Note : Three species namely *Russula gracillima, R. nitida* and *R. versicolor* belonging to the subgenus, were reported from Kumaon Himalaya by Rawla (2001). Unfortunately, during our extensive and intensive surveys of the study area, fresh specimens could not be procured. The descriptions provided in this manual are based only on the herbarium material as cited under the specimens examined.

KEY TO THE SPECIES

1a. Pileus bright to orange yellow, never red 2

b. Pileus reddish, reddish brown, or purplish or vinaceous atleast in part4

2a. Pileocystidia thin-walled, pileus lemon yellow ..... **R. raoultii**

b. Pileocystidia thick-walled, pileus orange yellow 3

3a. Spore ornamentation up to 1 µm high; basidia up to 16 µm broad ..... **R. flavida** var. **dhakurianus**

b. Spore ornamentation up to 0.6 µm high basidia up to 8 µm broad ..... **R. flavida**

4a. Basidiomes yellowing gradually after bruising or at maturity ..... **Russula** sp. 5

b. Basidiomes not yellowing 5

5a. Basidiomes quickly blackening ..... **R. rhodometanea**

b. Basidiomes not blackening 6

6a. Pileus orange, context reddening on exposure ..... **R. decolorans**

b. Pileus not orange, context not reddening 7

7a. Pileocystidia without septa 8

b. Pileocystidia always septate 9

8a. Stipe yellowish white to ochraceous, salmon pink in $FeSO_4$ ..... **R. decipiens**

b. Stipe white with vinaceous tinge, greenish in $FeSO_4$ ..... **R. xerampelina**

9a. Pileus distinctly discoloring gradually from the margin ..... **R. emetica**

b. Pileus not discoloring as above 10

10a. Pileus cracked or areolate, always with a yellowish tinge at the center; basidispores 7.7-11.5 x 6.2-8.3 µm ..... **Russula** sp. 6

b. Pileus never cracked or areolate, without a yellowish tinge; basidiospores not larger than 9.6 µm 11

11a. Pileus reddish orange; stipe up to 70 mm long ..... **R. vaurasiana**

b. Pileus vinaceous; stipe not more than 50 mm long 12

12a. Stipe buff to ochraceous ..... **R. gracillima**

b. Stipe vinaceous to sienna tinted 13

13a. Basidiospores never reticulate; stipe feebly striate ..... **R. nitida**

b. Basidiospores subreticulate; stipe distinctly veined ..... **R. versicolor**

Russula decipiens (Singer) Svrcek.

Cesk. Mycol. **21**: 228, 1967; *Russula maculata* var. *decipiens* Singer, Bull. Soc. Mycol. Fr. **46**: 212, 1931.

Pl. 27, fig. 68

Pileus 70-90 mm diam., convex to planoconvex with depressed center or slightly infundibuliform; pileipellis mat, soft red to red; margin regular, sulcate. Lamellae adnexed to subdecurrent, close, forked near the stipe, lamellulae present. Stipe 37-50 x 10-13 mm, central, subclavate to clavate, yellowish white, slightly graying after bruising, $FeSO_4$ (+); context yellowish white, stuffed unchanging. Odour indistinctive. Taste acrid. Spore print pale to orange yellow.

Basidiospores 8-9.3 x 6.6-7.5 µm, subglobose to broadly ellipsoid (Q = 1.08-1.25); ornamentation amyloid, up to 1 µm high of conic warts

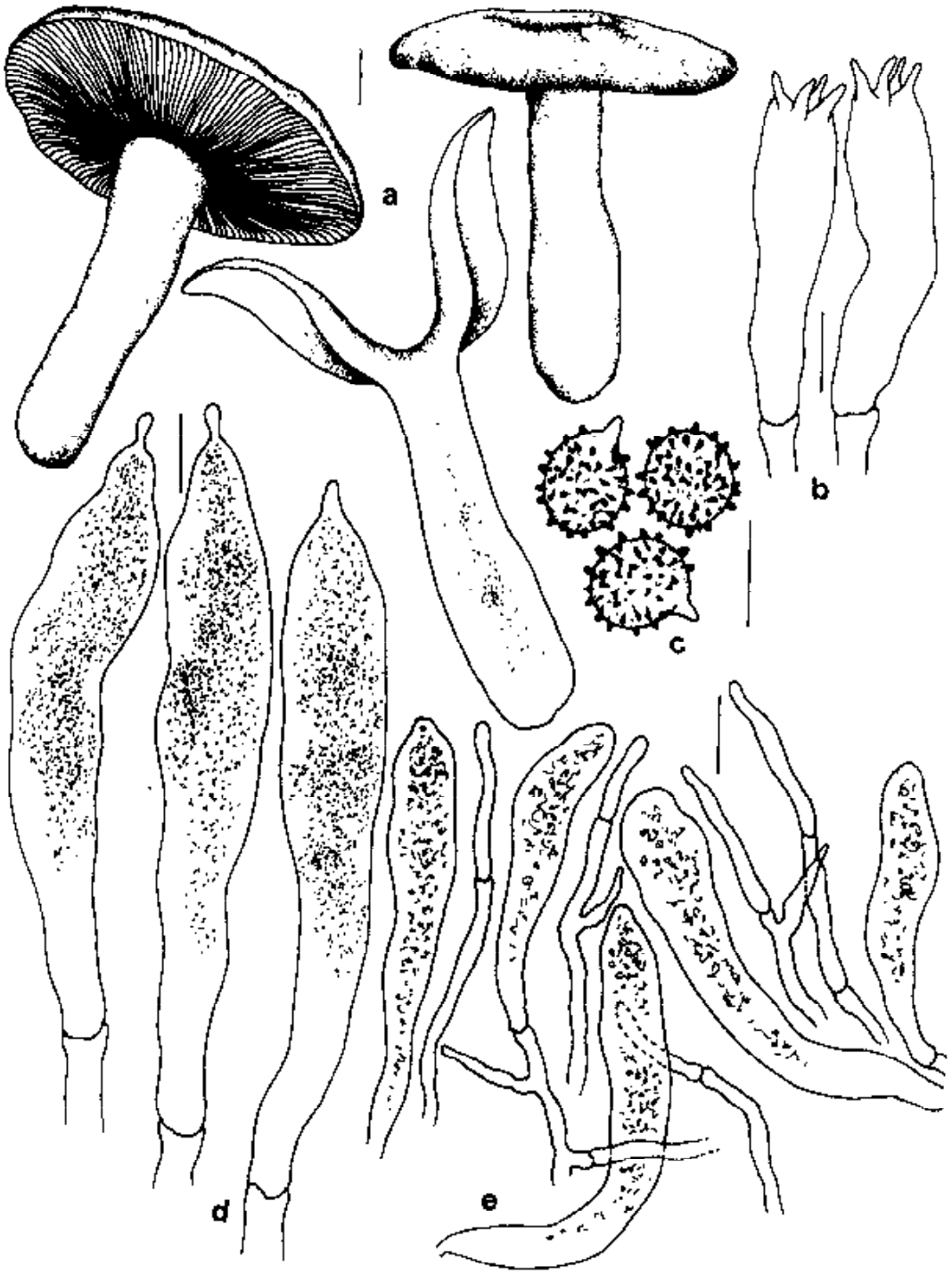


Fig. 68. *Russula decipiens*: a. Basidiomes b. Basidia c. Basidiospores d. Pleurocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 μm.

and few connectives forming somewhat broken reticulum; plage, distinct amyloid. Basidia 42-55 x 10-14 µm, clavate, 4-spored. Hymenial cystidia 60-90 x 11-15 µm, abundant, fusiform with mucronate to appendiculate apices; contents dense. Lamellae edge fertile with basidia and a few cystidia. Pileipellis composed of erect to suberect hyphae (up to 5 µm broad) and dermatocystidia. Pileocystidia, up to 11 µm, broad, subclavate to clavate, nonseptate; contents dense.

Ecology : Common, grows in ectomycorrhizal association with species of *Quercus* in temperate mixed forests.

Specimens examined : Uttaranchal, Nainital, Mukteshwar, August 2002, **col.** K. Das, KD2123; *ibid.*, KD2124.

Notes : Russula decipiens is easily distinguished by its whitish stipe which slouty becomes grayish after bruising, orange yellow spore print and nonseptate pileocystidia. The presence of 1-3 septate pileocystidia separates closely related *R. emetica* var. *emetica* from the present taxon.

Russula decolorans Fr.

Epicr. Syst. Mycol.: 361. 1838 ; Das & Sharma, Ind. J. For. **26**(2003) 323; Phytotax 4(2004) 2. Pl. 25; fig. 69

Pileus 40-85 mm, convex, center slightly depressed when mature; pileipellis viscid, glabrous, orange yellow or soft to very orange; margin even to sulcate, often radially furrowed, peeling at the margin only. Lamellae close (6-8 per cm), adnexed, forked near the stipe, lamellulae in a single row, yellowish white, grayish with age. Stipe 40-80 x 20-25 mm, subclavate to clavate, white, graying with age or after bruising, $FeSO_4$ (+). Context white turning reddish or orange gray on exposure. Odor indistinctive. Taste mild. Spore print pale yellow

Basidiospores 7-9.4 x 6-7.7 µm (Q = 1.06-1.26, av. 1.17-1.20), subglobose to broadly ellipsoid; ornamentation amyloid, conic to spiny warts up to 1.6 µm high, sometimes connected by fine ridges; plage distinct. Basidia 42-60 x 12-15 µm, subclavate to clavate, 4-spored; sterigma up to 6 µm long. Pleurocystidia 60-115 x 9-14 µm, abundant, subclavate to fusiform or conical with subacute to mucronate apices, emergent up to 40 µm; contents refractive. Lamellae edge fertile with basidia and a few cystidia. Cheilocystidia 40-60 x 7-10 µm, same as pleurocystidia. Subhymenium layer up to 25 µm thick, cellular. Pileipellis 50-90 µm thick, composed of repent to suberect hyphae (up to 5 µm broad) and dermatocystidia. Pileocystidia 40-58 x 7-9 µm, numerous, subclavate to obtuse, thick walled; 0-1 septate. Stipitipellis composed of mostly repent hyphae (up to 4 µm broad); caulocystidia not observed.

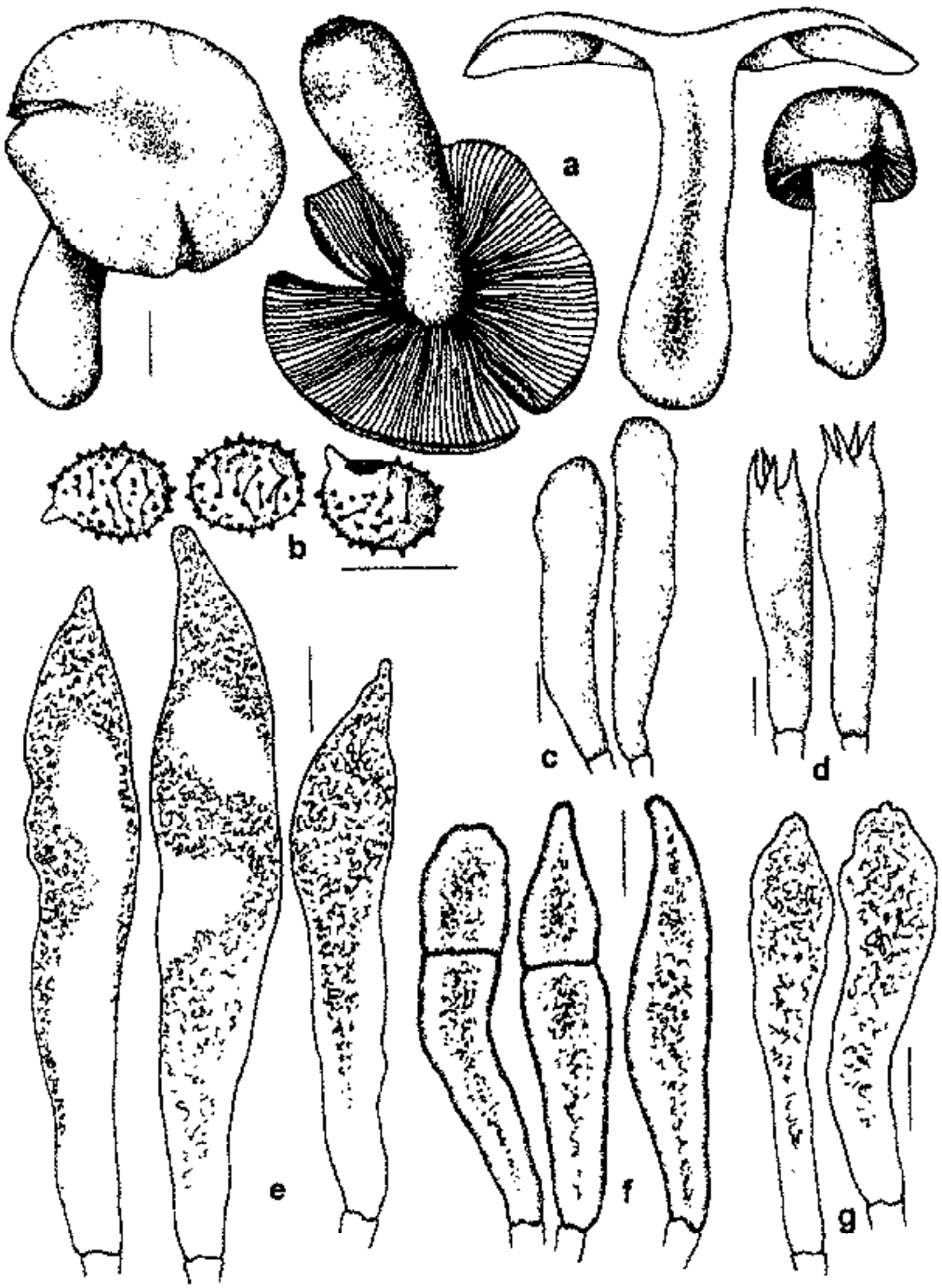


Fig. 69. *Russula decolorans*: a. Basidiomes b. Basidiospores c & e. Pleurocystidia d. Basidia f. Pileocystidia g. Cheilocystidia. Bars: a = 10 mm; b-g = 10 µm.

Ecology : Rare, grows in temperate deciduous and mixed forests, forming ectomycorrhizal association with species of *Quercus* and *Rhododendron*.

Specimens examined : Uttaranchal, Champawat, Mayawati, September 2002, **col.** K. Das & J.R. Sharma, KD4559; Uttaranchal, Almora, Mornoulla, October 2002, **col.** K. Das & J.R. Sharma, KD4593; Uttaranchal, Nainital, Ramgarh, August 2002, **col.** K. Das, KD2181.

Notes : The basidiomes of *Russula decolorans* have a close similarity with *R. aurantiolutea* Kauffman and *R. aurantioflammans* Ruotsalainen, Sarnari & Vauras. But *R. aurantiolutea* and *R. aurantioflammans* have distinct acrid taste and the context also lacks the reddening on exposure (Kibby & Fatto 1990, Sarnari 1998). Further, *R. aurantiolutea* has no lamellulae intermixed with lamellae.

Russula emetica (Schaeff. : Fr.) Pers.

Observations Mycologicae 1: 100, 1796. *Agaricus emeticus* Schaeff., Fungor. Bavdr. Icon IV: 9, 1774. Sys. Myc. 1: 56, 1821Berk. Hook. J. Bot. 3(1851) 43; Roy, Fungi. Beng. (1947); Rawla, Pl. Div. Him. (2001) 11; Kumar *et al.*, Ind. J. Mush. 5(1979) 23; Das & Sharma, Phytotax. 4(2004)2. Pl. 25; fig. 70

Pileus 35-65 mm diam., convex at first, planoconvex to planoconcave; pileipellis viscid when moist, very red, deep red to reddish orange, gradually discoloring from the margin; margin decurved at first, plane when mature. Lamellae adnexed to subdecurrent, crowded (12 per cm), forked near the stipe; lamellulae present. Stipe 37-50 x 10-13 mm, central, cylindrical to subclavate, yellowish white, slightly ochraceous after bruising, $FeSO_4$ (+); context white, unchanging. Odour indistinctive, Taste acrid. Spore print white to buff.

Basidiospores 7.4-9.8 x 6-7 µm, subglobose to ellipsoid (Q = 1.14-1.46); ornamentation amyloid, conic warts up to 1.2 µm with fine ridges forming incomplete reticulum; plage distinct. Basidia 35-50 x 10-11.5 µm, clavate, 4-spored. Hymenial cystidia 50-75 x 8-12 µm, fusoid, subfusoid, cylindrical or subclavate with mostly rounded to blunt apices, emergent up to 20 µm; contents dense. Lamellae edge fertile with basidia and cystidia. Pileipellis composed of erect to suberect branched septate hyphae and dermatocystidia; hyphae up to 3.5 µm broad; pileocystidia up to 10 µm broad, cylindrical, subclavate to clavate, 1-3 septate.

Ecology : Common, grows in grassy ground as well as in ectomycorrhizal association with species of *Quercus* and *Rhododendron* in temperate mixed forests. The species also has an extended distribution to the subalpine forests growing in close association with bushes.

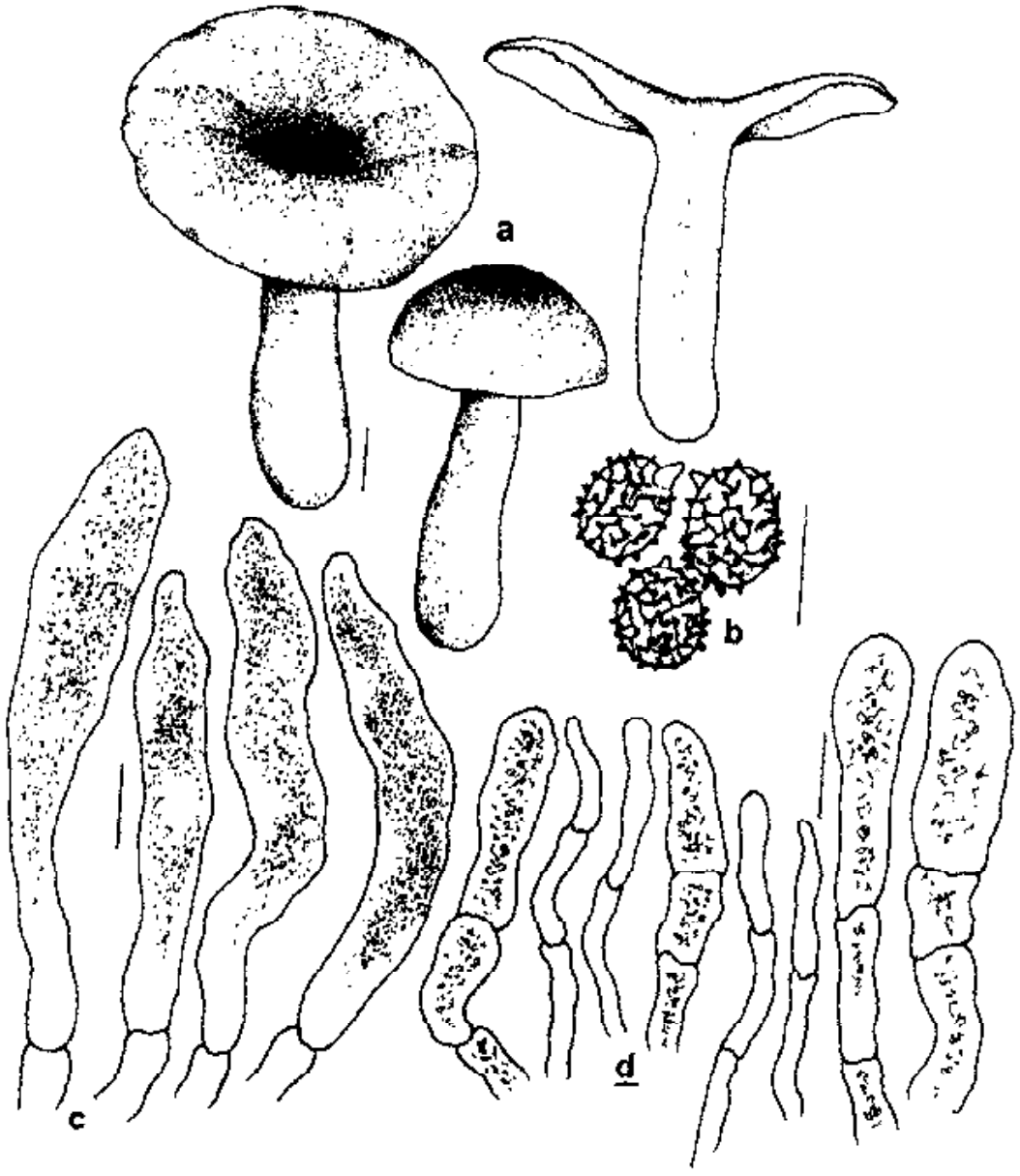


Fig. 70. *Russula emetica*: a. Basidiomes b. Basidiospores c. Pleurocystidia d. Cross section of pileipellis. Bars: a = 10 mm; b-d = 10 µm.

Specimens examined : Uttaranchal, Bageshwar, Dhakuri, September 2003, **col.** K. Das, KD7086; *ibid.*, KD7083; *ibid.*, September 1999, **col.** K. Das & J.R. Sharma, KD1034. Uttaranchal, Bageshwar, Phurkia, September 1999, **col.** K. Das & J.R. Sharma, KD1101; *ibid.*, September 2003, **col.** K. Das & J.R. Sharma, KD7007.

Notes : Russula emetica var. *emetica* can be differentiated in the field with bright red pileus which gradually discolors from the margin, distinctly acrid taste, larger spores, septate pileocystidia and blunt hymenial cystidia. It resembles *R. decipiens* but the latter is separated as mentioned in the notes under *R. decipiens*.

Russula flavida Frost

Ann. Rep. N.Y. State Mus. **32**: 32, 1880; Das *et al.*, Mush. Res. **11**(2002)9; Das & Sharma, Phytotax. **4**(2004) 2. Pl. 26; fig. 71

Pileus 35-65 mm diam., convex, planoconvex to applanate when mature; cuticle dry to moist, granulose, brilliant to orange yellow; margin incurved to plane. Context white, unchanging. Lamellae adnate to slightly notched, close (8 per cm), often forked near stipe, apex rounded, pale yellow. Stipe 40- 55 x 8.5-15 mm, cylindrical to slightly tapered towards base; surface dry, velvety, pruinose, concolorous with pileus, $FeSO_4$ (+); context white, unchanging, dark pink in sulfovanillin, dark red in 1% phenol. Spore print pale yellow.

Basidiospores 6.0-8.7 x 5.8-7.3 µm, subglobose to broadly ellipsoid (Q ≈ 1.06-1.3), amyloid, verrucae up to 0.6 µm, forming incomplete reticulation. Basidia 32-40 x 7-8 µm, subclavate, 4-spored. Pleurocystidia 45-70 x 10-13 µm, emergent up to 24 µm, clavate to ventricose-rostate, often with attenuated prolonged apices. Cheilocystidia 52-60 x 10-12 µm, subfusoid with blunt apices. Subhymenium up to 33 µm thick, cellular. Pileipellis a trichoderm, pileocystidia thick-walled, up to 11 µm broad. Pilear hyphae 4-6 µm broad, septate.

Ecology : Rare, grows in ectomycorrhizic association with *Rhododendron arboreum* Sm. in temperate deciduous forests.

Specimens examined : Uttaranchal, Pithoragarh, Dafia Dhura forest, September 2001, **col.** K. Das & J.R. Sharma, KD4072; ibid., October 2001, KD4092.

Notes : Its separation from *R. flavida* var. *dhakurianus* is discussed below.

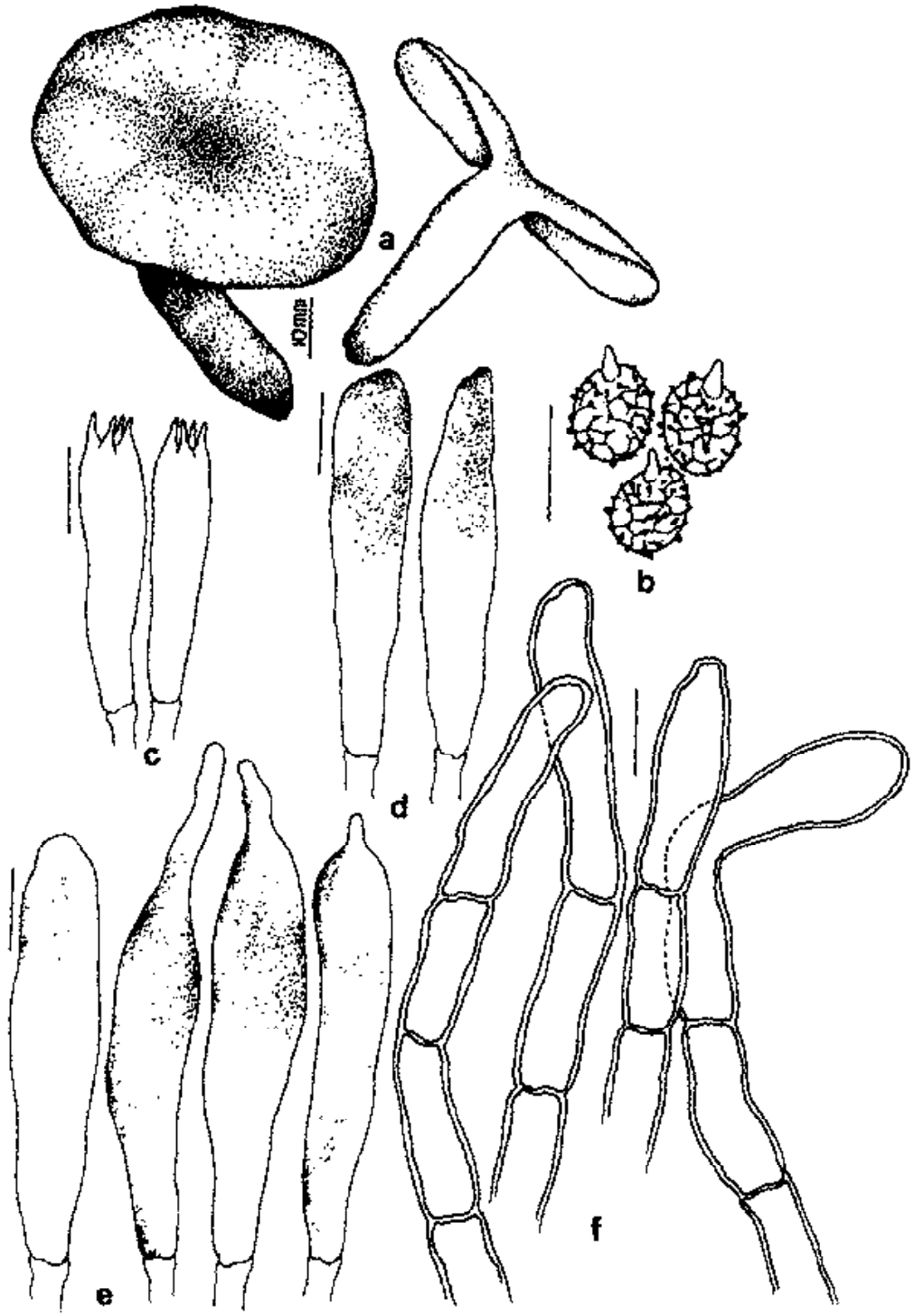


Fig. 71. *Russula flavida* var. *flavida*: a. Basidiomes b. Basidiospores c. Basidia d. Cheilocystidia e. Pleurocystidia f. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

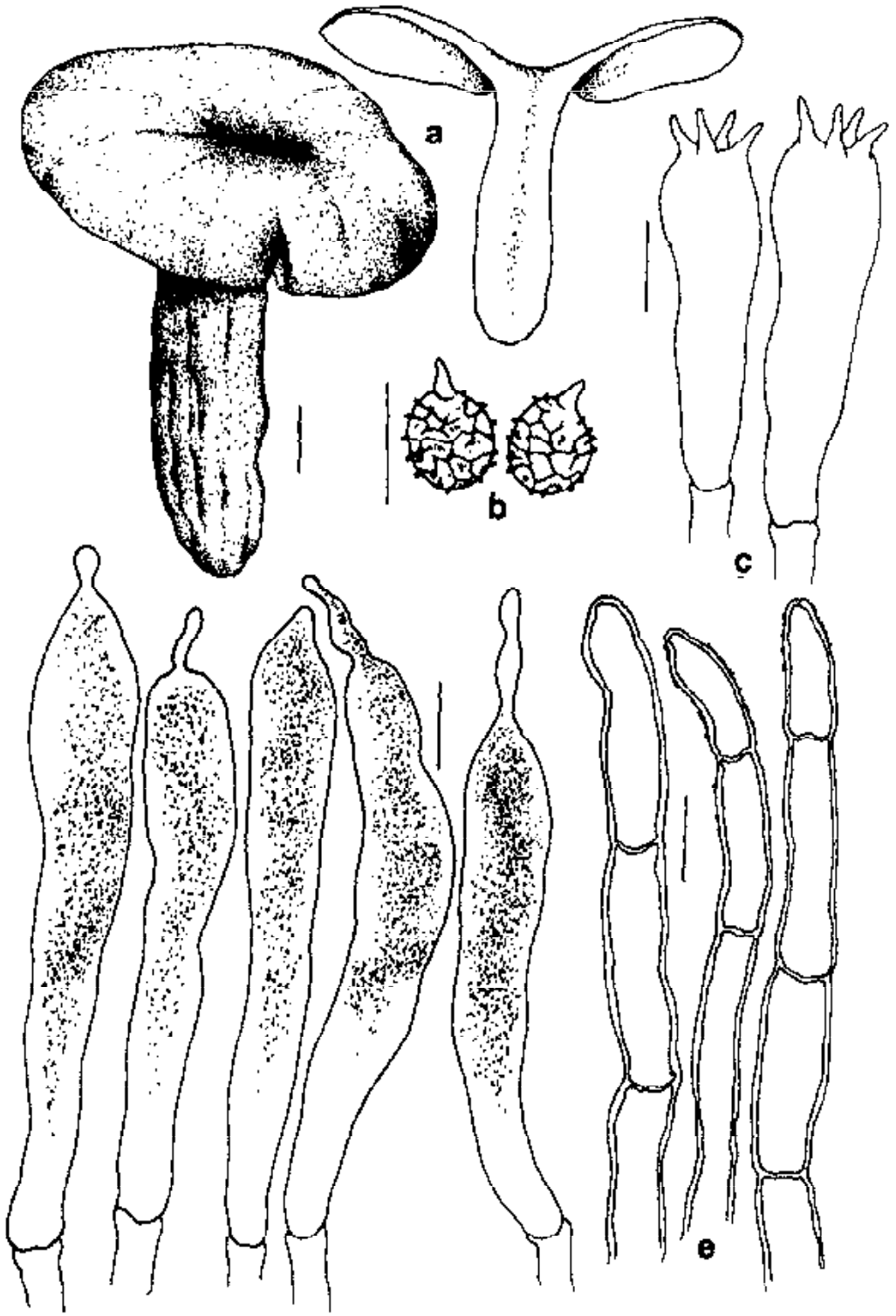


Fig. 72. *Russula flavida* var. *dhakurianus*: a. Basidiomes b. Basidiospores c. Basidia d. Pleurocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

Russula flavida Frost

Ann. Rep. N.Y. State Mus. **32**: 32, 1880. var. **dhakurianus** K. Das, J.R. Sharma & R.P. Bhatt ***var. nov.***
Pl. 26; fig. 72

Etymology : Dhakuri, referring to the type locality.

*Pileus 25-65 mm diam., convexus, planoconvexus ad depressus in centro, luteus. Lamellae late adnatae ad annexae luteae. Stipes 25-53 x 9.5-14 mm, cylindricus, pileo concolor. Sporae in cululo luteae, 6.6-8.5 x 6-7.1 µm, globosae vel ellipsoidae. Pleurocystidia 54-80 x 8-13 µm, subfusoidae ad ventricosae. India. Uttaranchal: Bageshwar, Dhakuri, September 1999, leg. K. Das & J.R. Sharma, KD1071 (**Holotypus**, BSD).*

Pileus 25-65 mm diam., convex with depressed center gradually planoconvex with slightly depressed center at maturity; cuticle dry, viscid when moist, pruinose, never areolate, brilliant to orange yellow; margin peeling up to 1/4th decurved to plane. Context very brittle, white, unchanging. Lamellae broadly adnate to adnexed, slightly notched, rather close (ca 6 per cm), apex rounded, pale yellow; lamellulae rare. Stipe 25-53 x 9.5-14 mm, central, cylindrical, often longitudinally grooved; surface dry, velvety, pruinose or scurfy, concolorous with pileus, often orange coloured at base; context white, unchanging. Spore print pale to brilliant yellow.

Basidiospores 6.6-8.5 x 6-7.1 µm, subglobose to ellipsoid or rarely globose [Q = (1.03) 1.08-1.33]; ornamentation amyloid, verrucae up to 1 µm, and connectives forming incomplete reticulation. Basidia 25-35 x 8-16 µm, clavate, 4-spored. Pleurocystidia 54-80 x 8-13 µm, fusoid to ventricose, with attenuated prolonged or mucronate apices. Cheilocystidia same as pleurocystidia. Subhymenium up to 20 µm thick, cellular. Pileipellis a trichoderm, composed of thick walled hyphae and pileocystidia. Pileocystidia up to 9 µm broad, thick walled; wall up to 0.8 µm thick. Pilear trama also composed of thick walled hyphae.

Ecology : R. flavida var. *dhakurianus* is rare and grows in ectomycorrhizic association with the species of *Rhododendron*, *Abies* and *Picea* in moist temperate forests.

Specimens examined : India. Uttaranchal: Bageshwar, Dhakuri, September 1999, **col.** K. Das & J.R. Sharma, KD1071 (**Holotype**, BSD); *ibid.*, KD1069.

Notes : Russula flavida var. *dhakurianus* is characterized by bright orange yellow, pruinose basidiomes notched lamellae with rounded apex, thick-walled pileocystidia and small partially reticulate spores. The absence of granulose pileipellis separates the present taxon from the typical variety (Bills & Miller 1984). Moreover, the lower spore-ornamentation (0.3-0.6 µm) and narrower basidia in the typical variety also help in its separation from the present variety.

Again, *R. ochroleucoides* Kauffman is also quite close to the present taxon but, *R. ochroleucoides* has nearly white stipe, bitter to acrid taste, larger pileus and duller yellow pileus.

Russula gracillima Schaeff.

Zeitschr. F. Pilzk. **10**: 105, 1931; Rawla, Pl. Div. Him. (2001)14; Das & Sharma, Phytotax. 4(2004)3.

Pileus 20-40 mm diam., convex to applanate, depressed at maturity; pileipellis purple, dark vinaceous, violaceous, margin complete, smooth, sulcate. Lamellae adnate to subdecurrent, crowded, ochreous; margin smooth, concolorous. Stipe 20-35 x 3-5 mm, cylindric, feebly striate, white, buff, ochreous. Spore print yellowish white to saffron luteous.

Basidiospores 7.5-9 x 6.5-8 µm (Q = 1.1), subglobose; ornamentation amyloid, up to 0.75 µm high of mostly conic isolated warts. Basidia 25-50 x 8-10 µm, clavate, 4-spored. Pleurocystidia 60-100 x 10-14 µm, subfusiform with attenuated apices. Pileipellis of erect hyphae and cystidia; hyphae 2-3 µm broad, terminal cell not attenuated, basal cell swollen; Pileocystidia 60-100 x 5-10 µm, cylindrical to clavate, aseptate. SV positive (faint).

Ecology : Rare, grows in ectomycorrhizal association with species of *Cupressus* in temperate coniferous forest.

Specimens examined : Uttaranchal, Nainital, Naini Peak, September 1981, **col.** G.S. Rawla, PAN 9815.

Notes : Russula gracillima can be easily distinguished by its smaller fruiting body, purple, dark vinaceous-violaceous pileus (up to 4 cm diam.), feebly striate stipe (50 x 3-5 mm). Moreover, microscopically, aseptate pileocystidia in pileipellis make the species more distinct.

It is quite close to *R. queletii* Fr., but strong fruity smell of the later separates it from the present taxon.

Russula nitida (Pers.: Fr.) Fr.

Epicr. Syst. Mycol., 361. 1838: Rawla, Pl. Div. Him. (2001) 19: Atri & Saini, Geob. N. Rep. **5**(1986) 102; Atri *et al.*, Bot. Sci. Res. Ind. (1991) 97; Das & Sharma, Phytotax. 4(2004)3.

Pileus 17-25 mm diam., applanate to infundibuliform at maturity; pileipellis smooth, viscid, brownish-orange to brown, sienna, purplish red or vinaceous;

margin inrolled, sulcate. Lamellae free to decurrent, rather crowded (7-8 per cm), yellowish white; margin smooth, concolorous. Stipe 30-35 x 5-10 mm, central, clavate, feebly striate, viscid, white to yellowish white, tinted red to brown, $FeSO_4$ (+). Context in stipe yellowish white. Spore print 'Pale saffron luteous'.

Basidiospores 7.5-9 x 6.5-9 µm, subglobose; ornamentation amyloid, 1-1.5 µm high of conic to spiny isolated to sometimes connected warts, never reticulate. Basidia 30-40 x 10-12 µm, clavate, 4-spored. Pleurocystidia 40-100 x 5-7 µm, Pileipellis of hyphae and pileocystidia; hyphal terminal cells cylindrical with somewhat subcapitate apices; pileocystidia 40-100 x 4-6 µm, abundant, cylindrical to clavate, aseptate to septate, up to 3.5-4.2 µm wide.

Ecology : Rare, grows in ectomycorrhizal association with species of *Cupressus* in temperate coniferous forest.

Specimens examined : Uttaranchal, Nainital, China Peak, October 1981, col. G.S. Rawla, PAN 9816 & 9817.

Notes : Russula nitida is characterized by small basidiomesbrownish to vinaceous pileus, white with red to brown tinted and viscid stipe. The presence of strongly veined stipe, sulcate pilear margin and the presence of subreticulate spores separate *R. versicolor* from the present taxon.

Russula raoultii Quélet,

Ass. Fr. av. Sci. **14**: 449. 1886; Das & Sharma, Ind. J. For. **26**(2003) 320. Pl. 25; fig. 73

Pileus 40-60 mm diam., convex at first, applanate to slightly umbilicate at maturity; pileipellis dry, peeling up to 1/4th, light to greenish yellow (lemon yellow), gradually fading towards margin at maturity. Lamellae adnexed, rather crowded (10-11 per cm), interveined, lamellulae in a single row, white to yellowish white. Stipe 33-44 x 5-14 mm, cylindrical to subclavate, white, slightly grayish after bruising, $FeSO_4$ (+). Odour indistinctive, Taste acrid. Spore print white.

Spores 6.6-9.2 x 5.8-7 µm (Q = 1.06-1.38, av. 1.19-1.27), subglobose to ellipsoid; ornamentation amyloid, composed of conic warts (less than 1 µm) and fine ridges forming almost complete reticulation; plage distinct. Basidia 30-45 x 7.8-11 µm, subclavate, 4-spored; sterigmata up to 6 µm long. Pleurocystidia abundant 44-80 x 8-11 µm, fusiform with obtuse, mucronate to moniliform apices, emergent up to 24 µm; contents refractive. Lamellae edge fertile with basidia and cystidia. Cheilocystidia fusiform with tapering apices. Subhymenium layer up to 30 µm thick, cellular. Pileipellis up to 30

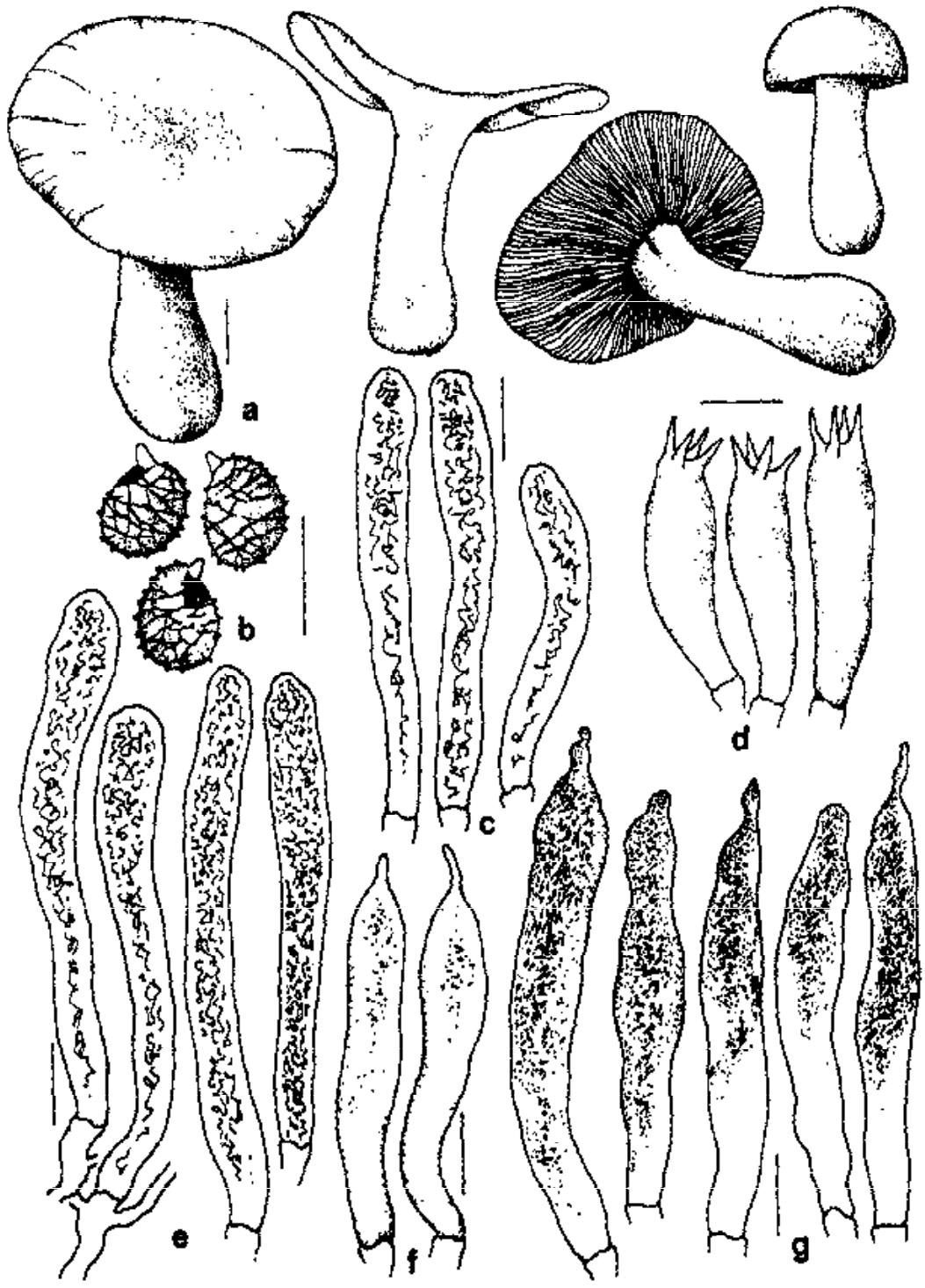


Fig. 73. *Russula raoultii*: a. Basidiomes b. Basidiospores c. Caulocystidia d. Basidia e. Pileocystidia f. Cheilocystidia g. Pleurocystidia. Bars: a = 10 mm; b-g = 10 µm.

µm, composed of erect to suberect hyphae and pileocystidia. Pileocystidia 6-8.5 µm broad, abundant, subfusiform, cylindric or subclavate, unseptate; contents refractive. Stipitipellis composed of hyphae and caulocystidia. Caulocystidia up to 7 µm broad, abundant, cylindrical to subclavate.

Ecology : Rare, grows in ectomycorrhizal association with species of *Quercus* in temperate deciduous forests.

Specimens examined : Uttaranchal, Pithoragarh, Dafia Dhura, September 2001, **col.** K. Das & J.R. Sharma, KD4076; Uttaranchal, Almora, Mornoulla, October 2002, **col.** K. Das & J.R. Sharma, KD4563.

Notes : Russula raoultii may be confused with *R. cyanoxantha* Fr. var. *flavoviridis* (Romagn.) Sarnari and *R. heterophylla* Fr. var. *chlora* (Gill.) Kühn. & Romagn. in the field. *Russula cyanoxantha* however, has larger basidiomes (Pileus 90-140 mm diam.; Stipe 50-60 x 25-27 mm), mild taste and the spores with hemispherical scattered warts without forming reticulations (Sarnari 1998). *R. heterophylla* var. *chlora* differs from the present species by its lamellae which are forked and anastomosing at the stipe attachment, dermatocystidia which show distinct blackening bodies only with sulphoaldehydic agents (Romagnesi 1996) and smaller (5.5-6.7 x 4.2-6 µm), verruculose to verrucose spores with a few connective lines and without reticulations.

Russula rhodomelanea Sarnari

Rivista di Micologia **36**: 53. 1993; Das & Sharma, Mush. Res. **10**(2001) 109; Das & Sharma, Phytotax. **4**(2004)3. Pl. 25; fig. 74

Basidiomes solitary to gregarious. Pileus 45-65 mm diam., convex to plano-convex, sometimes applanate to uplifted, slightly depressed at center; cuticle thin, viscid when moist, glabrous, medium to deep red, blackish red to black after bruising. Lamellae adnexed, equal, entire, medium crowded (8-9 per cm), pale yellow, gradually black after bruising or on maturity. Stipe 50-65 x 9-18 mm, central, subequal to subclavate, white to yellowish white, black after bruising, $FeSO_4$ (+), stuffed. Spore print yellowish white.

Spores 7.5-9 x 6.3-7.6 µm, subglobose, amyloid, ornamentation mostly of conic warts, up to 1 µm high with few connectives forming a partial reticulum. Basidia 35-46 x 9.9-12.5 µm, clavate, 4-spored. Pleurocystidia 66-91.5 x 7.9-10.5 µm, subcylindrical, fusiform or fusoid clavate; apices mucronate, appendiculate, capitate or acute, content dense, niddle-like to granular. Cheilocystidia 54-76 x 6.5-8, similar to pleurocystidia. Pileipellis a trichoderm, up to 45 µm thick; hyphae up to 1.6 µm broad; pileocystidia septate, up to 8 µm broad.

Ecology : Common, grows in ectomycorrhizal association with the species of *Quercus* in temperate deciduous forests.

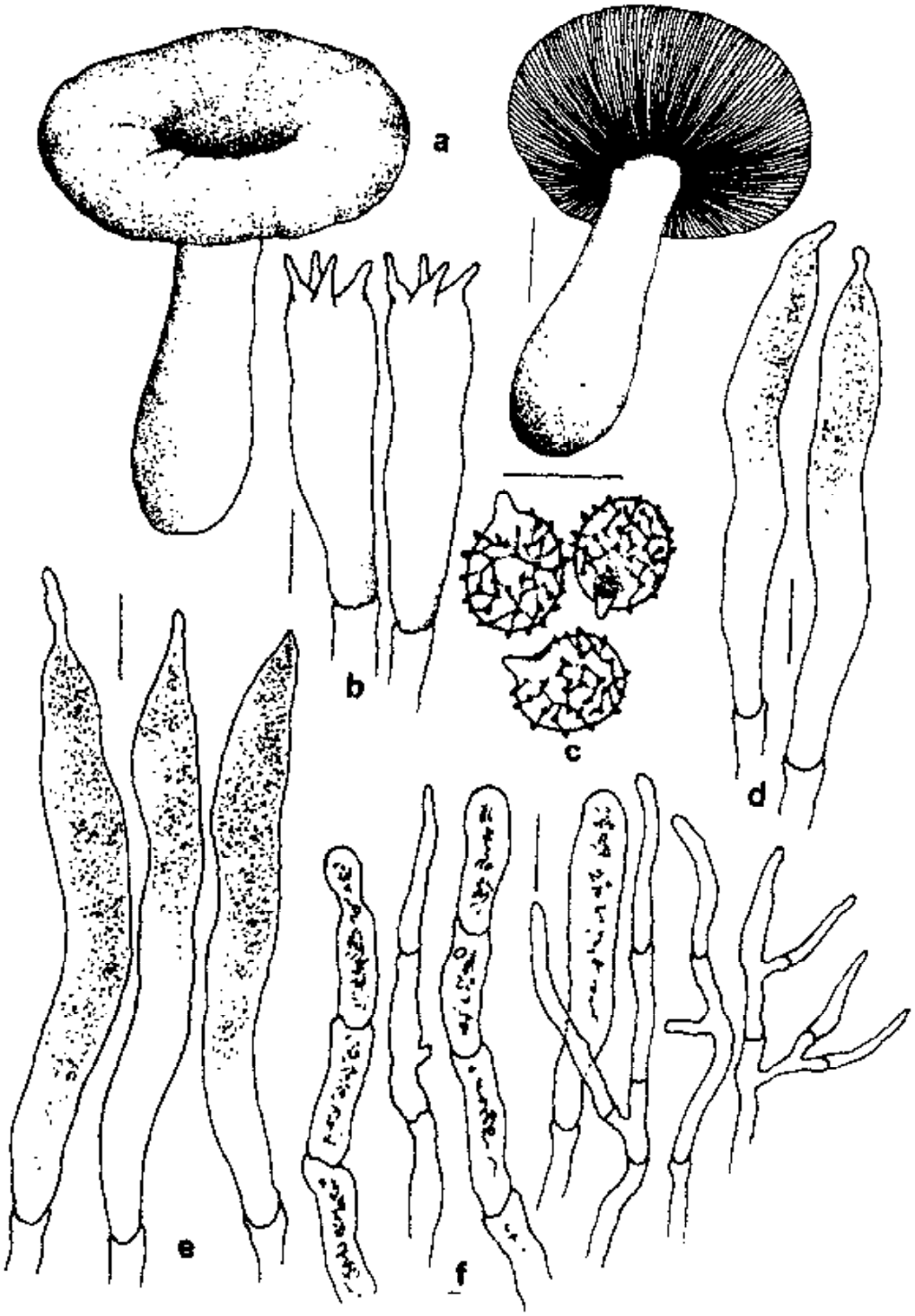


Fig. 74. *Russula rhodomelanea*: a. Basidiomes b. Basidia c. Basidiospores d. Cheilocystidia e. Pleurocystidia f. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

Specimens examined : Uttaranchal, Bageshwar, Dhakuri top, September 1999, **col.** K. Das & J.R. Sharma, KD719; *ibid.*, KD728, KD732.

Notes : The present species can easily be characterized morphologically by its bright red pileus and white stipe, turning slowly jet black after bruising or on maturity and microscopically by the presence of abundant appendiculate to fusoid pleurocystidia with dense contents. *R. rhodomelanea* resembles closely with *R. emetica* (Schaeff.: Fr.) Pers., *R. mairei* Sing. and *R. emeticella* (Sing.) Romagn., all belonging to the series *Russula* (Sarnari 1998). But the distinct bluish shade in the stipe of young basidiocarps of *R. mairei*; smaller spores (7-8.2 x 6-7 µm) of *R. emeticella* and the larger spores (8.8-10.5 x 7.4-8.8 µm) of *R. emetica* coupled with the unchanging context separate all the three species from *R. rhodomelanea*. The purple coloured pileus and whitish stipe which remains unchanged on bruising in *R. fragilis* (Pers.: Fr.) Fr. separates it from the present species in the field itself even if they resemble in taste and odour.

Russula vaurasiana K. Das & J.R. Sharma *sp. nov.*
Pl. 26; fig. 75

Etymology: After Jukka Vauras for his contribution on the genus Russula

*Pileus 40-65 mm diam., convexus ad infundibuliformis erythroaurantiacus. Lamellae annexae, densae luteoalbae. Stipes 50-75 x 17-20 mm, subclavatus, luteoalbus. Sporae in cumulo albidae, 7.3-9.8 x 6.2-8.0 µm, globosae vel ellipsoidae. Pleurocystidia 60-110 x 10-16 µm, fusiformia. Cheilocystidia 36-70 x 7.6-12 µm, fusiformia, clavatus ad cylindricus. Pileocystidia cylindricus ad subclavatus. INDIA, Uttaranchal, Nainital, Mukhteshwar, August 2002, leg. K. Das, KD2123 (**Holotypus**, BSD).*

Pileus 40-65 mm diam., convex, umbelicate at maturity; pileipellis viscid when moist, matty, soft to deep yellowish pink to reddish orange, light orange yellow tinge at center; margin upturned, tuberculately sulcate. Lamellae adnexed, close (7-8 per cm), forked, interveined; lamellulae in a single row, yellowish white. Stipe 50-75 x 17-20 mm, central, subclavate, yellowish white, $FeSO_4$ (+); context white. Taste mild. Spore print whitish.

Basidiospores 7.3-9.8 x 6.2-8 µm, globose to ellipsoid (Q = 1.02-1.35); ornamentation amyloid, up to 2 µm high, composed of elongated warts and ridges, aligned or joined with few connectives. Basidia 40-50 x 8-10 µm, subclavate, 4-spored; sterigma long, up to 6 µm. Pleurocystidia 60-110 x 10-16 µm, emergent up to 36 µm, abundant, fusiform to subfusiformor with mucronate, tapering or sometimes forked apices; contents dense. Lamellae edge fertile with basidia and few cystidia. Cheilocystidia 36-70 x 7.6-12 µm, fusiform, subclavate to cylindrical with rounded or mucronate apices;

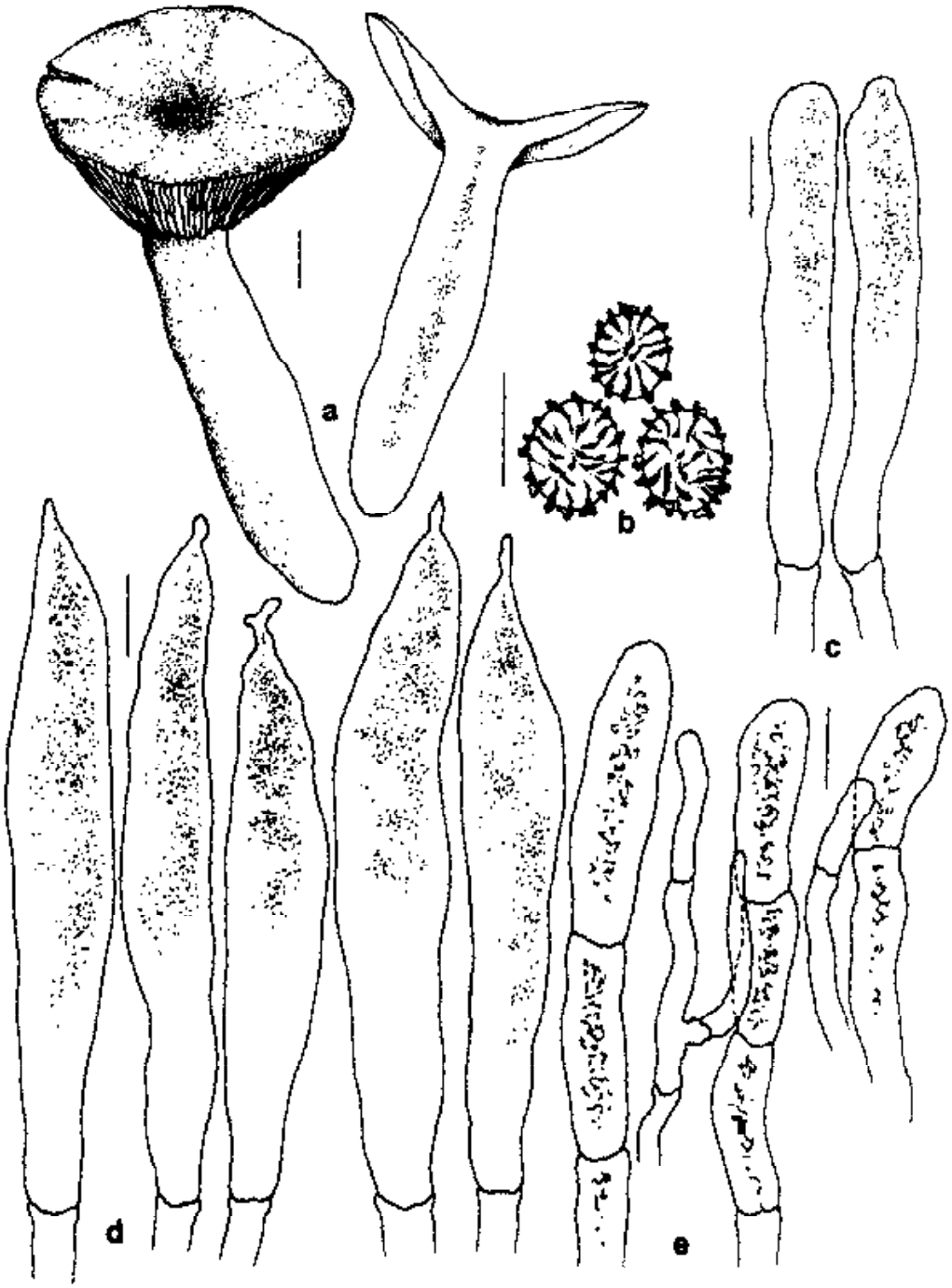


Fig. 75. *Russula vaurasiana*: a. Basidiomes b. Basidiospores c. Cheilocystidia d. Pleurocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-e = 10 µm.

contents dense. Subhymenium layer up to 20 µm thick, cellular. Pileipellis composed of erect to suberect hyphae and pileocystidia; hyphae up to 4 µm broad; pileocystidia up to 8.5 µm, broad, cylindrical to subclavate, 1-3 septate. Stipitipellis composed of mostly repent hyphae. Caulocystidia absent.

Ecology : Rare, grows in ectomycorrhizal association with species of *Quercus* in temperate mixed forests.

Specimens examined : Uttaranchal, Nainital, Mukteshwar, August 2002, **col.** K. Das, KD2123.

Notes : These specimens undoubtedly belong to the subgenus *Russula* due to bright red colouration of pileus and presence of pileocystidia. The combination of characters is uniques and does not match with any known taxon of the subgenus.

Russula versicolor Schaeff.

Russula monographie Ann. Mycol. **31**: 369, 1933; Rawla, Pl. Div. Him. (2001) 25; Atri & Saini, Geob. N. Rep. **5**(1986) 103; Atri *et al.*, Bot. Sci. Res. Ind. (1991) 94; Das & Sharma, Phytotax. **4**(2004)4.

Pileus 15-30 mm diam., convex to planoconvex; pileipellis reddish purple to dark vinaceous; margin complete, inrolled, almost smooth. Lamellae adnate, forked near base, interveining; lamellulae present, yellowish to ochreous. Stipe 10-25 x 5-10 mm, cylindric, feebly to strongly veined, buff. $FeSO_4$ (+). Taste acrid. Spore print pale saffron yellow to ochreous.

Basidiospores 7.5-9.6 x 6-7 µm (Q = 1.2), subglobose to broadly ellipsoid; ornamentation amyloid, up to 0.8 µm high, composed of isolated to connected warts forming broken to partial reticulum. Basidia 25-40 x 8-10 µm, clavate, 4-spored. Pleurocystidia 50-80 x 4-5 µm, fusiform. Pileipellis repent of hyphae and cystidia; hyphal terminal cells cylindric with subcapitate apices; pileocystidia 40-50 x 4-7 µm, cylindrical, fusiform or clavate, up to 8-septate.

Ecology : Rare, grows in ectomycorrhizal association with species of *Cupressus* in moist temperate coniferous forest.

Specimens examined : Uttaranchal, Nainital, Naini Peak, September 1981, **col.** G.S. Rawla, PAN 9819.

Notes : This species is close to *R. nitida*. But in contrast to the present species the latter has sulcate pilear margin, sticky stipe without veination and isolated spores.

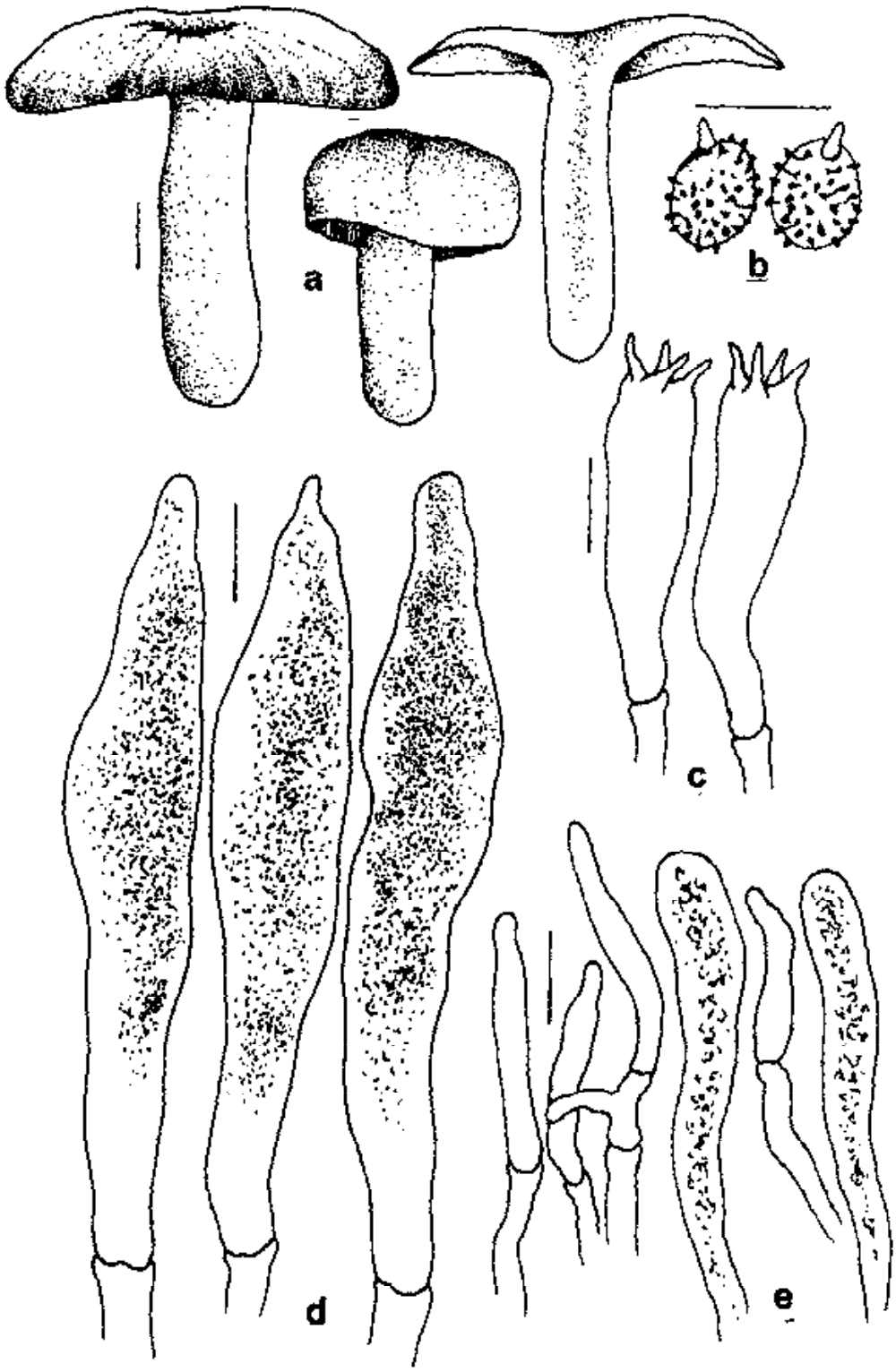


Fig. 76. ***Russula xerampelina***: a. Basidiomes b. Basidiospores c. Basidia d. Pleurocystidia e. Cross section of pileipellis. Bars: a = 10 mm; b-f = 10 µm.

Russula xerampelina (Schaeff.) Fr.

Epicr. Syst. Mycol., 1838; Rawla, Pl. Div. Him. (2001) 26; Saini & Atri, Geob. N. Rep. 3(1984) 5; Atri *et al.*, Curr. Res. Pl. Sci. (1994) 87; Das & Sharma, Phytotax. 4(2004)4. Pl. 26; fig. 76

Pileus 40-75 mm diam., convex, planoconvex with slightly depressed center at maturity; pileipellis viscid when moist, peels off easily, deep red with dark red at center or vinaceous red overall; margin plane, smooth or slightly sulcate at maturity. Lamellae adnexed to subdecurrent, subdistant to rather close (6-8 per cm), entire, forked from the stipe, sometimes intervenose, cream. Stipe 28-60 x 8-15 mm, central, cylindrical to slightly broder at base, white tinged with vinaceous red, browning at maturity, greenish in $FeSO_4$. Taste mild. Spore print ochraceous yellow.

Basidiospores 6.6-8.2 x 5.4-7.4 µm, subglobose to ellipsoid or rarely globose (Q = 1.05-1.28); ornamentation amyloid, up to 1.6 µm high, composed of conic to spinoid isolated warts. Basidia 40-55 x 11-13 µm, clavate, 4-spored. Pleurocystidia 90-116 x 11-17 µm, emergent up to 46 µm, abundant, fusiform to ventricose with blunt to rounded apices; contents dense. Cheilocystidia same as pleurocystidia. Pileipellis composed of upper erect to suberect hyphae and dermatocystidia; hyphae up to 4 µm broad; pileocystidia narrow up to 7 µm, broad, fusiform, cylindrical to subclavate.

Ecology : Rare, grows in ectomycorrhizal association with species of *Quercus* in temperate deciduous forests.

Specimens examined : Uttaranchal, Champawat, Hingla Devi forest, August 2002, **col.** K. Das, KD2101; Uttaranchal, Pithoragarh, Sandev, Sept. 2001, **col.** K. Das & J.R. Sharma, KD4010.

Notes : Russula xerampelina is easily differentiated in the field with vinaceous red pileus and stipe. Microscopically, aseptate pileocystidia and basidiospore ornamentation of isolated spinoid warts are also distinct. *Russula decipiens* which resembles closely with the present species lacks the vinaceous colour on pileus and stipe.

Russula sp. 5 Pl. 27; fig. 77

Pileus 20-35 mm diam., convex, planoconvex with slightly depressed center at maturity; pileipellis viscid when moist, soft to dark reddish purple with blackish purple center, light grayish or grayish to dark purplish red, slowly yellowish orange at maturity or after bruishing, peeling up to ½ of the radius; margin plane, tuberculately striated. Lamellae adnexed to subdecurrent, crowded (10-12 per cm), entire, forked from the stipe, yellowish

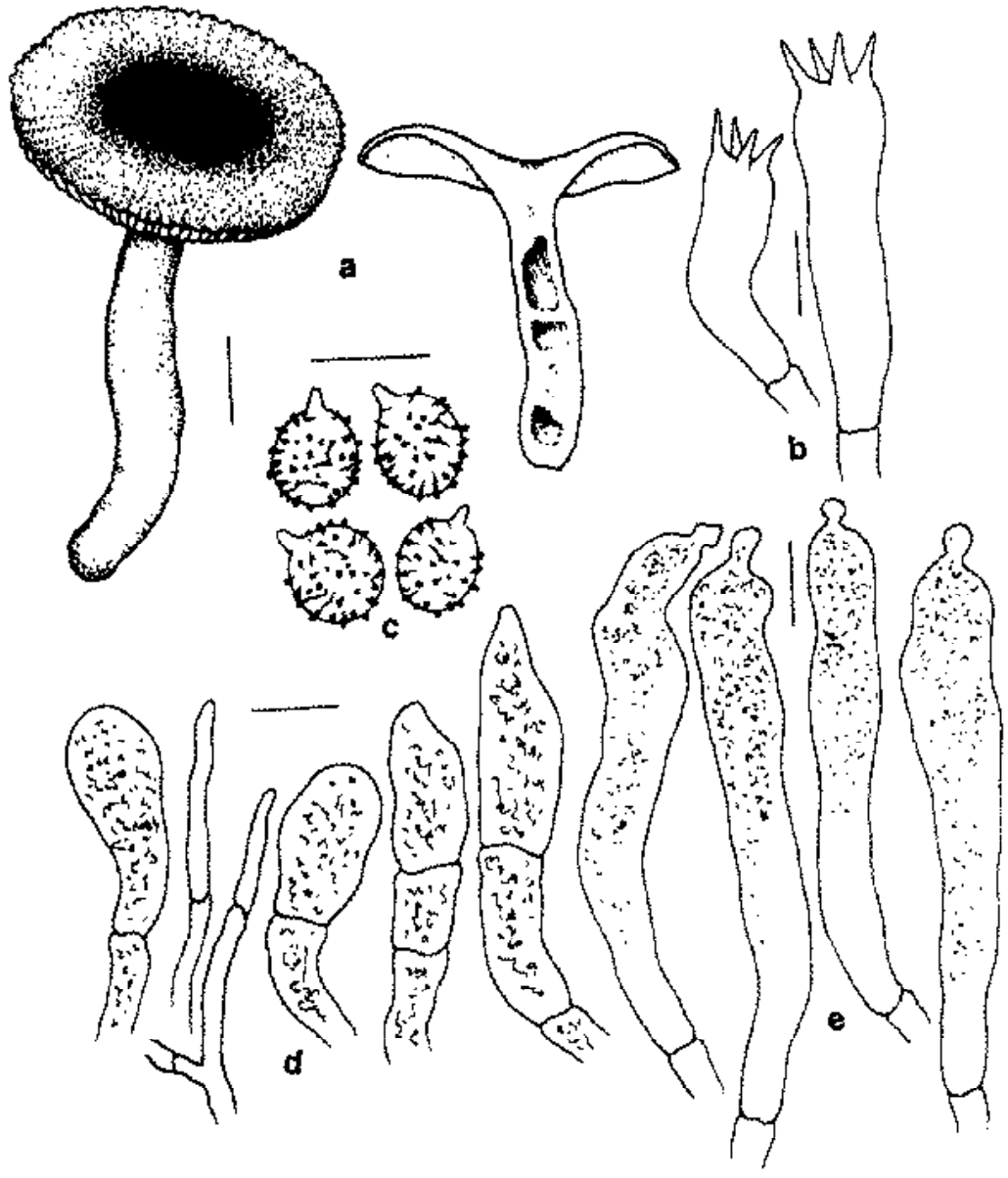


Fig. 77. *Russula* sp. 5: a. Basidiomes b. Basidia c. Basidiospores d. Cross section pf pileipellis e. Pleurocystidia. Bars: a = 10 mm; b-e = 10 µm.

white, yellowish orange at maturity or after bruising. Stipe 23-63 x 5-13 mm, central, cylindrical to clavate, yellowish white, distinctly yellowish orange after bruising or at maturity $FeSO_4$ (+); context white, yellowing after bruising. Taste mild. Spore print yellowish to buff.

Basidiospores 7.4-9.6 x 6-7.7 µm, subglobose to ellipsoid (Q = 1.08-1.43); ornamentation amyloid, up to 1.4 µm high, composed of conic to spinoid warts and ridges, aligned or joined with few connectives to form broken reticulum. Basidia 26-40 x 7-11 µm, clavate, 4-spored; sterigma up to 6 µm. Pleurocystidia 50-70 x 9-12 µm, emergent up to 12 µm, abundant, fusiform to cylindrical with capitate, or appendiculate apices; contents dense. Lamellae edge ferile with basidia and few cystidia. Cheilocystidia same as pleurocystidia. Subhymenium layer up to 28 µm thick, cellular. Pileipellis composed of upper erect to suberect hyphae and pileocystidia; hyphae up to 5 µm broad; pileocystidia up to 10 µm, broad, subclavate to clavate, 1-2 septate; contents dense; below a layer of parallel compact hyphae.

Ecology : Common, grows in ectomycorrhizal association with species of *Quercus* and *Rhododendron* in temperate deciduous to mixed forests.

Specimens examined : India, Uttaranchal : Bageshwar, Dhakuri, September 2003, **col.** K. Das & J.R. Sharma, KD7022 (**Holotype**, BSD); *ibid.*, Pithoragarh, Dafia Dhura, October 2001, **col.** K. Das & J.R. Sharma, KD4063.

Notes : This species is differentiated in the field by reddish purple pileus with tuberculately striate margin and basidiomes gradually turning yellow to yellowish orange after bruising. Bright coloration of the pileus, septate pileocystidia and nature of hymenial cystidia place the present taxon in the subgenus *Russula*. The morphological and microscopic characters of specimens from Kumaon Himalaya match closely with *R. puellaris* Fr. except variation in the spore ornamentation. The molecular analysis (Fig. 79) also supports its similarity with *R. puellaris* (clade 9).

Russula sp. 6 Pl. 27; fig. 78

Pileus 40-65 mm diam., convex, then planoconvex to infundibuliform with a depression at maturity; pileipellis viscid when moist, often crustose (cracked) at the center, peeling only at margin, deep yellowish pink to medium or deep red or yellowish red, medium to dark or orange yellow at center; margin slightly sulcate. Lamellae adnexed to subdecurrent, close (7-8 per cm), forked, pale to orange yellow. Stipe 40-50 x 7-12 mm, central, cylindric to subclavate, yellowish white. $FeSO_4$ (+). Taste acrid. Spore print pale yellow.

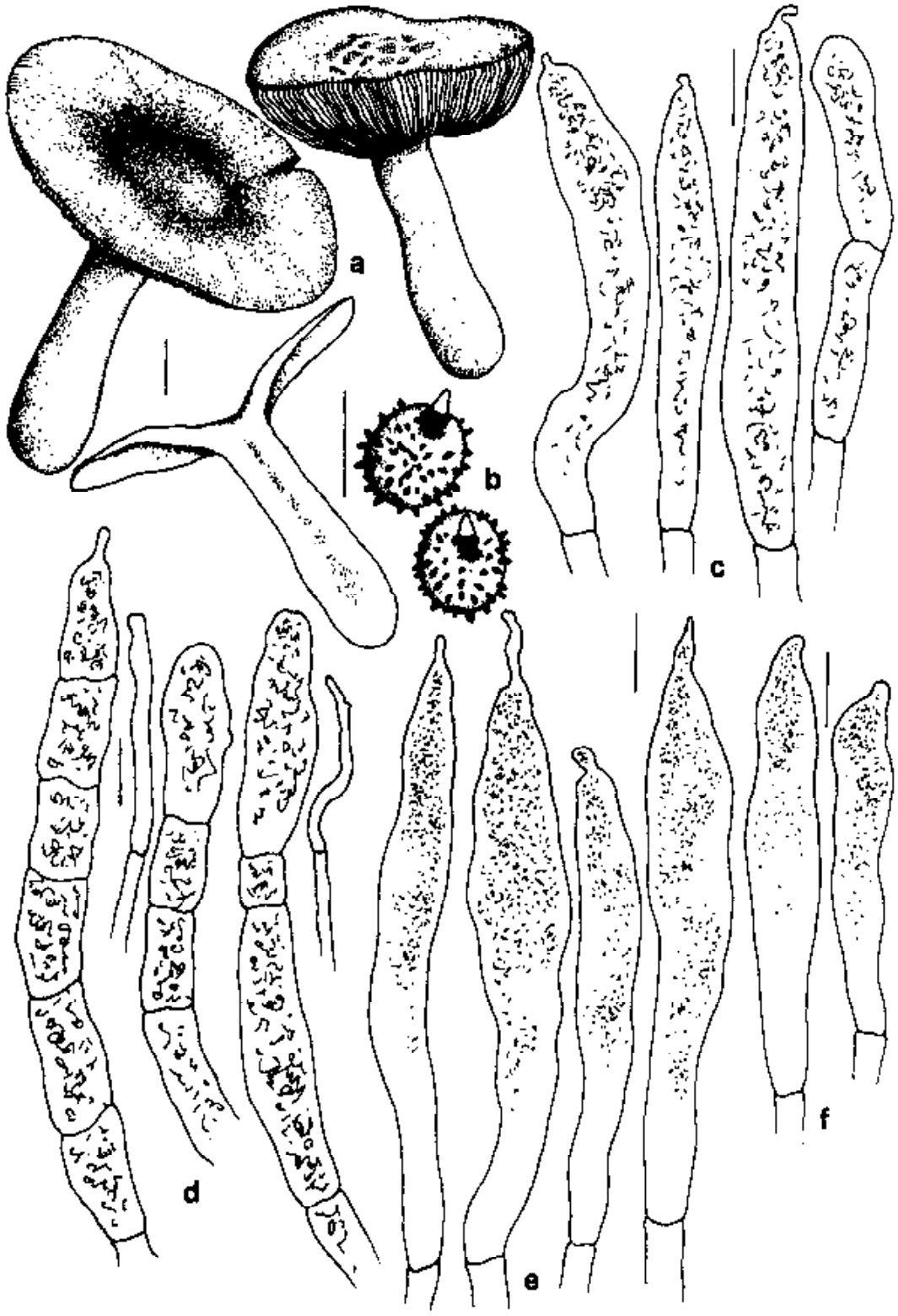


Fig. 78. *Russula* sp. 6: a. Basidiomes b. Basidiospores c. Caulocystidia d. Cross section of pileipellis e. Pleurocystidia f. Cheilocystidia. Bars: a = 10 mm; b-f = 10 µm.

Basidiospores 7.7-11.5 x 6.2-8.3 µm, globose, subglobose, broadly ellipsoid to ellipsoid (Q = 1.05-1.4); ornamentation amyloid, warty; conic warts up to 1.75 µm high, of numerous conic warts, rarely connected by fine ridges. Basidia 40-50 x 7-9 ìm, subclavate to clavate, 4-spored; sterigma up to 6 µm long. Pleurocystidia 68-125 x 9-15 µm, emergent up to 40 µm, abundant, fusiform or with acute, acuminate to narrowly moniliform apices; contents dense. Lamellae edge sterile with a few cystidia. Cheilocystidia 50-70 x 6-9 µm, fusiform; contents dense. Subhymenium layer up to 20 µm thick, cellular. Pileipellis up to 100 µm thick, composed of erect to suberect hyphae and abundant pileocystidia; pileocystidia up to 12 µm, broad, fusiform to cylindrical or acuminate-rostrate, 3-6 septate. Stipitipellis composed of mostly repent hyphae and abundant cystidia. Caulocystidia up to 8 µm broad, clavate, subclavate or fusoid; contents dense.

Ecology : This species grows in close association with species of *Quercus* and *Rhododendron* in moist mixed temperate forests.

Specimens examined : India, Uttaranchal : Champawat, Mayawati, September 2002, **col.** K. Das & J.R. Sharma, KD4542 (**Holotype**, BSD; isotype, TUR-A, GUH,); *ibid.*, Nainital, Gagar, August 2002, **col.** K. Das, KD2149, KD2158).

Notes : Bright reddish coloration of pileus, pale yellow spore print, multiseptate (3-6 septate) pileocystidia firmly place this taxon in the subgenus *Russula* emend. Sarnari. It is differentiated easily by its reddish pileus with yellowish center, distinctly acrid taste, larger basidiospores and 3-6 septate pileocystidia. The present taxon is close to *R. maculata* Quélet & Rose and *R. cuprea* Krombholz. But the smaller basidiospores [8 10 (10.4) x 7 9 µm], fusiform and less septate pileocystidia in *R. maculata* and diverticulate pileocystidia and hyphal ends of pileus in *R. cuprea* separate these species from the present species. The molecular analysis (fig. 79) clearly shows the closeness between the present species and *R. maculata* (clade 8), whereas, *R. cuprea* is distantly related (apical clade).

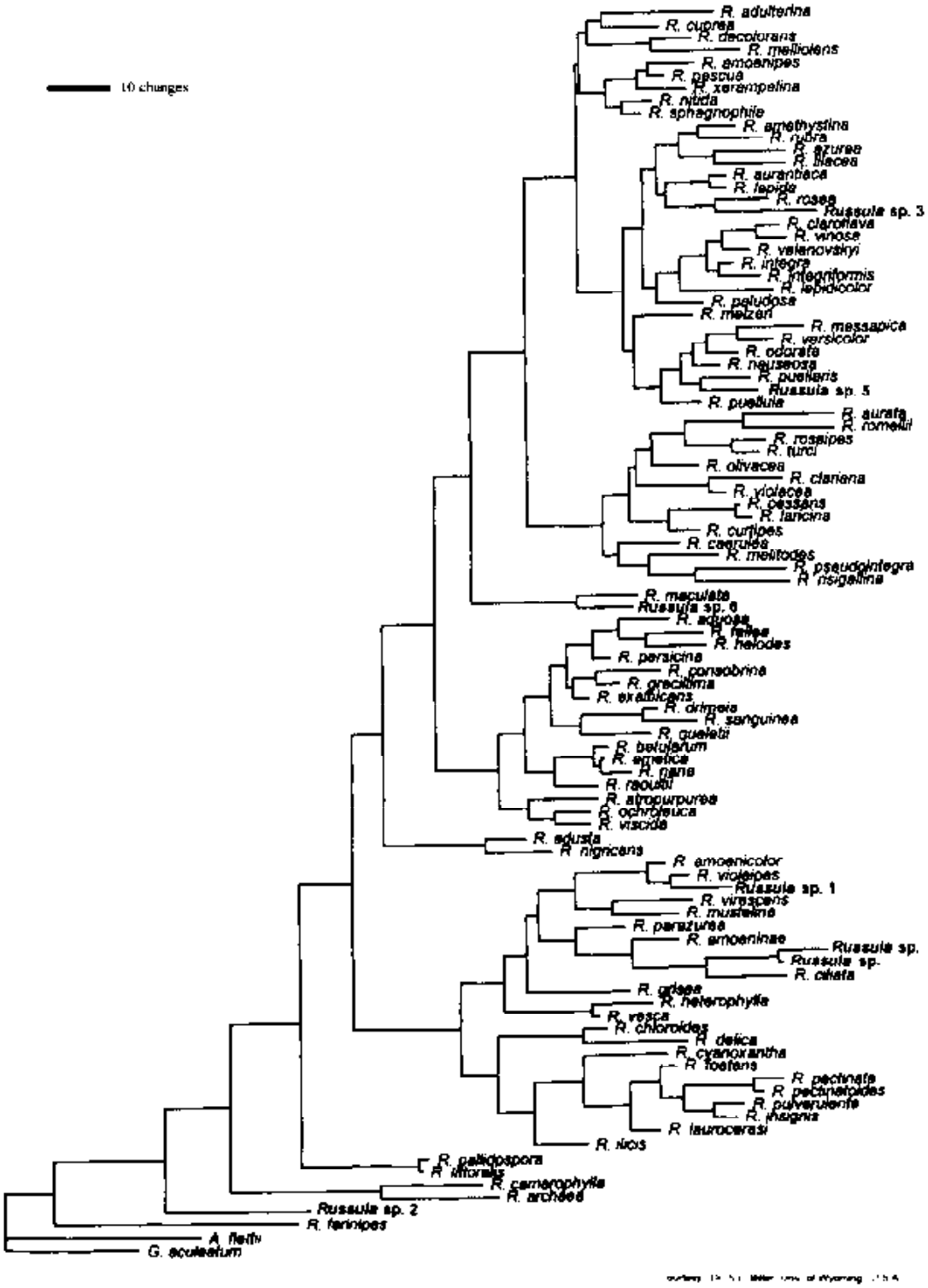


Fig. 79. Best of 16 most parsimonious trees of 2183 steps inferred from equally weighted parsimony analysis of ITS1, 5.8S and ITS2 nrDNA sequences depicted as a phylogram.

Plate 25: a. *Russula rhodomelanea* b. *R. raoultii* c & d. *R. decolorans* e. *R. emetica*.

Plate 26: a. *Russula flavida* var. *dhakurianus* b. *R. flavida* var. *flavida* c. *R. vaurasiana* d. *R. xerampelina*.

Plate 27: a. *Russula decipiens* b. *Russula* sp. 5 c. *Russula* sp. 6.

ECOLOGICAL STUDIES

The information provided in the following pages is the result of intensive foraying by the authors into all forest types of Kumaon Himalaya from 800 m to alpine meadows / glacial morains (up to 3500 m). The data so collected in the field was supplemented by the reports published by earlier workers. A summarized account of forest types, mycorrhizal host(s), range of distribution and frequency of occurrence for all the recorded species is presented below.

The study sites included the rich forested areas selected randomly during each foray (10-20 days). The survey was conducted mostly between July and October, repeatedly for 4 to 5 days at each study site. On the basis of limited survey and the data available at present, it is not possible to establish the groups of Extinct, Endangered, etc. on the basis of IUCN criteria. The personnel experience and judgement supported by the number of basidiomes encountered at each study site and then averaged for each forest type, formed the basis for assigning the status for each species as **Rare** (1 to 10 basidiomes, present in 5-10 of the localities surveyed), **Common** (approx. 100 basidiomes, present in about 50% of the localities surveyed) and **Abundant** (> 100 basidiomes, present in all the localities surveyed).

DISTRIBUTION OF TAXA IN KUMAON HIMALAYA

Forest types: Deciduous (1); Mixed (2); Coniferous (3); Alpine meadows (4).

Associated trees: *Quercus* a; *Pinus* b; *Cedrus* c; *Rhododendron* d; *Abies* e; *Shorea* f; *Cupressus* g.

Frequency status: Abundant - A; Common C; Rare R.

Name of the species	Forest type	Asso. trees	Altitude	Status
Russula abbotensis K. Das & J.R. Sharma	2	a	2000-2100 m	C
R. adusta (Pers.: Fr.) Fr.	2,3	c	1700-1900 m	R
R. albonigra (Krombh.) Fr.	2,3	a,b,d	1600-2700 m	C
R. amoenicolor var. *amoenicolor* Romagnesi	1	d	2200-2400 m	C
R. amoenicolor Romagnesi var. *ramgarhensis* K. Das, J.R. Sharma & R.P. Bhatt	2	a	1700-1800 m	R
R. anatina Romagnesi	1,2	a	2300-2700 m	C
Russula sp. 5	1,2	a,d	2200-2700 m	R
R. brevipes Peck var. *brevipes*	2,3	c	1800-2000 m	A
R. brevipes Peck var. *acrior* Shaffer	2,3	c	1700-2000 m	R
Russula sp. 2	2	b	1900-2000 m	R
R. compacta Frost & Peck	1	a	1900-2100 m	C
R. cyanoxantha (Schaeff.) Fr. var. *cyanoxantha*	1,2,3	a,c	1600-2300 m	A
R. dafianus K. Das & J.R. Sharma	1,2	a	2300-2700 m	R
R. decipiens (Sing.) Svreek	2	a	2100-2300 m	C
R. decolorans Fr.	1,2	a,d	1700-2200 m	C
R. delica Fr.	1,3	b,f	800-1800 m	C
R. densifolia (Secr.) Gill.	1,2	a,c	1800-2200 m	C
Russula sp. 3	1	d	2600-2800 m	R
R. emetica (Schaeff.: Fr.) var. *emetica*	1,4	a,d	2700-3200 m	C
R. flavida Frost var. *flavida*	1	d	2100-2300 m	R
R. flavida Frost var. *dhakurianus* K. Das, J.R. Sharma & R.P. Bhatt	1	a	2800-2900 m	C

Name of the species	Forest type	Asso. trees	Altitude	Status
R. foetens Pers.: Fr.	2,3	c	1700-1900 m	A
R. gracillima J. Schaeff.	3	g	2000 m	R
R. grisea Pers.: Fr.	1	a	2100-2300 m	C
R. heterophylla (Fr.: Fr.) Fr.	2,3	a,c, d	1700-1900 m	C
R. laurocerasi Melzer	1,2	a	1600-2200 m	C
Russula sp. 6	2	a,d	1700-1900 m	C
R. minutula var. *robusta* Saini, Atri & Sing.	2	d	2500-2600 m	R
Russula sp. 1	1,2	a	2100-2300 m	R
Russula sp. 4	2	a	2600-2800 m	R
R. nigricans Fr.	1,2,3	a,c	1800-2200 m	A
R. nitida (Pers.: Fr.) Fr.	3	g	2000 m	R
R. nothofaginea Sing.	1	a,d	2200-2300 m	R
R. pectinata Fr.	1,2	a	1900-2300 m	A
R. praetervisa Sarnari	1,2	a,c,d	1800-2700 m	C
R. raoultii Quel.	1,2	a	2100-2300 m	R
R. rhodomelanea Sarnari	1	a	2800-3000 m	C
R. rosea Quel.	1,2	a	2100-2300 m	C
R. subfoetens W.G. Smith	2	a	2700-2800 m	R
R. vaurasiana K. Das & J.R. Sharma	2	a	2200-2300 m	R
R. versicolor J. Schaeff.	3	g	2000 m	R
R. virescens (Schaeff.) Fr.	2,3	b	1600-1900 m	A
R. xerampelina (Schaeff.) Fr.	1	a	1800-1900 m	R
Lactarius abbotanus K. Das & J.R. Sharma	1	a	1900-2100 m	R

Name of the species	Forest type	Asso. trees	Altitude	Status
L. alnicola A.H. Sm. var. *alnicola*	2	e	2700-2900 m	R
L. capitatus K. Das, J.R. Sharma & Montoya	1	a,d	1800-1900 m	R
L. controversus (Fr.) Fr.	2	a,d	1800-2200 m	R
L. corrugis Peck	1	a	1700-2300 m	C
L. dafianus K. Das, J.R. Sharma & Verbeken	1	d	2100-2300 m	R
L. deliciosus (Fr.) Gray	2	a,d,e	2600-2800 m	C
L. dhakurianus K. Das, Basso & J.R. Sharma	1	d	2800-2900 m	R
L. dwaliensis K. Das, J.R. Sharma & Verbeken	1	a	2200-2600 m	R
L. gerardii Peck var. *subrubescens* (A.H. Sm. & Hesler) Hesler & A.H. Sm.	1	a,d	2300-2700 m	C
L. hygrophoroides var. *lavendulaceus* Hesler & A.H. Sm.	1,2,3	a,b	1600-1800 m	C
L. hygrophoroides var. *odoratus* Hesler & A.H. Sm.	2	a	1700-1900 m	C
L. lignyotus Fr. var. *lignyotus*	2	b,e	2000-2800	R
L. lignyotus Fr. var. *canadensis* A.H. Sm. & Hesler	2	a,d	1800-2700 m	R
L. maitlyensis K. Das, J.R. Sharma & Verbeken	1	a	1500-1800 m	R
L. mayawatianus Kanad Das & J.R. Sharma	1	d	1700-2200 m	R
L. montoyae K. Das & J.R. Sharma	1,2	a, d	2700-2900 m	R
L. mukteswaricus K. Das, J.R. Sharma & Montoya	1	a	2200-2300 m	R

Name of the species	Forest type	Asso. trees	Altitude	Status
L. paradoxus Beardslee & Burlingham	1,2	a,d,e	2300-2700 m	R
L. picinus Fr.	1,2	a	1700-1900 m	R
L. piperatus (Fr.) S.F. Gray var. *piperatus*	1,2,3	a,b,c	1800-2200 m	A
L. piperatus (Fr.) S.F. Gray var. *glaucescens* (Crossl.) Hesler & A.H. Smith	1	a	1800-2000 m	C
L. rubrifluus Gillet	3	b	1600-1900 m	C
L. sanjappae K. Das, J.R. Sharma & Montoya	1	a	2100-2300 m	C
L. serifluus (DC.: Fr.) Fr.	1	a	1800-2300 m	C
L. subindigo Verbeken & E. Horak	1,2	a	1800-2200 m	C
L. subpurpureus Peck	2	e	2600-2800 m	C
L. subvellereus Peck var. *subdistans* Hesler & A.H. Sm.	1,2	a	1600-2200 m	A
L. vellereus (Fr.) Fr.	2	a	2200-2700 m	R
L. verbekenae K. Das, J.R. Sharma & Montoya	2,3	a,c	1700-2300 m	C
L. volemus (Fr.) Fr. var. *volemus*	1,2	a,d	1800-2700 m	C
L. volemus (Fr.) Fr. var. *flavus* Hesler & A.H. Sm.	2,3	a,b	1500-2200 m	C
L. zonarius (Bull.) Fr.	1,2	a,d	1800-2200 m	A

Observations

In the present study, 76 taxa belonging to the family Russulaceae are recorded as occurring in the Kumaon Himalaya. All are mycorrhizal with forest trees.

A relatively large number of species are found in deciduous forests followed by coniferous and mixed forests. About 46 taxa (61%) either grow

exclusively (22) in or at least prefer (24) deciduous forests, 18 taxa (24%) either grow exclusively (4) or at least prefer (14) coniferous forests while 17 taxa (22%) grow only in mixed forests and four (5%) have no preference. Only *Russula emetica* var. *emetica*, *R. flavida* var. *dhakurianus*, *R. rhodomelanea*, *Lactarius alnicola* var. *alnicola*, *L. dhakurianus* and *L. montoyae* have distribution extended up to subalpine zone (>2800 m) and surprisingly *R. emetica* var. *emetica* has repeatedly been collected from near the snowline or glacier morains. Only a few species like *R. cyanoxantha* var. *cyanoxantha*, *R. nigricans* and *L. piperatus* var. *piperatus* have been found with high constancy of occurrence in all forest types. Species like *R. albonigra*, *R. cyanoxantha* var. *cyanoxantha*, *R. laurocerasi*, *R. praetervisa*, *L. subvellereus* var. *subdistans* and *L. volemus* var. *volemus* are widely distributed and grow at wider altitudinal ranges, while some taxa like *R. nothofaginea*, *R. flavida* var. *dhakurianus*, *R. subfoetens* and *L. capitatus* are altitude-specific and flourish only in narrow altitudinal ranges.

There is a set of species which yield heaviest and dominate in a particular forest type at different altitudes. For example, *Russula cyanoxantha* var. *cyanoxantha*, *R. rosea*, *Lactarius piperatus* var. *piperatus*, *L. subvellereus* var. *subdistans* and *L. zonarius* var. *zonarius* have highest degree of constancy in deciduous forests. Similarly, *R. brevipes* var. *brevipes*, *R. delica*, *R. foetens*, *R. virescens*, *L. volemus* var. *flavidus* and *L. rubrifluus* dominate in coniferous forests. However, *R. nigricans*, *R. brevipes* var. *acrior*, *L. hygrophoroides* var. *lavendulaceus* and *L. subindigo* are dominant in mixed forests. The sequence of dominant species as recorded above in each forest type is not constant even at similar altitudes probably due to the variation in temperature, precipitation timings, soil pH, nutrient availability as well as successional patterns in the vegetation. It is also recorded that the number of Russulacean taxa produced by a given area fluctuated widely each year. Some species new to each woodland were added with more years of sampling, however, 90% of the weight of species was due to those set of species regularly present each year in the respective woodlands.

Among the mycorrhizal taxa, 51 (67%) are exclusively ectomycorrhizal with angiospermic trees and 12 (16%) with coniferous trees while 13 (17%) are opportunistic and prefer both. The oaks are the most liked hosts among the hardwoods and *ca* 70% of Russulacean taxa grow ectomycorrhizally either exclusively or jointly with them, followed by *Rhododendron* 31%. Similarly, out of the 25 species which grow either exclusively on conifers or share them as their hosts, about 46% prefer *Cedrus*, followed by *Pinus* (25%), *Abies* (17%) and *Cupressus* (12%).

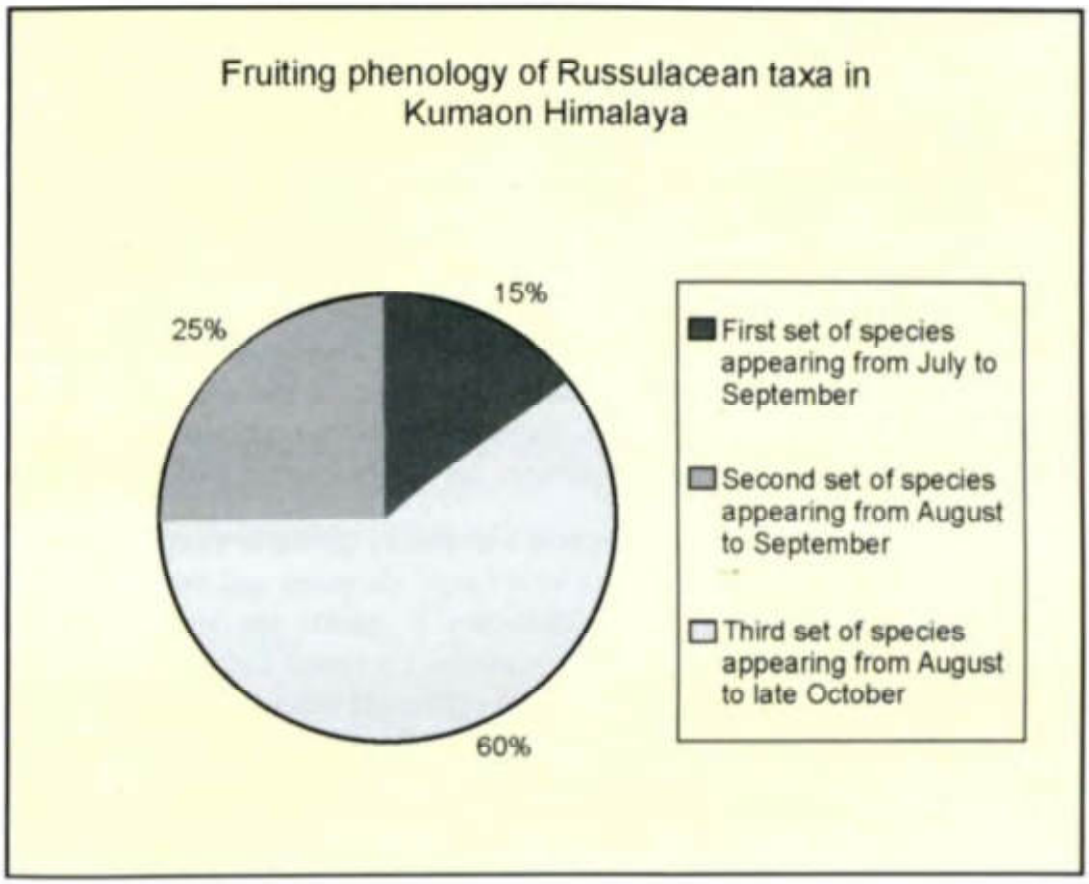
It is further clear that the temperate zone is the most productive for Russulacean fungi probably due to the presence of the suitable mycorrhizal

hosts. Almost all taxa recorded are found growing between 1500-2800 m. Only six species (8%) have extended distribution in and above the tree line (> 2800 m) out of which only *R. emetica* var. *emetica* is found in the glacial morains. On the basis of criteria used in the field for assigning the status to each species, about 38% species are rare, 44% are common and only 20% grow in abundance.

Fruiting phenology

The species of Russulaceae fruit at different times because of the difference in their temperature and moisture requirement. The total fruiting period of these fungi depends upon the required conditions of temperature and moisture being met at a particular elevation. However, some widely distributed species appeared early in the season at lower elevations and later in the season at higher elevation.

During the course of this study the fruiting period of 76 taxa of Russulaceae was recorded. The members generally appear in the month of July and disappear by the end of September which is also the normal period of fruiting for most of the Agarics in the Himalayan forests. Based on the observation made, the Russulacean taxa fall under three categories. 1) Out of 76 taxa found in Kumaon Himalaya, about 12 taxa i.e. roughly 15% (*Russula cyanoxantha*, *R. flavida* var. *dhakurianus*, *R. brevipes* var. *brevipes*, *R. rhodomelanea*, *Lactarius paradoxus*, *L. piperatus*, *L. volemus* var. *flavus*, etc.) appear early in the season i.e. just within 15 days of the first showers of monsoon rains and usually last up to the end of the September. None of them has usually been found extending up to October. These species fruit approximately for three months. 2) About 45 taxa (roughly 60%) appear after about 30 days of the first showers of monsoon rains. Species like, *Russula albonigra*, *R. amoenicolor* var. *amoenicolor*, *R. anatina*, *R. compacta*, *R. foetens*, *R. pectinata*, *R. rosea*, *R. virescens*, *Lactarius capitatus*, *L. alnicola* var. *alnicola*, *L. corrugis*, *L. hygrophoroides* var. *lavendulaceus*, *L. subpurpureus*, *L. subvellereus* var. *subdistans*, *L. zonarius*, etc. grow between August and September. These species fruit approximately for two months. A major portion of Russulacean taxa found in Himalayan forests belong to this group. 3) Only about 19 taxa (roughly 25%) appear in August but are found growing with almost the same frequency even up to the end of October when the average day-night temperature falls considerably. Species like *Russula brevipes* var. *acrior*, *R. minutula* var. *robusta*, *R. delica*, *R. emetica* var. *emetica*, *R. laurocerasi*, *R. nigricans*, *R. praetervisa*, *R. raoultii*, *Lactarius mayawatianus*, *L. abbotanus*, *L. montoyae*, etc. are found in abundance in Himalayan temperate forests up to the end of October. These species though appear late as compared to first set of species but fruit approximately for three months.



Conservation

It is difficult to draw up a list of generally acknowledged edible species due to considerable regional differences in appreciation and variability of individual allergic type reactions. Picking of Russulacean species for eating is quite unpopular as only a few like *R. virescens*, *R. heterophylla*, *R. cyanoxantha* var. *cyanoxantha*, *R. brevipes* var. *brevipes*, *L. deliciosus*, *L. volemus*, *L. subpurpureus and L. paradoxus* have been recorded as edible in Kumaon Himalaya.

Disappearance and destruction of habitats, ambient concentration of air pollutants, and excessive harvesting of basidiomes are the factors which predominantly have threatened these fungi in Himalayan forests and in fact do not differ from those responsible throughout. Of the three well known functional groups (soil inhabiting, wood inhabiting seprotrophs and necrotrophs and ectomycorrhizals species) to which the species of macrofungi can be attributed, the Russulacean members belong to the most important category i.e. ectomycorrhizals. The family has the highest proportion among fungi living in ectomycorrhizal symbiosis with forest trees and serve their obligate requirement.

The analyzed changes in the species composition in about 25 forays from 1999 to 2004 respectively, show that not fewer than 40% species are considered as threatened (only 1-10 basidiomes were collected). A significant decrease in the frequency of occurrence of mycorrhizal species is due to the loss of suitable hosts. The species like *Russula virescens*, *R. anatina*, *R. brevipes* var. *acrior*, *Lactarius dhakurianus*, *L. rubrifluus*, *L. mayawatianus* which are ectomycorrhizal with a limited number of trees are however, more threatened than those which are symbiotic with a wide variety of trees. This strong decline which is correlated with decrease of mycorrhizal-roots frequency and tree vitality is not only regrettable from a view point of mycologists, naturalists and nature conservationists but also has a far reaching consequences for the functioning of ecosystems.

Attempts to maintain the genetic variability of these fungi must be a part of general attempts to conserve total fungal diversity and their ecological functions. Maintaining genetic variability in edible species is essential for continued harvest in natural environments, for future cultivation research and for possible improvements of existing cultivated strains. The conservation of a particular species *in situ* is not a realistic goal, only conservation of that species in an ecological context is meaningful (Arnolds 1995).

The protection of natural or seminatural habitats whose destruction has threatened the existence of these fungi particularly host trees or plantation of some trees (Oaks / Pines) which support specific mycoflora may potentially provide the favourable habitats for such threatened species and is the first step necessary towards their conservation. It is also advisable to devise a code of conduct for wise management of harvesting of wild mushrooms by way of over-picking, habitat disturbance, overturning logs and trampling. Restoration of ectomycorrhizal flora also depends on the reduction of environmental pollution. Besides, full legal protection to some rare and beautiful species with splendid and peculiar basidiomes will also go a long way in this direction stressing the fact of threats to fungi. Apart from getting protection, these popular and charismatic species belonging to the threatened ectomycorrhizal group will serve as rallying points for stimulating conservation awareness and action on fungi (Sharma 2002).

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